Liveweight gain and feed intake of weaned Bali cattle fed grass and tree legumes in West Nusa Tenggara, Indonesia

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Abstract. Two experiments were conducted with weaned entire male Bali cattle (Bos javanicus) between 6 and 12 months of age. A randomised block design was used in both experiments, which consisted of four treatments (diets), with five replicates (animals) per treatment. In both experiments, the average daily liveweight gain (LWG), feed and water intake and diet digestibility were determined over 8 or 10 weeks, with chest girth and wither height measured at the commencement and end of the experiments. In Experiment 1, the treatments were fresh native grass, native grass supplemented with fresh sesbania, fresh sesbania and fresh sesbania supplemented with rice bran. In Experiment 2, the treatments were sole diets of leucaena hay, sesbania hay, moringa hay or gliricidia hay supplemented with sesbania hay. In Experiment 1, animals fed sesbania supplemented with rice bran had higher DM intake than did animals fed the other three diets. DM digestibility (DMD) was significantly lower for weaners fed the native grass diet than for those fed the other diets. Animals fed sesbania or sesbania supplemented with rice bran had a higher LWG (0.34 and 0.43 kg/day, respectively) and estimated metabolisable energy (ME) intake (0.71 and 0.80 MJ of ME/kg W0.75 day, respectively) than did animals fed native grass alone (0.03 kg/day; 0.38 MJ of ME/kg W0.75 day) or native grass supplemented with sesbania (0.07 kg/day; 0.64 MJ of ME/kg W0.75 day). In Experiment 2, animals fed gliricidia hay had the lowest DM intake. DM intake of animals fed moringa hay was higher than that of animals fed gliricidia hay, but lower than the intake of animals fed sesbania hay or leucaena hay. DMD of the sesbania and leucaena hay diets was lower than that of the gliricidia and moringa hay diets. Animals fed leucaena and sesbania hays had a higher LWG (0.47 and 0.43 kg/day, respectively) and estimated ME intake (0.75 and 0.78 MJ of ME/kg W0.75 day, respectively) than did animals fed moringa hay (0.22 kg/day; 0.66 MJ ME/kg W0.75 day) or gliricidia hay supplemented with sesbania hay (0.0 kg/day; 0.48 MJ ME/kg W0.75 day). In conclusion, tree legumes can safely be fed to growing Bali cattle as the sole component of the diet and some of them will increase LWGs above that of native grasses, which are typically fed to Bali cattle in villages.

Additional keywords: digestibility, leucaena, sesbania, water intake.

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Introduction
Slaughter of domestic cattle in Indonesia has increased by 4.7% per annum between 2007 and 2011 (Kementerian Pertanian 2011), indicating an increasing demand for beef products. This increased demand has not been able to be met by domestic cattle production and Indonesia imports live cattle and boxed beef to meet this increasing demand. Live cattle imports have declined recently (Meat and Livestock Australia 2013) due to a reduction in the quota by the Indonesian government. The national policy to reduce beef cattle imports provides an opportunity for domestic cattle producers (predominantly small holders with fewer than five cattle/household) to meet this increasing demand for beef by increasing household cattle productivity.

