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2 Executive summary

Increased demand for beef and increased prices for beef cattle in Indonesia provide an opportunity for small-holder farmers in Indonesia to increase their cash-flow by increasing their cattle production. Beef production in South East Sulawesi (Sultra) is restricted by the quality and quantity of feed available in the dry and wet seasons. This project investigated two strategies to address the issue of the quality and quantity of available feed during the dry season in Sultra. The first strategy was to utilise cocoa-pods, a by-product of cocoa production, as a feed resource for cattle thereby addressing feed gaps as well as removing cocoa-pods from the field eliminating a potential reservoir for the cocoa-pod borer (an insect pest which reduces subsequent cocoa yield and quality). The second strategy was to establish forage legumes on fallow rice paddy fields and to introduce the feeding of tree legumes to cattle in Sultra. The project also developed a long-term growth path for male and female Bali cattle (*Bos sondaicus*) fed tree legume diets.

Cocoa-pods were successfully fed to Bali cattle at two different stages of maturity. Treatment of cocoa-pods with *Aspergillus niger* increased the crude protein content and decreased the neutral detergent fibre content of cocoa-pods. Treatment of cocoa-pods with *Aspergillus niger* resulted in a slightly greater live weight gain response compared to untreated cocoa-pods when fed to growing Bali cattle but had no influence on animal response when fed to more mature animals. Processing of cocoa-pods is required for the long-term storage of materials to fill feed gaps, however this needs to be cheap and simple to use for adoption by small-holder farmers. Simple, low-cost processing methods were successfully established in villages in Sultra. It is recommended that chopped or ground, dried untreated cocoa-pods be fed to mature Bali cows, but not growing animals, as a component of a diet to maintain live weight and body condition score but not as the sole component of the diet. The wide-scale uptake of cocoa-pod feeding in Sultra would address existing feed gaps while reducing the threat of cocoa-pod borer infestation of subsequent cocoa crops.

The successful establishment of forage legumes on fallow rice fields would provide high quality feed materials during the dry season or provide an opportunity to conserve forages for feeding during the subsequent wet season, when all available land is allocated to field and plantation crops. Small plots of *Lab lab purpureus*, *Clitoria ternatea*, *Centrosema pascuorum* and *Macroptilium bracteatum* were successfully established in villages. However, excessive rainfall during the 2008 dry season resulted in poor establishment of forage legumes on fallow rice paddy fields, accept for one area of *Clitoria ternatea* which was more elevated and better drained than other areas. The approach of tethered grazing of forage legumes on fallow rice fields should provide benefits in terms of supply of high quality feed for growing and fattening animals and an organic nutrient source directly to the rice field, and warrants further investigation. *Gliricidia sepium* (Gliricidia) is widely available in Sultra but is rarely used by small-holders. Studies within this project demonstrated to small-holders that Bali cattle would consume Gliricidia and that feeding Glircidia either as a supplement or as the sole component of the diet will result in live weight gains greater than if cattle were fed native grass. The successful establishment of *Sesbania grandiflora* (Sesbania) on rice field bunds and dry-land areas in the current project provides an additional opportunity for feeding tree legumes and also makes use of previously unused land resources.

Growth paths were determined for male and female Bali cattle fed Sesbania from 6 to 27 months of age. There was no difference in growth rates of male and female Bali cattle from 6 to 12 months of age. Growth of female cattle was significantly reduced after puberty compared to growth prior to puberty, and to growth of entire males after puberty. Growth of castrates was intermediate between entire males and females, from 18 to 27 months of age.

3 Background

Increasing demand for beef across Indonesia is unable to be met from domestic supply alone under the prevailing production systems. As such, a large number of cattle and an increasing amount of packaged beef are imported into Indonesia. As a result, the price paid for beef cattle across Indonesia continues to increase. Small-holder farmers have the potential to capture this opportunity of increased demand for beef and increased prices if they can maximise the productivity of their beef cattle enterprise. In South East Sulawesi (Sulawesi Tenggara, i.e. Sultra; Figure 1) beef cattle production, in terms of reproductive output, live weight gain and herd size, is restricted by both the quality and quantity of feed available which are inadequately matched with animal requirements. This occurs during both the dry season, when forage availability is low, and the wet season, when all available land is allocated to rice production and plantation crops, such as cocoa (*Theobroma cacoa*) and cashew (*Anacardium occidentale*). This project investigated the use of cocoa industry by-products as a cattle feed resource and the establishment of forage legumes on dry season rice paddy fields to address the issue of dry season feed shortages that occur in Sultra.

Figure 1. Location of project research activities conducted at Kendari (Δ) and Ladongi sub-district (□) in South East Sulawesi (O) and Nusa Tenggara Barat (+), Indonesia.

Typically Sultra experiences a prolonged wet season (December to May) followed by an intense dry season (June to November). As a result farmers traditionally planted only one rice crop each year across large areas of Sultra, with a second opportunistic rice crop planted if rainfall extends into August. Despite the high annual rainfall (2200 mm/year) feed shortages occur during both the wet and dry seasons. During the rice field fallow period (July to January) cattle are either tethered or allowed to free graze across unused rice fields, consuming standing rice straw and weeds. The availability of cut and carry forages is limited and small-holder farmers must travel a great distance to collect sufficient feed for the day, increasing the labour requirements for cattle rearing during this time. During the wet season feed shortages also occur, as the ability to graze or tether animals on rice paddy fields is lost while land is prepared for rice planting, in addition little or no forages persist under the heavily shaded conditions of the cocoa plantations. The feed shortages observed during both the dry and wet seasons in Sultra are likely to be limiting reproductive rate and growth rate of animals, while the increased time and labour inputs required to source feeds are restricting any significant expansion of the beef cattle population in the region.