Bali cattle (Bos javanicus) are the dominant cattle species across eastern Indonesia. Females have a small mature body size of 211–303 kg liveweight (LW) (Talib et al. 2003) and are highly fertile, with the calving rate ranging from 75% to 90% (Wiradhayati and Bamualim 1994). Their small size means that they have a low daily feed requirement, making them well suited to cow–calf systems within crop–livestock systems in the tropics. Previous research conducted in West Nusa Tenggara province of Indonesia introduced an integrated village management system (IVMS) for Bali cattle, which consisted of natural mating, seasonal calving and weaning of the calf at 5–6 months of age (Panjaitan et al. 2010; Poppi et al. 2010). Economic analysis of the IVMS indicated that introduction of the new management system would increase household cash flow, with further increases in cash flow expected if growth rates of weaned calves were increased from 0.1 to 0.3 kg/day and weaners were retained up to 12 months of age (Rutherford 2004).
The nutrient and energy requirements of weaned Bali cattle 6–12 months of age are largely unknown. Available information on growth performance of Bali cattle is generally based on studies conducted with older animals (Moran 1985) or on observational work conducted in villages (Copland 1974). Nevertheless, from the available literature, it appears that growth rates of Bali cattle are considerably lower than those of other genotypes, with Moran (1985) reporting that mature Bali bulls grew at 0.66 kg/day on a high concentrate ration compared with 0.81 and 0.90 kg/day for Ongole (Bos indicus) and Grati (Bos indicus × Bos taurus) beef breeds, respectively. A review by Marsetyo et al. (2006) demonstrated a large variation in growth rates of Bali cattle (0.02–0.85 kg/day) across a large range of diets and animal classes in Indonesia over the past 20 years. Marsetyo et al. (2012) reported that weaned Bali calves would respond to the inclusion of protein (copra meal) and energy (rice bran) supplements in the diet. However, these supplements are not always available and may be relatively expensive for small-holder farmers. Therefore, cheap, locally available supplements need to be identified and evaluated. The objective of these experiments was to evaluate a range of locally available diets designed to increase the growth rate of young Bali cattle within the constraints of the existing small-holder systems in eastern Indonesia, where feed, financial and labour resources are scarce and to demonstrate that a diet consisting solely of tree legumes could be fed effectively to weaned Bali cattle.

Materials and methods

Experimental design, animals and diets

Two experiments were conducted at the University of Mataram, Faculty of Animal Science Teaching and Research Farm, Lingsar, West Nusa Tenggara, Indonesia (8°31′48″S, 116°11′41″E). Experiment 1 was conducted between February and April 2006 (wet season) and Experiment 2 was conducted between August and October 2006 (dry season). Long-term annual rainfall at the experimental site is 2643 mm. The average minimum and maximum daily temperatures are 23°C and 33°C, respectively, and are relatively constant throughout the year (Badan Pusat Statistik 2011). All procedures used in these experiments were conducted under 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.

Experiment 1 was 10 weeks in duration and Experiment 2 was 12 weeks in duration. Each experiment consisted of a 2-week preliminary period, for adaptation to diets, followed by an 8- and 10-week experimental period (Experiments 1 and 2, respectively). Each experiment was a completely randomised block design, with four treatments and five replicates (animals) per treatment. At the commencement of each experiment, animals were ranked and blocked on an unfasted weight. Within blocks, animals were then randomly allocated to one of four dietary treatments and to adjacent individual pens. Animals remained in the same pens throughout each experiment. The pens were within an open-sided, covered animal house.

The animals were entire male Bali cattle, approximately 6 months of age and 73.1 ± 1.7 kg LW (mean ± s.e. of the mean) at the commencement of Experiment 1 and were purchased from the local saleyards. On arrival at the research facility, animals were given an individual identification number and were treated with Ivomec (Merial, Mumbai, India) to control internal and external parasites.

Experiment 1

Twenty weaned, entire male Bali cattle approximately 6 months of age and 73.1 ± 1.7 kg LW were allocated to treatments and pens as described above. The four experimental diets were (1) native grass (865 g organic matter (OM), 87 g crude protein (CP), 618 g neutral detergent fibre (NDF) and 357 g acid detergent fibre (ADF)/kg DM) ad libitum (NG), (2) Sesbania grandiflora (918 g OM, 232 g CP, 430 g NDF and 306 g ADF/kg DM) at 10 g DM/kg LW.day with native grass ad libitum (NGS), (3) sesbania ad libitum (SES) and (4) rice bran (839 g OM, 122 g CP, 350 g NDF and 150 g ADF/kg DM) at 10 g DM/kg LW.day with sesbania ad libitum (SESRB). Native grass and sesbania were collected in the evening before feeding and rice bran was sourced as a single batch at the commencement of the experiment. Native grass refers to a mixture of grasses (900 g/kg DM) and forbs (100 g/kg DM) that are typically fed to cattle by small-holder farmers under cut and carry systems in West Nusa Tenggara and include Digitaria sanguinalis, Heteropogon contortus and Brachiaria millichum and was chopped to ~5 cm in length before feeding. Supplements were provided at 0700 hours each day, with basal diets being offered two times each day; initially, at either after the supplement was consumed or at 1000 hours, and again at 1600 hours. The amount of supplement offered was adjusted after each measurement of animal LW and the amount of basal feed offered was the previous day intake plus ~20% (on an as-fed basis). Water was available ad libitum.