The area of land under cocoa plantations is increasing rapidly in Sultra due to good financial returns to small-holders on a per unit area of land basis. Sultra produces 11.6%

of Indonesia's cocoa production and is ranked third after South Sulawesi (20.7%) and Central Sulawesi (17.7%) (Suryani and Zulfebriansyah, 2007), in terms of provincial cocoa production. Cocoa plantations cover approximately 196,884 Ha within Sultra (Statistik Perkebunan Sulawesi Tenggara, 2007). The continued expansion of the cocoa industry places increasing pressure on the availability of land for forage production. Cocoa trees have a dense canopy which limits the potential for forages to establish within the plantations. Recently, cocoa yields in Sultra have declined due to several pests and diseases. The most threatening of these pests is the cocoa-pod borer (*Conopomorpha cramerella*). The cocoa-pods left on the ground in the plantations, after removal of the cocoa bean, harbour the cocoa-pod borer which may then attack the subsequent cocoa crop, significantly reducing cocoa bean quality and cocoa yields by 20-50% (Sulistyowati *et al*., 2002). A practical control method of the cocoa-pod borer is the removal of the trash that remains within the plantation, including previously harvested cocoa-pods. These cocoa-pods could then either be transported to a land area isolated from cocoa plantations, limiting the opportunity for infestation of the subsequent cocoa crop. Alternatives to simply relocating the cocoa-pods include utilisation within the existing crop-livestock system, either as a form of compost or as a ruminant feed source. The advantage of the use of cocoa-pods as a ruminant feed resource is that not only is the reservoir for the cocoa-pod borer removed, feed shortages are addressed and faeces will be generated which can then be utilised for biogas production and/or as a source of organic fertiliser to be used on plantations or rice crops. The availability of cocoa-pods in Sultra can be calculated based on the data and assumptions of Owusu-Domfeh (1972) and Ashun (1975). One Ha of land is typically planted with 800 cocoa trees, with each tree producing 30 cocoa fruit each year, with each fruit approximately 400 g in weight. The proportion of cocoa-pod in each fruit is 75%, consisting of 60% dry matter. Therefore, the cocoa-pod yield is estimated to be approximately 4,320 kg DM/Ha/year. Across Sultra this would translate to a dry matter yield of approximately 850,500 tonnes of cocoa-pod/year. Therefore, cocoa-pods could in part address the issue of dry season feed supply in Sultra, providing they are suitable for inclusion of the diet of cattle.

The use of cocoa-pods as a feed resource for ruminants is often dismissed due to a perception that they are low in crude protein (CP) and high in fibre, although this is not supported in the literature where moderate values of 63 to 85 g CP/kg DM (Ashun, 1975; Bateman and Fresnillo, 1967; Wong *et al*., 1987) and 240 to 360 g crude fibre/kg DM (Ashun, 1975; Bateman and Fresnillo, 1967; Wong *et al*., 1987) are reported. There is little data on the effect of cocoa-pods on digestibility and performance of cattle. Earlier workers (Bateman and Fresnillo, 1967; Olubajo *et al*., 1976; Smith and Adegbola, 1985) indicated that the DM digestibility of cocoa-pods was low and was within the range 45 to 52%. Previous studies indicated a negative response in live weight gain and feed conversion efficiency to increasing levels of cocoa-pods in the diet, although this was only significant when cocoa-pods comprised approximately 60% of the diet (Smith and Adegbola, 1982).

Some Indonesian agencies have advocated the treatment of cocoa-pods with *Aspergillus niger*, as a means of improving cocoa-pod quality. However, there is little published evidence to support this. The majority of cocoa-pods are harvested in July in Sultra. To be available as a feed resource throughout the dry season the material must be processed in some form to facilitate long-term storage and feeding to livestock in times of inadequate supply of other feed resources. This processing can be time consuming and costly to small-holder farmers and often requires technologically advanced equipment which is expensive to purchase, maintain and operate. The addition of *Aspergillus niger* treatment to this process increases the time and costs involved, becoming a major deterrent to the adoption of cocoa-pod feeding to cattle by small-holder farmers.

In addition to cocoa plantations, Gliricidia is widespread in Sultra. The Gliricidia trees are planted for living fences/hedges, shade for other plants such as cocoa and firewood. In other areas of Indonesia Gliricidia has been successfully used a feed resource for young Bali cattle (*Bos sondaicus*) either as a sole feed or as a supplement, to grasses or crop residues, resulting in average live weight gains of 0.27 kg/d and 0.31 kg/d, respectively, compared to growth rates of less than 0.2 kg/d when grasses or crop residues were fed alone (Quigley *et al*., 2009). Gliricidia contains 18-30% CP and has an in vitro digestibility of 60-65%. Gliricidia is very tolerant of repeated cutting and has a high dry matter production; annual yields of 5-16 tonne/Ha have been obtained in fodder plots (Direktorat Pebenihan Tanaman Hutan, 2002), while it is generally accepted that dry matter leaf yields range from 2 to 20 tonne/Ha/year in the field. Despite this the plant is not widely used as a feed resource for beef cattle in Sultra, mainly due to a lack of knowledge of its potential use by the small-holder farmers in the region.

Small-holder farmers in Sultra typically plant one rice crop each year, despite the prolonged wet season. During the rice fallow period, from the late wet to early subsequent wet season cattle are tethered or free graze rice straw on fallow paddy fields. It is likely that these paddy fields contain sufficient sub-soil moisture to support dry season forage legume growth. The incorporation of forage legumes into the crop-livestock system, as a ley crop on fallow rice paddy fields has the potential to provide a high quality feed resource during the dry season, increase soil fertility through nitrogen fixation and provide additional nutrients to the soil from faeces and urine if cattle are tethered on the paddy fields to graze forage legumes. This may potentially increase small-holder farmer cash reserves through increased cattle production and decreased fertilizer costs. However, no forage legumes have previously been evaluated or established in Sultra, so it is unknown which species are most likely to perform well under these conditions. In addition, the rice paddy field bunds in Sultra are unproductive, potential also exists to establish tree or forage legumes on these bunds as an additional feed supply for cattle, during both the wet and dry seasons when feed shortages occur.