Experiment 2

The same 20 animals as used in Experiment 1 were used in Experiment 2. The cattle were ~12 months of age and 89.6 ± 3.2 kg LW at the commencement of the experiment. The four experimental diets were (1) Leucaena leucocephala hay (919 g OM, 210 g CP, 468 g NDF and 267 g ADF/kg DM) ad libitum (LEU), (2) sesbania hay (914 g OM, 194 g CP, 444 g NDF and 332 g ADF/kg DM) ad libitum (SES), (3) Moringa oleifera hay (882 g OM, 207 g CP, 455 g NDF and 286 g ADF/kg DM) ad libitum (MORH) and (4) sesbania hay at 7 g DM/kg LW.day with Gliricidia sepium hay (902 g OM, 223 g CP, 360 g NDF and 263 g ADF/kg DM) ad libitum (GLIRH). The GLIRH treatment was originally intended to be gliricidia ad libitum; however, the sesbania supplement was added due to poor acceptance and low intakes of the gliricidia by the cattle in preliminary feeding. All feeds were collected 1–2 weeks before feeding and dried to between 85% and 90% DM on a concrete slab under the sun, for approximately 5 days, with twice-daily turning before storing in a covered shed. For the GLIRH treatment, sesbania hay supplement was offered at 0700 hours with the gliricidia hay offered after all the sesbania hay was consumed. For the other treatments, feeds were offered twice daily at 0700 hours and 1600 hours and the amount offered was the previous day intake plus 20% (on an as-fed basis). Water was available ad libitum.
**Measurements**

Liveweight was measured two times each week, except during faecal collection periods when it was measured at the start and end of the 7-day collection period. Wither height and chest girth were measured at the start and end of each experiment. Basal diet and supplement intake were measured throughout each experiment by recording the amount of feed and supplement offered and refused each day. Duplicate subsamples of feed offered were collected and dried to a constant weight at 65°C each day; an additional sample was sorted into grass and non-grass components, which were both dried to a constant weight at 65°C. Feed refusals were collected and weighed each day and bulked over seven consecutive days, with duplicate subsamples being collected every 7 days and dried to a constant weight at 65°C. Digestibility was determined by collecting total faecal output from individual animals over seven consecutive days on two separate occasions during each experiment (Weeks 5 and 8). Animals were monitored constantly during the faecal collection periods, with faeces collected from the concrete floor of each pen regularly over 24 h. Daily faecal output was weighed at 0800 hours, a 10% subsample was collected and stored at −20°C. Samples were thawed and bulked for each animal over the 7-day period, with duplicate samples dried to a constant weight at 65°C. Water intake was measured during the faecal collection periods by measuring the amount of water offered and the amount of water refused and adjusted for evaporation rates in the animal house, at the same time each day. Water intake from feed was calculated from the water content of the feed and feed intake.

**Chemical analysis**

The OM contents of feeds offered, feed refusals and faeces were determined according to AOAC (2005, Method 990.5). The CP content of feeds offered was determined according to AOAC (2005, Method 2001.11). The NDF content of feeds offered, feed refusals and faeces and the ADF content of feeds offered were determined on an ash-free basis, following the method of Goering and Van Soest (1970).

**Calculations and statistical analyses**

Average daily liveweight gain (LWG) was calculated by regression of LW over the duration of the experiment (days). Changes in height and girth were determined by difference between start and end of the experiment. Metabolisable energy (ME) intake was estimated following Freer et al. (2007), as described by Marsetyo et al. (2012). Total water intake was the sum of water imbibed and water consumed in the feed, as described by Marsetyo et al. (2012).