The research groups at BPTP-Sultra and the Department of Animal Production, University of Haluoleo (UNHALU) are expanding rapidly. Large investments have been made in staff training and infrastructure. However, the Sultra groups remain isolated from other research groups conducting similar work elsewhere across eastern Indonesia, while exposure to international research projects is limited. This project provided an opportunity to link researchers from BPTP-Sultra and UNHALU with each other and similar researchers and research organisations across eastern Indonesia, particularly those involved in LPS 2004 023. The aim was to build the capacity of BPTP-Sultra and UNHALU staff to conduct farmer relevant ruminant nutrition research, to provide opportunities for further training and development and to provide an opportunity for linkages with other research organisations in Indonesia and Australia.

The connections between this project and LPS 2004 023 extended beyond capacity development and linkages between organisations. The experimental design, protocols and scientific rigor employed in LPS 2004 023 were used in the current project. In addition, to further build on the large amount of feeding and growth data for 6 to 12 month old Bali cattle generated in LPS 2004 023, a longer term growth study was conducted within this project at the University of Mataram, Nusa Tenggara Barat (NTB). The long-term growth path study aimed to demonstrate that cattle could be fed a sole diet of Sesbania for long periods of time without any ill effects and to monitor changes in live weight and body dimensions of male and female Bali cattle fed a diet containing a high proportion of tree legumes from 6 to 27 months of age. The data generated provide important information on growth paths of male and female Bali cattle which can be incorporated into growth models specific for Bali cattle.

In conclusion, the project aimed to broaden the range of feedstuffs evaluated in LPS 2004 023 for feeding Bali cattle. A particular emphasis was placed on addressing the dry season feed shortage in Sultra by evaluating the use of cocoa-pods and the establishment of forage legumes on paddy fields. The capacity of BPTP-Sultra and UNHALU staff to conduct farmer relevant ruminant nutrition research was enhanced through linkages developed with research staff and organisations involved in LPS 2004 023.

4 Objectives

1. To evaluate cocoa-pods as a potential dry season feed for cattle.
2. To establish and assess the value of forage and shrub legumes as supplements in the diet of cattle.
3. To build the capacity of BPTP-Sultra and University of Haluoleo staff to undertake feed evaluation research.
4. To establish lifetime growth paths of male and female Bali cattle under ideal nutrition and management conditions.

5 Methodology

All studies involving animals 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.

In the various studies within this report samples of feed, refusals and faeces were analysed for dry matter, ash (AOAC, 1984), nitrogen with the Kjeldahl method, ash-free neutral detergent fibre (NDF) and ash-free acid detergent fibre (ADF) (Goering and Van Soest, 1970). Metablisable energy content of the various feeds was estimated according to CSIRO (2007), where

ME (MJ/kg DM) = 0.0157 x Digestible Organic Matter in Dry Matter (DOMD) (g/kg), and

DOMD (g/kg) = ((OM intake (kg/d) – OM faeces (kg/d))/ DM intake (kg/d)) x 1000

All data were analysed using Genstat (GenStat for windows, 11th edition, VSN International Ltd.). Differences between treatments were accepted as significantly different at $P<0.05$. Differences in mean values between treatments were compared by Fisher's Protected Least Significant Difference (LSD).

5.1 To evaluate cocoa-pods as a potential dry season feed for cattle

The effect of treatment with *Aspergillus niger* on cocoa-pod feed value was evaluated in a laboratory study. The effect of treatment with *Aspergillus niger* and level of inclusion in the diet were evaluated in on-station and in village feeding studies. The form in which cocoa-pods should be fed to cattle was determined from observations by project team members and small-holder farmers.

5.1.1 Effect of *Aspergillus niger* and urea on the crude protein, neutral detergent fibre and acid detergent fibre content of cocoa-pods

A laboratory based study was conducted at the Department of Animal Science, University of Tadulako, Palu, Central Sulawesi, Indonesia (0°41'0"South; 119°44'0"East). Cocoa-pods were collected immediately after harvest in Central Sulawesi. The pods were chopped to 2.5 cm^2 and divided into five treatment groups, with three replicates per treatment. The five treatments were, immediately dried cocoa-pods, fresh cocoa-pods, cocoa-pods treated with $5x10^6$ spores of *Aspergillus niger* per kg of cocoa-pods, cocoa-pods with 20 g of urea added per kg cocoa-pods and cocoa-pods treated with $5x10^6$ spores of *Aspergillus niger* plus 20 g of urea per kg of cocoa-pods. All cocoa-pods were placed in fertiliser bags, either alone or in the presence of their treatment additives, and maintained under aerobic conditions. Samples were collected from each treatment replicate 0, 6, 12 and 21 days later. Replicate samples at each time point were bulked and analysed for dry matter content at 60^{o}C, nitrogen and ash-free NDF content.

5.1.2 Effect of *Aspergillus niger* treatment and level of feeding of cocoa-pods on intake and growth of young Bali cattle in South East Sulawesi

Location, animals, experimental design and measurements

The experiment was conducted at the University of Haluoleo cattle research facility, Kendari, Sultra, Indonesia (3^{o}58'17S; 122^{o}34'40E). Male Bali cattle (n=25), approximately 12 months of age and 118 ± 3 kg (SEM) live weight were given an individual identification number and were treated for internal and external parasites with 1 mL of Dovenix/24 kg live weight. Prior to the experiment all animals were offered untreated cocoa-pods mixed with rice bran (1:1, as fed) at 5 g DM/kg W/d plus native grass *ad libitum*, for one week. Cattle were then weighed and allocated to individual pens and treatments (n=5 per treatment) in a randomised block design. The five treatments were native grass *ad libitum*, untreated cocoa-pods (10 g DM/kg W/d) plus native grass *ad libitum*, treated cocoa-pods (10 g DM/kg W/d) plus native grass *ad libitum*, untreated cocoa-pods *ad libitum* and treated cocoa-pods *ad libitum*. The animals were adjusted to their treatments over a one week preliminary period. This was followed by an eight week measurement period, where feed intake was measured daily, live weight was measured once each week and digestibility was measured by total faecal collection over seven consecutive days on three occasions, during weeks two, four and six of the experimental period.