Average daily LWG and DM intake data were analysed using the MIXED procedure for repeated-measures in Statistical Analysis Software (SAS 1999). Change in height and girth, and digestibility data were analysed as a randomised block design using the general linear model procedure. The model included diet, as the treatment effect, and block, as the blocking effect. One animal in Experiment 1 consistently consumed less than 10% of its rice-bran allocation and was omitted from the statistical analysis.

**Results**

**Experiment 1**

The main results of Experiment 1 are presented in Table 1. Entire male Bali cattle fed SES and SESRB had higher LWGs than did those fed NG or NGS over 8 weeks. Similarly, change in wither height and chest girth were higher for animals fed SES and SESRB diets than for those fed the NG and NGS diets. Basal diet intake was higher for unsupplemented animals than for animals that received supplements. Supplement intake was similar for animals offered the NGS and SESRB treatments, with ~85% of the supplements consumed by the animals over the experimental period. Total DM intake was highest for animals receiving the SESRB treatment, with no difference among the other treatments. Digestibility of DM and OM was

<table>
<thead>
<tr>
<th>Parameter</th>
<th>NG</th>
<th>NGS</th>
<th>SES</th>
<th>SESRB</th>
</tr>
</thead>
<tbody>
<tr>
<td>LWG (kg/day)</td>
<td>0.03 ± 0.05a</td>
<td>0.07 ± 0.05a</td>
<td>0.34 ± 0.05b</td>
<td>0.43 ± 0.05b</td>
</tr>
<tr>
<td>Change in girth (mm/100 day)</td>
<td>54.5 ± 20.5a</td>
<td>21.8 ± 20.5a</td>
<td>163.6 ± 20.5b</td>
<td>172.7 ± 23.0b</td>
</tr>
<tr>
<td>Change in wither height (mm/100 day)</td>
<td>39.3 ± 12.7a</td>
<td>11.3 ± 12.7a</td>
<td>78.5 ± 12.7b</td>
<td>83.6 ± 14.1b</td>
</tr>
<tr>
<td>Basal diet intake (g DM/kg LW.day)</td>
<td>28.1 ± 0.9c</td>
<td>18.7 ± 1.0a</td>
<td>26.9 ± 0.9bc</td>
<td>24.7 ± 1.0b</td>
</tr>
<tr>
<td>Supplement intake (g DM/kg LW.day)</td>
<td>n.a.</td>
<td>8.3 ± 0.2</td>
<td>n.a.</td>
<td>8.5 ± 0.3</td>
</tr>
<tr>
<td>Total intake (g DM/kg LW.day)</td>
<td>28.1 ± 0.9a</td>
<td>27.0 ± 1.0a</td>
<td>26.9 ± 0.9a</td>
<td>33.2 ± 1.0b</td>
</tr>
<tr>
<td>DMD (g/kg)</td>
<td>499 ± 11a</td>
<td>541 ± 10b</td>
<td>584 ± 10c</td>
<td>550 ± 12b</td>
</tr>
<tr>
<td>OMD (g/kg)</td>
<td>549 ± 16a</td>
<td>591 ± 15ab</td>
<td>623 ± 15b</td>
<td>591 ± 17ab</td>
</tr>
<tr>
<td>NDFD (g/kg)</td>
<td>592 ± 24a</td>
<td>585 ± 22a</td>
<td>456 ± 22b</td>
<td>360 ± 22c</td>
</tr>
<tr>
<td>ME intake (MJ/kg W0.75/day)</td>
<td>0.58 ± 0.02a</td>
<td>0.64 ± 0.02a</td>
<td>0.71 ± 0.02b</td>
<td>0.80 ± 0.03c</td>
</tr>
<tr>
<td>Imbibed water intake (g/kg LW.day)</td>
<td>19 ± 3a</td>
<td>36 ± 3b</td>
<td>47 ± 3c</td>
<td>56 ± 3d</td>
</tr>
<tr>
<td>Total water intake (g/kg LW.day)</td>
<td>140 ± 4</td>
<td>151 ± 4</td>
<td>143 ± 4</td>
<td>142 ± 4</td>
</tr>
</tbody>
</table>

Values are means ± standard error of the mean. Within rows, means followed by the same letter are not significantly different at $P = 0.05$. n.a., not applicable as no supplement offered.
lowest for animals fed the NG treatment and highest for animals fed the SES treatment. Digestibility of NDF was lowest for animals that received the rice-bran supplement (SESRB). The CP : ME of the diets was estimated to be 11.6, 15.7, 25.5 and 23.9 g CP/MJ of ME for NG, NGS, SES and SESRB, respectively. The amount of water imbibed was highest for animals that received the rice-bran supplement and lowest for animals offered the NG treatment. Animals were able to compensate for the different DM content of the treatment diets, with no differences in estimated total water intake (imbibed plus feed) evident.

Experiment 2

The main results of Experiment 2 are presented in Table 2. Entire male Bali cattle fed LEUCH and SESH had higher LWGs than did those fed MORH or GLIRH treatment diets over 10 weeks, with animals fed MORH having higher LWGs than those fed GLIRH. Similarly, changes in wither height and chest girth were higher for animals fed LEUCH and SESH diets than for those fed the GLIRH diet. Total DM intake was highest for animals receiving the LEUCH and SESH treatments, with MORH intake higher than that of the GLIRH treatment. The DM intake of glicricidia hay at the commencement of the 2-week preliminary period was similar to the other tree legumes; however, during the preliminary period and Week 1 of the experimental period, intake of glicricidia hay decreased from ~20 to 11 g DM/kg LW.day, with no signs of increasing; at this point, a supplement of sesbania hay (7 g DM/kg LW.day) was included in the diet. Digestibility of DM and OM was lowest for animals fed LEUCH and highest for animals fed MORH. Digestibility of NDF was lowest for animals that received the GLIRH and highest for animals consuming the MORH treatment. The CP : ME of the diets was estimated to be 28.0, 24.0, 22.8 and 23.8 g CP/MJ of ME for LEUCH, SESH, MORH and GLIRH, respectively. The amount of water imbibed was related to DM intake and was highest for animals that were fed SESH and lowest for animals that were fed GLIRH, with a similar trend observed for estimated total water intake (imbibed plus feed).

Discussion

Approximately 40% of Bali calves in eastern Indonesia are born between April and late June, with another 40% born between July and September when feeds are scarce (Wirdahayati and Bamualim 1990; Wirdahayati 1994). Improved reproductive performance of Bali cows can be achieved by weaning calves at 5–6 months of age to remove lactation nutritional requirements, allowing them to maintain or recover body condition (Dahlanuddin et al. 2011; Pippi et al. 2011). To enhance the benefits of weaning, improved management of the weaned calf is required to offset the negative impacts of weaning on the calf, specifically identification of the best low-cost feeds available to small-holder farmers to increase growth of weaned calves, either for yearling sale or to achieve production targets such as age at puberty and weight at slaughter if held longer-term.

The results of the current experiments demonstrated that feeding some tree legumes (sesbania and leucaena) with a high CP content is the best strategy to increase growth rates of weaned Bali calves. The inclusion of rice bran to sesbania did not provide any statistically significant benefit on LWG of weaned Bali cattle but in the presence of low sesbania biomass could be used effectively as a supplement. This experiment, for the first time, directly compared the response of early weaned Bali cattle to leucaena, sesbania, moringa and glicricidia hays in the one experiment and clearly demonstrated the advantages of feeding leucaena or sesbania above moringa and glicricidia. The use of hay also provided a strategy for feed storage and demonstrated that it can be used effectively. Growth rates of ~0.4 kg/day achieved in response to leucaena and sesbania hays (Experiment 2) and fresh sesbania supplemented with rice bran (Experiment 1) were approximately double that observed on farm under prevailing management conditions for Bali cattle of comparable age or LW (<0.1 kg/day; Marsetyo et al. 2012). Implementation of such a strategy would allow small-holder farmers to increase growth of weaned calves, either for yearling sale or to achieve production targets such as age at puberty and weight at slaughter if held longer-term.