Feeds and feeding

Cocoa-pods were collected from cocoa plantations within two days of harvest. The pods were chopped to 1 x 5 cm in dimension, mixed thoroughly and divided into two equal lots. The first lot of pods were dried in the sun for three days before grinding through a 2 mm screen and storing in plastic bags. The remaining pods were treated with an *Aspergillus niger* solution. The *Aspergillus niger* solution was prepared by adding 10 g urea, 10 g sugar, 2.5 g SP36 (36% total P205 fertilizer; Petrokimia), 2.5 g KCl and 5 mL *Aspergillus niger* (containing 1×10^6 spores/mL) to 1 L of water, which was diluted in an additional 10 L of water. The diluted solution was then applied to cocoa-pods at a rate of 1L/kg fresh cocoa-pods. This was the equivalent of 4.55×10^5 spores of *Aspergillus niger*/kg fresh cocoa-pod. Treatment occurred for six days under aerobic conditions. The treated pods were then dried in the sun for three days before grinding through a 2 mm screen and storing in sealed plastic bags. Native grass was cut fresh each day and was representative of locally available cut and carry forages typically used by farmers in the region.

5.1.3 Effect of *Aspergillus niger* treatment on the performance of Bali cattle in villages in Ladongi sub-district, South East Sulawesi

The experiment was conducted in Ladongi sub-district, Kolaka district, South East Sulawesi province (3^{o}0' to 4^{o}15'S and 121^{o}00' to 122^{o}10'E). Yearling Bali cattle (n=7 males; n=5 females) aged approximately 18 months of age and 156 ± 10 kg live weight, belonging to 8 small-holder farmers, were given an individual identification number and were treated for internal and external parasites with verm-O (Bayer; 1 bolus administered to the rumen of each animal). Cattle were weighed and allocated to either treated cocoa-pod (n=6) or untreated cocoa-pod (n=6) treatments. Cattle were kept in individual pens associated with each small-holder farmer and fed allocated treatments at 15 g cocoa-pod DM/kg live weight for 84 days; water was available *ad libitum*. Cocoa-pods were collected, processed and stored similar to that described in section 5.1.2, with the same batch of *Aspergillus niger* used in both studies. Treated and untreated cocoa-pods were fed at 07:00 h each day. Native grass was available *ad libitum* to all animals after their daily allocation of cocoa-pods was consumed. Animals were weighed once each week over the 84 day experimental period. Upon completion of the study, results were disseminated to farmers at a demonstration day. A survey was conducted to ascertain the perceptions of farmers to cocoa-pod feeding.

5.1.4 Implementation of a simple cocoa-pod chopper in Ladongi sub-district, Sulawesi Tenggara

Two potential cocoa-pod choppers, one manual and one electric operated, were sourced from Toko Mesin Engineering Company, Malang, East Java and established in villages in Ladongi sub-district, Sultra during the main cocoa harvest in 2008. The ability of these choppers to process cocoa-pods was evaluated and compared with the existing large scale cocoa-pod grinder. The operation of all choppers was demonstrated to farmers.

5.2 To establish and assess the value of forage and shrub legumes as supplements in the diet of cattle.

5.2.1 Biomass production of forage legumes on dryland and lowland areas in Ladongi sub-district, South East Sulawesi

Four species of forage legume were sown on Oxisol soils in dryland and lowland areas in Ladongi sub-district in November 2007, as described in Table 1. Legumes were sown in 6x10 m plots, with three replicates per species, in a completely randomised block design. Biomass production was determined by cutting all herbage in 1 m^2 quadrants, in triplicate within each plot, approximately 56, 84, 98, 112, 126 and 140 days after sowing (DAS). Samples were oven dried to a constant weight and biomass production calculated (kg DM/Ha).

Table 1. Sowing rate of forage legumes planted in dryland and lowland areas in Ladongi sub-district, South East Sulawesi

Species	Sowing rate (kg/Ha)	Treatment	Sowing depth (cm)	Spacing (cm)
Lab lab purpureus	12	none	2-6	30 x 50 rows
Clitoria ternatea	6	none	2-6	15 x 40 rows
Centrosema pascuorum	8	Heat treatment	1-2	15 x 30 rows
Macroptilium bracteatum	4	Mechanic scarification	3	Broadcast

5.2.2 Establishment of *Sesbania grandiflora* on rice paddy field bunds in Ladongi sub-district, South East Sulawesi

Sesbania seeds were sourced from NTB and were planted in poly bags at the BPTP-Sultra nursery. Seedlings were maintained in the nursery until they reached 20-50 cm in height and then transferred to Ladongi sub-district where they were planted on rice paddy field bunds and dryland areas at 5 m intervals (October 2008). Survival of seedlings was monitored at three monthly intervals (January and April 2009).

5.2.3 Establishment and grazing of best-bet forage legumes on rice paddy fields after the rice harvest in Ladongi sub-district, South East Sulawesi

In July 2008, after the rice harvest, approximately 0.4 Ha of rice paddy fields in Ladongi sub-district were sown with forage legumes. The area consisted of 852 m^2 of *Lab lab purpureus* (12 kg/Ha), 1942 m^2 of *Clitoria ternatea* (6 kg/Ha) and 1202 m^2 of *Macroptilium bracteatum* (4 kg/Ha). It was planned that approximately 60 days after sowing a rotational grazing strategy would be introduced where a number of calves would be tethered and graze on the forage legumes growing on fallow rice fields for four months during the dry season. Calves would graze legumes during the morning and return to the household pen (kandang) during the afternoon and evening. The following day calves would be moved to a new patch of legume in a rotational system. The persistent unseasonal rainfall that occurred in Sultra during the 2008 dry season resulted in water logging and poor establishment of the forage legumes. Attempts were made to drain the paddy fields and the legumes were resown on several occasions with poor success. On those areas which were elevated with better drainage, small areas of forage legume were successfully established. Due to the excessive rain and poor establishment, insufficient biomass of forage legumes was available for the grazing study to occur as planned. The revised protocol involved grazing a smaller number of growing Bali cattle (n=4; 131 ± 15 kg live weight) for a shorter period of time (6 weeks), prior to the commencement of preparation of the paddy field for the subsequent rice crop.

5.2.4 Village study and demonstration of Gliricidia feeding to Bali cattle in Ladongi sub-district, South East Sulawesi

Bali cattle (n=8 males; n=4 females) aged approximately 15 months of age and 122 ± 5 kg live weight, belonging to 9 small-holder farmers, were given an individual identification number and were treated for internal and external parasites with verm-O (1 bolus administered to the rumen of each animal). Cattle were weighed and allocated to the Gliricidia (n=6) or native grass (n=6) treatments. Cattle were kept in individual pens associated with each small-holder farmer and fed allocated treatments *ad libitum* for 84 days; water was available *ad libitum*. Animal live weight was recorded once each week over the 84 day experimental period. Upon completion of the study, results were disseminated to farmers at a demonstration day. A survey was conducted to ascertain the perceptions of farmers to Gliricidia feeding.

5.2.5 Evaluate feed value of forage legumes and Gliricidia for young Bali cattle

Two experiments were conducted at the Department of Animal Production, University of Haluoleo experimental farm.

Experiment 1

Male Bali cattle (n=24), approximately 8 months of age and 96 ± 2 kg live weight were given an individual identification number and were treated for internal and external parasites with 1 mL of Dovenix/24 kg live weight. Cattle were weighed and allocated to individual pens and treatments (n=6 per treatment) in a randomised block design. The four treatments were:

- native grass *ad libitum*
- Gliricidia (10 g DM/kg W/d) plus native grass *ad libitum*
- Gliricidia *ad libitum*
- rice bran (10 g DM/kg W/d) plus Gliricidia *ad libitum*

Animals were gradually introduced to their allocated treatments over a one week preliminary period. This was followed by an eight week measurement period, where feed intake was measured daily, live weight was measured twice each week and digestibility was measured on three occasions, during weeks two, five and eight, for seven days each.

Experiment 2

At the completion of Experiment 1, the majority of the cattle used were fed a diet of Gliricidia plus rice bran (10 g DM/kg W/d) for approximately eight weeks and then re-used in Experiment 2. Male Bali cattle (n=20), approximately 12 months of age and 116 ± 3 kg live weight were weighed and allocated to individual pens and treatments (n=5 per treatment) in a randomised block design. The four treatments were:

- native grass *ad libitum*
- Gliricidia *ad libitum*
- forage legume (*Clitoria ternatea* and *Centrosema pascuorum*) *ad libitum*
- rice bran (10 g DM/kg W/d) plus Gliricidia *ad libitum*

Animals were gradually introduced to their allocated treatments over a one week preliminary period. This was followed by a four week measurement period, where feed intake was measured daily, live weight was measured twice each week and digestibility was measured over a seven day period during week two of the experimental period.

An area of land (approximately 0.5 Ha) adjacent to the University of Haluoleo cattle kandang at the experimental farm was cleared of weeds and prepared for sowing. *Centrosema pascuorum* and *Clitoria ternatea* were planted on 0.25 Ha of land each at a rate of 8 kg/Ha in February 2008. The extended wet season resulted in difficulties in establishing sufficient biomass for the legumes to be tested as sole feeds. Poor biomass production was attributed to excessive rainfall and water logging of the soil, weed infestation, poor soil fertility and a fungal attack. As a result the two legumes were harvested fresh each day prior to feeding and fed in combination.

5.3 To build the capacity of BPTP-Sultra and University of Haluoleo staff to undertake feed evaluation research.

The project aimed to develop the capacity of BPTP-Sultra and the UNHALU staff at several levels:

- Train senior scientists in the conduct of ruminant nutrition research on-station and in villages.
- Facilitate interaction and linkages between BPTP-Sultra and UNHALU staff and with scientists and organisations from other areas across eastern Indonesia. This included joint annual project meetings between LPS 2004 023 and SMAR 2007 013 project members and members of LPS 2004 023 acting as mentors and providing guidance for activities conducted within SMAR 2007 013.
- Provide all project team members with the opportunity to attend a range of national and international meetings, training workshops, seminars and conferences.
- Involve undergraduate students in the on-station experiments. These students prepared their Honours thesis based on the experiments conducted within this project. This provided the next generation of livestock scientists with an opportunity to receive training in ruminant nutrition research from experienced Indonesian and Australia researchers.
- Frequent communication and visits between Australian and Indonesian project team members to develop the capacity of Indonesian and Australian staff involved in the project.

5.4 To establish lifetime growth paths of male and female Bali cattle under ideal nutrition and management conditions.

The experiment was conducted at the University of Mataram, Teaching and Research Farm, Lingsar, NTB. Male (n=12; 69 ± 2 kg live weight) and female (n=6; 79 ± 2 kg live weight) weaned Bali cattle, approximately 6 months of age were sourced from Kelebuh village and the Selagalas cattle market, NTB, in February 2007. At approximately 18 months of age half of the male cattle were castrated. All animals were maintained in individual pens and offered an identical diet of Sesbania *ad libitum* from 6 to 22 months of age and were offered Sesbania *ad libitum* plus rice bran (5 g DM/kg W/d) from 22 to 28 months of age. Live weight was recorded each week and chest circumference, wither height and hip height were recorded once each month from 6 to 27 months of age. Photographs of individual animals were also taken once each month. Blood samples were collected at an average of 100 kg, 190 kg and 260 kg live weight.