Table 2. Liveweight gain (LWG), change in girth and height, basal diet and supplement intake, digestibility of dry matter (DMD), organic matter (OMD) and ash-free neutral detergent fibre (NDFD), metabolisable energy (ME) intake and water intake of recently weaned entire male Bali calves fed leucaena hay ad libitum (LEUCH), sesbania hay ad libitum (SESH), morgina hay ad libitum (MORH) and glicricidia hay ad libitum supplemented with sesbania hay (7 g DM/kg LW.day) (GLIRH) in Experiment 2

Values are means ± standard error of the mean. Within rows, means followed by the same letter are not significantly different at P = 0.05. n.a., not applicable as no supplement offered

<table>
<thead>
<tr>
<th>Parameter</th>
<th>LEUCH</th>
<th>SESH</th>
<th>MORH</th>
<th>GLIRH</th>
</tr>
</thead>
<tbody>
<tr>
<td>LWG (kg/day)</td>
<td>0.47 ± 0.05c</td>
<td>0.43 ± 0.05c</td>
<td>0.22 ± 0.05b</td>
<td>0.0 ± 0.05a</td>
</tr>
<tr>
<td>Change in chest girth (mm/100 day)</td>
<td>103.9 ± 22.2b</td>
<td>116.9 ± 22.2b</td>
<td>41.6 ± 22.2a</td>
<td>78.4 ± 22.2a</td>
</tr>
<tr>
<td>Change in wither height (mm/100 day)</td>
<td>59.7 ± 14.9b</td>
<td>72.7 ± 14.9b</td>
<td>18.2 ± 14.9a</td>
<td>52.1 ± 14.9a</td>
</tr>
<tr>
<td>Basal diet intake (g DM/kg LW.day)</td>
<td>29.3 ± 0.9c</td>
<td>29.2 ± 0.9c</td>
<td>22.5 ± 0.9b</td>
<td>11.1 ± 0.9a</td>
</tr>
<tr>
<td>Supplement intake (g DM/kg LW.day)</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>6.9 ± 0.3</td>
</tr>
<tr>
<td>Total intake (g DM/kg LW.day)</td>
<td>29.3 ± 0.9c</td>
<td>29.2 ± 0.9c</td>
<td>22.5 ± 0.9b</td>
<td>18.1 ± 0.9a</td>
</tr>
<tr>
<td>DMD (g/kg)</td>
<td>474 ± 11a</td>
<td>532 ± 11b</td>
<td>633 ± 11d</td>
<td>578 ± 11c</td>
</tr>
<tr>
<td>OMD (g/kg)</td>
<td>506 ± 11a</td>
<td>555 ± 11b</td>
<td>658 ± 11d</td>
<td>608 ± 11c</td>
</tr>
<tr>
<td>NDFD (g/kg)</td>
<td>311 ± 25ab</td>
<td>365 ± 25b</td>
<td>654 ± 25c</td>
<td>247 ± 27a</td>
</tr>
<tr>
<td>ME intake (MJ/kg W0.75.day)</td>
<td>0.75 ± 0.04c</td>
<td>0.78 ± 0.04c</td>
<td>0.66 ± 0.04b</td>
<td>0.48 ± 0.04a</td>
</tr>
<tr>
<td>Drinking water intake (g/kg LW.day)</td>
<td>136 ± 6c</td>
<td>161 ± 6d</td>
<td>108 ± 6b</td>
<td>87 ± 6a</td>
</tr>
<tr>
<td>Total water intake (g/kg LW.day)</td>
<td>141 ± 6c</td>
<td>167 ± 6d</td>
<td>111 ± 6b</td>
<td>90 ± 6a</td>
</tr>
</tbody>
</table>
farmers to raise male Bali cattle to slaughter weight and female Bali cattle to first calving ages ~12–24 months earlier than what is normally observed under village conditions.