6 Achievements against activities and outputs/milestones

Objective 1: To evaluate cocoa-pods as a potential dry season feed for cattle

no.	activity	outputs/ milestones	completion date	comments
1.1	Conduct on-station trials that evaluate usefulness of cocoa-pods as feed resources and if processing is required.	Determine if cattle live weight and condition is influenced by: i. treatment of cocoa-pods with *Aspergillus niger*. ii. level of inclusion of cocoa-pods in the diet. iii. form of feeding of cocoa-pods	October 2008	Mature Bali cattle could not be sourced to evaluate the use of cocoa-pods as a maintenance feed for mature cattle. The experiments were conducted with less mature Bali cattle approximately 120 kg live weight. Animals offered treated or untreated cocoa-pods at 10 g DM/kg W/d gained live weight over the experimental period (0.232 and 0.136 kg/d, respectively). Animals offered treated or untreated cocoa-pods *ad libitum* lost live weight over the experimental period (-0.116 and -0.282 kg/d, respectively). Animals consume ground treated and untreated cocoa-pods, either as a slurry when mixed with water, or dry when mixed with rice bran. Animals do not consume dried unchopped cocoa-pods. Animals do consume fresh cocoa-pods; however this strategy does not lend itself to long-term storage so that cocoa-pods can be fed during periods of feed shortage.
1.2	Conduct in village demonstration experiment of cocoa-pod feeding	Demonstrate and monitor feeding treated and untreated cocoa-pods to Bali cattle in villages	December 2007	There was no effect of treatment on average daily live weight gain of Bali cattle 140 to 160 kg in live weight. Farmers considered the cost and equipment associated with processing to be the primary constraint to the adoption of feeding cocoa-pods to cattle.
1.3	Establish simple cocoa-pod processing method in village.	Establish a low operating cost and simple maintenance method for chopping cocoa-pods in villages	August 2008	A low cost cocoa-pod chopper was established in village and demonstrated to farmers. Farmers were impressed by the new choppers and offered suggestions to further improve the choppers.

Objective 2: To establish and assess the value of forage and shrub legumes as supplements in the diet of cattle.

no.	activity	outputs/ milestones	completion date	comments
2.1	Forage legume plots and shrub legumes on bunds to be established in villages.	Evaluate biomass production of forage legumes in dry land area.	January 2009	*Lab lab purpureus*, *Centrosema pasuorum*, *Clitoria ternatea*, *Macroptilium bracteatum*, *Stylosanthes hamata* and *Desmanthus pernambucanus* were evaluated in dryland area, Ladongi sub-district. Biomass production was greatest for Lab lab, followed by Clitoria, Macroptilium and Centrosema.

		Evaluate biomass production of forage legumes in low land rice field area.		*Lab lab purpureus*, *Centrosema pasuorum*, *Clitoria ternatea* and *Macroptilium bracteatum* were evaluated in lowland area, Ladongi sub-district. Biomass production was greatest for Lab lab, followed by Clitoria, Macroptilium and Centrosema and was generally slightly less than the dryland area.
		Establish Sesbania on bunds.		Sesbania seed was collected from Nusa Tenggara Barat and established in Ladongi sub-district.
2.2	Best-bet legumes to be established on paddy fields in villages after 2008 rice harvest and grazed by growing cattle	Scale-up area of legumes planted on paddy fields after rice harvest, so that grazing can occur.	January 2009	Approximately 0.4 Ha of land was planted with *Clitoria ternatea*, *Lab lab purpureus* and *Macroptilium bracteatum* after the rice harvest in 2008. Excessive rainfall resulted in poor establishment and survival of the forage legumes.
		Bali calves to be tethered on paddy fields and grazed on forage legumes during dry season.	January 2009	A small number of calves were tethered and grazed on a reduced area of forage legumes which survived the flooding of the rice paddy fields. Calves grazed the area each morning for approximately six weeks. Animals grew at 0.20 kg/d and it was demonstrated to small-holder farmers that no detrimental effects on animal wellbeing occurred.
		Village study and demonstration of Gliricidia feeding.	December 2007	Gliricidia was successfully fed *ad libitum* to cattle in villages in Ladongi sub-district, Sultra for approximately 12 weeks. Small-holder farmers were impressed by animal performance and labour savings.
2.3	On-station experiment conducted to evaluate feed value of forage legumes and Gliricidia as feed for growing Bali cattle.	Evaluate use of Gliricidia as a feeding strategy for growing Bali calves.	May 2008	Strategies to incorporate Gliricidia into the diet of young, growing Bali cattle were evaluated. The best strategy involved the feeding of Gliricidia supplemented with rice bran, although animals performed well when fed Gliricidia alone.
		Evaluate use of forage legumes as a feeding strategy for growing Bali calves.	August 2008	Due to the excessive rainfall in Kendari it was not possible to obtain sufficient biomass to conduct a full experiment to evaluate a range of forage legumes. The animals fed the available forage legumes displayed similar performance to those fed Gliricidia but slower growth rates than animals fed native grass or Gliricidia supplemented with rice bran.

Objective 3: To build the capacity of BPTP-Sultra and University of Haluoleo staff to undertake feed evaluation research.

no.	activity	outputs/ milestones	completion date	comments
3.1	Increase interaction between groups in Sultra and with other groups in eastern Indonesia	Involve BPTP-Sultra and UNHALU staff in all LPS 2004 023 activities and communication.	May 2009	LPS 2004 023 and SMAR 2007 013 project meetings were conducted together in December 2007 and April 2009. Sultra staff were included in all communication and discussions with staff from LPS 2004 023.
		Organise visits of scientists between sites.		Prof. Marsetyo visited Sultra to assist scientists with the development of protocols for feeding experiments. Dr Esnawan Budisantoso visited Sultra to assist with the establishment of forage legumes and protocols for evaluation. Staff from Sultra visited research facilities at the University of Mataram, West Nusa Tenggara and the Beef Cattle Research Institute, East Java, and the village cattle production systems in both regions.
3.2	Provide opportunities for BPTP-Sultra and UNHALU staff to attend various ACIAR workshops in Indonesia	Capacity of BPTP and UNHALU staff to conduct farmer relevant research increased.	December 2008	BPTP and UNHALU staff attended ACIAR and ATSE Crawford funded training workshops on - laboratory analysis of soil and plant materials - experimental design and statistical analysis. - program linkage on beef cattle management (Lolit Sapi - Beef Cattle Research Institute)

Objective 4: To establish lifetime growth paths of male and female Bali cattle under ideal nutrition and management conditions.

no.	activity	outputs/ milestones	completion date	comments
4.1	Monitor changes in live weight and body dimensions of male and female Bali cattle fed Sesbania from 6 to 27 months of age	Develop lifetime growth path information for reference point for comparison of other studies. Provide information to the cattle growth component of the Integrated Analysis Tool.	December 2008	Live weight and body dimensions of male and female Bali cattle fed a 100% Sesbania diet were recorded from approximately 6 to 27 months of age. Data is available for inclusion in the Integrated Analysis Tool.