The LWGs recorded in these experiments were similar to those reported elsewhere for this class of animal. Weaned male Bali cattle fed native grass had a LWG of ~0.1 kg/day (Marsetyo et al. 2012) while LWG of weaned Bali cattle fed tree legumes ranged from 0.22 to 0.42 kg/day (Quigley et al. 2009). The highest LWG reported for male Bali cattle weaned at approximately 6 months of age is 0.65 kg/day when the cattle were fed a soybean and maize-based diet with a CP content of ~180 g CP/kg DM (Quigley et al. 2009).

In Experiment 2, the DMD of moringa and gliricidia hays was higher than that of leucaena and sesbania hays, with comparable CP content, but LWGs of calves consuming moringa- and gliricidia-based diets were much lower than those of calves fed leucaena and sesbania. Intake of leucaena and sesbania was higher than that of the moringa and gliricidia hays and this would have been the main driver of LWG in Experiment 2, as seen in the differences in estimated ME intake in Table 2.

It was expected that rice-bran supplementation of the high-protein sesbania diet in Experiment 1 would increase LWG above that of sesbania-alone diet because the extra fermentable carbohydrate would have utilised the excess rumen-degradable N from sesbania (Yang et al. 2010). However, the additional LWG of 0.11 kg/day was not significantly different from the LWGs of the calves fed sesbania alone. This is in contrast to the 0.15–0.20 kg/day additional LWG achieved when leucaena was supplemented with a comparable amount of rice bran or maize grain to a similar class of cattle in East Nusa Tenggara (Quigley et al. 2009).

The weaned Bali calves fed gliricidia hay in Experiment 2 could barely maintain LW as a result of the low intake of gliricidia. This is in contrast to Marsetyo et al. (2012) who reported an LWG of 0.27 kg/day for a comparable class of Bali cattle fed fresh gliricidia alone. Despite its high nutritive value (CP and DMD), the response of livestock to gliricidia-based diets is often below expectation and is variable despite its reported high CP and ME content. Issues with feeding gliricidia to livestock have been documented elsewhere and several factors, including coumarine, hydrocyanic acid, nitrate, undefined alkaloids and tannin content, have all been associated with low gliricidia intake by livestock (Smith and van Houtert 1987).

Moringa is known to have high CP content and negligible amount of anti-nutritional substances (tannins and trypsin inhibitors) and has been used as a source of protein for high-producing dairy cows (Makkar and Becker 1996). Therefore, it has been used to replace soybean meal in the concentrate of dairy cows (Mendieta-Araica et al. 2011), fed to goats in combination with leucaena or gliricidia (Asaolu et al. 2011) and as a substitute for sunflower meal in the diet of laying hens (Kakengi et al. 2007). In Experiment 2, the intake and LWG of Bali cattle fed moringa were intermediate between leucaena–sesbania and gliricidia, despite having a comparable CP and ME content. Aregheore (2002) also found that the inclusion of high proportion of moringa (20% grass and 80% moringa) reduced DM intake and DMD in goats. However, Asaolu et al. (2011) reported that there was no significant difference in DM intake and DMD between 100% moringa and combination of either moringa and gliricidia or moringa and leucaena when fed to goats. These results suggest that the intake of moringa by ruminants has been inconsistent.

It has been suggested that the optimum inclusion of tree legumes in the diet is 30–50% of the total diet (Devendra 1988; Kaitho et al. 1988). Jones and Hegarty (1984) also reported that the optimum growth rate of cattle occurred when the diet consisted of 40% leucaena. Anganga and Tshwenyane (2003) suggested that the anti-nutritional factors, mimosine, cyanogens and saponins, present in some tree legumes, may reduce palatability and digestibility. However, the current experiments demonstrated that feeding sesbania and leucaena, as the sole component of the diet, increases LWG above that which can be achieved by grass alone. In some on-farm situations in Indonesia, such as in Amarassi (East Nusa Tenggara), feeding 100% leucaena is considered the most practical way of fattening cattle by small-holder farmers because, in these areas, it is difficult to find grasses or other forages, particularly in the dry season when leucaena continues to provide a source of protein that is much cheaper than by-products such as copra meal (Nullik 1998). The current results demonstrated that sesbania can also be fed as the sole diet, resulting in a high LWG similar to that of leucaena. Sesbania is preferred in Lombok as it establishes easily on the rice bunds, grows rapidly and is able to be used in the first year of establishment, in contrast to the longer establishment period required for leucaena. However, in many areas of Indonesia, it may not be possible to establish areas of tree legumes that produce sufficient biomass for feeding as the sole component of the diet. For example, the successful and sustainable planting and use of sesbania as cattle feed in the southern part of Lombok island, West Nusa Tenggara, has been documented (Dahlanuddin et al. 2005). In this region, sesbania is planted on the rice field bunds and fed to cattle as a small component of the diet, with LWG of 0.38 kg/day reported when sesbania was fed at ~30% of the total diet (Quigley et al. 2009). Therefore, feeding these tree legumes as a supplement to grass and crop residues is appropriate and beneficial for small-holder farmers in areas where large-scale tree-legume establishment is not possible, such as in the more intensively farmed crop–livestock systems. In Experiment 2, intake of gliricidia was low and did not result in a high LWG, which was in contrast to Marsetyo et al. (2012). Smith and van Houtert (1987) outlined the variability in the results with gliricidia and this is an issue still to be resolved. Gliricidia is a very useful tree legume as it establishes easily, forms a living fence and grows in a variety of soil types, unlike leucaena. Because of its high CP content, it has a valuable role as a N supplement for low-CP crop residues (e.g. rice straw; Syahniar et al. 2012) and can be used successfully for this role in crop–livestock systems. In Experiment 2, the forages were fed as hays, and although feeding these forages fresh in cut and carry systems is most common, the present work demonstrated that hays can be used successfully within these systems.

Digestibility of NDF was lower when tree legumes were fed in large proportions or as the sole component of the diet. This low NDF digestibility might be related to the anti-nutritional factors such as soluble phenolic, insoluble and soluble proantocyanidins and tannin in the tree legumes (Merkel et al. 1999), but could also be related to the woody stem material in the hays.
Unfortunately, a measurement of leaf and stem proportions was not made. The NDF digestibility values recorded in the present study (24.7, 31.1, 36.5 and 45.6% for gliricidia hay, leucaena hay, sesbania hay and fresh sesbania, respectively) were lower than the average of published results. Merkel et al. (1999) reported a 43% NDF digestibility when gliricidia was fed as the sole diet to cattle.

Ad libitum total water intake (including water in feed), for this class of Bali cattle, was estimated to be 5.2 kg water/kg DM intake (calculated from Tables 1 and 2) across all treatments in both experiments, which was comparable to the intake of 4.8 kg water/kg DM reported by Moran et al. (1979) for older and heavier Banteng cattle, and higher than the intake of 3.4 kg water/kg DM reported by Marsetyo et al. (2012) for a similar class of Bali cattle. For 100 kg weaned Bali cattle consuming 20–30 g DM/kg L.W.day this is ~10–15 kg of water/day, which must be provided either in the feed or in drinking water. Under cut and carry systems, farmers often carry water to household cattle or take cattle to water points once each day. As a result, cattle are not provided with ad libitum access to water. The amount of water imbibed is influenced by the form of diet fed (fresh or dried) as this is related to the water content in the feeds. It is also affected by the physiological status of the animals and climatic conditions. The implication of this is that farmers should provide sufficient drinking water to cattle on the basis of their physiological state, climatic conditions and the DM content of the diet and the above values provide an estimate of water needed for this class of cattle.

Conclusions
Bali cattle, between 6 and 12 months of age, will grow faster when fed leucaena or sesbania than when fed native grass or gliricidia or moringa. As such, these two legumes can be used effectively within crop livestock systems to improve the LWG of early weaned Bali calves within the IVMS. These two legumes can be fed solely without any adverse effects, provided adequate biomass is available, but can also be used as supplements or mixed with other crop by-products such as rice bran.

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References


Merkel RC, Pond KC, Burns JC, Fisherd DS (1999) Intake, digestibility and nitrogen utilization of three tropical tree legumes I. As sole feeds compared to *Asystasia ingrana* and *Brachiastra brizantha*. *Animal Feed