7 Key results and discussion

7.1 To evaluate cocoa-pods as a potential dry season feed for cattle

7.1.1 Effect of *Aspergillus niger* and urea on the crude protein and neutral detergent fibre content of cocoa-pods

Untreated cocoa-pods had a CP content of 75 g/kg DM and a NDF content of 590 g/kg DM. The treatment of cocoa-pods with *Aspergillus niger* increased the CP content above that of dried or fresh cocoa-pods, treated similarly (Figure 2 a.). Further, *Aspergillus niger* treatment in the presence of urea resulted in an increase in CP content above that of urea alone (Figure 2a.). Treatment of cocoa-pods with *Aspergillus niger*, and the addition of urea, both resulted in a decrease in NDF content over time (Figure 2 b.).

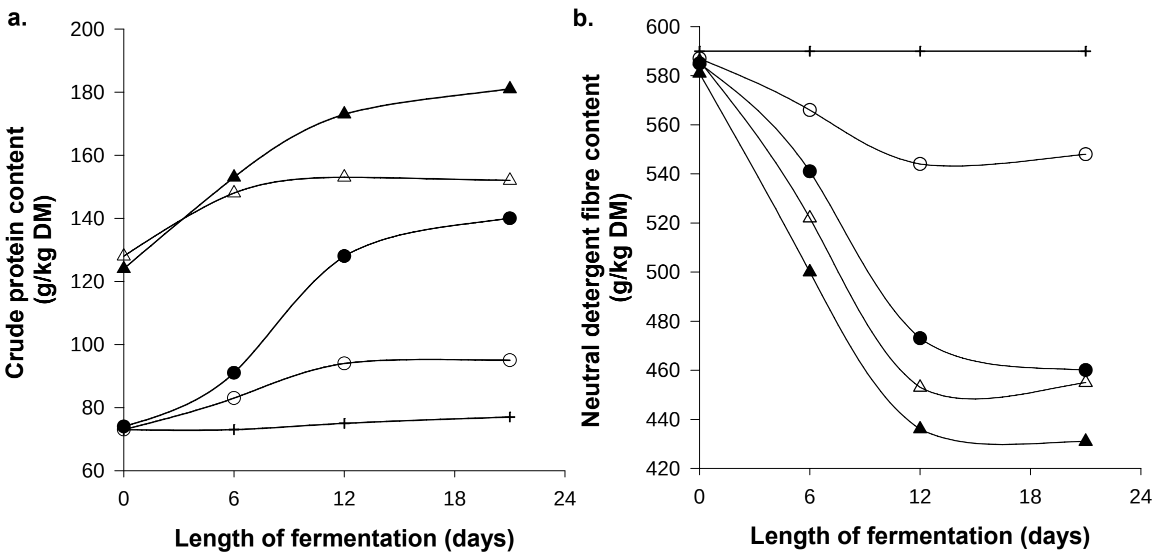

Figure 2. The effect of *Aspergillus niger* and urea treatment on the crude protein content (a.) and ash-free neutral detergent fibre content (b.) of cocoa-pods over time. Treatments were -+- untreated, immediately dried cocoa-pods; -○- untreated, fresh cocoa-pods; -●- *Aspergillus niger* treated cocoa-pods; -△- urea treated cocoa-pods; -▲- *Aspergillus niger* and urea treated cocoa-pods.

The increased CP content of the cocoa-pods is presumably the result of the growth of the mycelia of *Aspergillus niger*, where additional nitrogen is derived from fixation from external sources. The sources of the additional nitrogen measured in cocoa-pods treated with *Aspergillus niger* remain unknown but possible explanations may include fixation of atmospheric nitrogen by *Aspergillus niger* or bacterial or other sources of contamination (as the present study was not conducted under sterile conditions). The use of *Aspergillus niger* to improve the quality of low quality feedstuffs or agro-industrial by-products warrants further investigation. While the change in total dry matter production over time, as a result of *Aspergillus niger* treatment, was not measured in the present study it is unlikely that the decrease in NDF content was due to a change in the proportion of *Aspergillus niger* relative to cocoa-pod on a dry matter basis alone.

7.1.2 Effect of *Aspergillus niger* treatment and level of feeding of cocoa-pods on intake and growth of young Bali cattle in South East Sulawesi

The growth response of 12 month old weaned Bali cattle to untreated and treated cocoa-pods at different levels of inclusion was evaluated. Treatment of cocoa-pods with *Aspergillus niger* resulted in higher CP and lower NDF compared with untreated cocoa-pods (Table 2). Untreated cocoa-pods were similar in CP content to native grass but contained less NDF.

Table 2. Nutritive composition of native grass, and untreated and *Aspergillus niger* treated cocoa-pods offered to weaned Bali cattle at South East Sulawesi[1]

Feedstuff	DM2	OM2	CP2	NDF2
Native grass	204[a]	918[c]	76[a]	658[c]
Untreated cocoa-pods	829[c]	894[b]	78[a]	598[b]
Treated cocoa-pods	782[b]	878[a]	135[b]	539[a]
SEM[1]	5	5	4	7

[1]*Values are mean and SEM is standard error of difference of means over 8 weeks; different alphabetical superscripts within a column within an experiment are significantly different ($P < 0.05$).*

[2]*Dry matter (DM), organic matter (OM), crude protein (CP), ash-free neutral detergent fibre (NDF) content.*

Young Bali cattle offered cocoa-pods *ad libitum* lost live weight, while cattle offered cocoa-pods with native grass or native grass alone gained live weight, over the eight week experimental period (Table 3; Figure 3). The daily live weight loss was less for cattle fed cocoa-pods treated with *Aspergillus niger* than those offered untreated cocoa-pods. Similarly live weight gain was greater in cattle fed native grass with treated cocoa-pods, compared with those fed native grass with untreated cocoa-pods. While young cattle fed cocoa-pods *ad libitum* did lose weight over the duration of the study, the majority of this loss occurred during the initial two to four weeks with live weight basically maintained thereafter. This suggests that after a period of adaptation cocoa-pods may be a suitable maintenance feed resource, particularly for mature cattle such as dry cows and this is one area of work which requires further investigation. *Ad libitum* intake of cocoa-pods was greater when the pods were treated with *Aspergillus niger* (17.1 g DM/kg W/d) compared with untreated cocoa-pods (13.9 g DM/kg W/d), however treatment had no affect on cocoa-pod intake (5.9 to 7 g DM/kg W/d) when offered with native grass. Treatment with *Aspergillus niger* had no affect on dry matter digestibility, digestible organic matter intake or estimated metabolisable energy intake of cocoa-pods. Dry matter digestibility, digestible organic matter intake and estimated metabolisable energy intake were all lower when cocoa-pods were offered *ad libitum*, as the sole component of the diet.

Table 3. Average daily live weight gain, feed intake and digestibility of 12 month old weaned Bali cattle fed native grass *ad libitum* (NG) and increasing levels of untreated (UTCP) and *Aspergillus niger* treated (TCP) cocoa-pods[1]

Parameter	NG	NG + UTCP[2]	NG + TCP[2]	UTCP ad lib	TCP ad lib	SEM[1]
Live weight gain (kg/d)[3]	0.173^{c}	0.136^{c}	0.232^{d}	-0.282^{a}	-0.116^{b}	0.03
Native grass intake (kg DM[4]/d)	2.85^{b}	2.51^{a}	2.55^{a}	-	-	0.03
Cocoa-pod intake (kg DM/d)	-	0.75^{a}	0.89^{b}	1.45^{c}	1.78^{d}	0.04
Total intake (kg DM/d)	2.85^{b}	3.26^{bc}	3.44^{c}	1.45^{a}	1.78^{a}	0.21
Total intake (g DM/kg W/d)	22.5^{c}	26.0^{d}	27.9^{d}	13.9^{a}	17.1^{b}	1.5
DM digestibility (g/kg)	527^{b}	523^{b}	536^{b}	423^{a}	449^{a}	28
DOMI[5] (g/kg W/d)	10.9^{b}	12.7^{bc}	14.0^{c}	5.6^{a}	7.5^{a}	0.9
Estimated MEI[6] (MJ/kg $W^{0.75}$/d)	0.57^{b}	0.66^{bc}	0.73^{c}	0.28^{a}	0.38^{a}	0.05

[1]Values are treatment means; SEM is standard error of the difference of the means; alphabetical superscripts across the rows indicate significant difference between treatment means (P<0.05).
[2]Untreated and treated cocoa-pods were offered at 10 g DM/kg W/d before feeding native grass.
[3]Average daily gain over the 8 week experimental period.
[4]Dry matter (DM).
[5]Digestible organic matter intake (DOMI).
[6]Metabolisable energy (ME) intake estimated from CSIRO (2007), where ME (MJ/kg DM) = 0.0157 x DOMD.

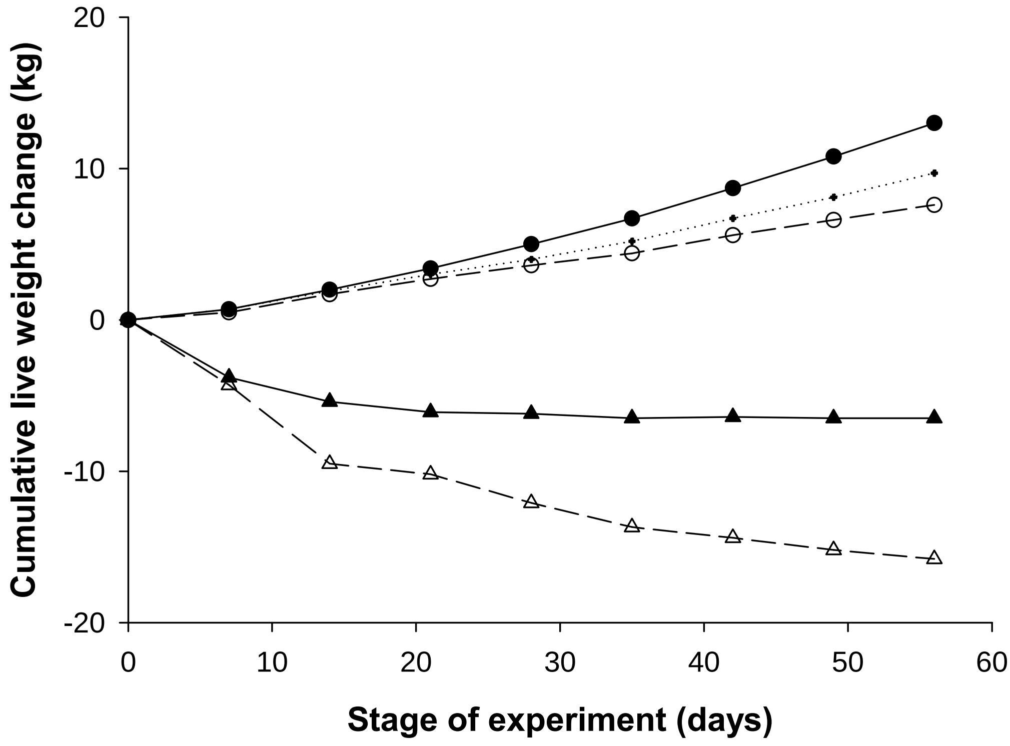

Figure 3. Cumulative live weight change of young Bali cattle offered native grass *ad libitum* ( ), native grass *ad libitum* plus 10 g untreated cocoa-pods DM/kg W/d ( ), native grass *ad libitum* plus 10 g treated cocoa-pods DM/kg W/d ( ), untreated cocoa-pods *ad libitum* ( ) and treated cocoa-pods *ad libitum* ( ).

7.1.3 Effect of treatment of cocoa-pods with *Aspergillus niger* on the performance of Bali cattle in villages in South East Sulawesi

Untreated and treated cocoa-pods were successfully fed to Bali cows and yearlings in villages in Sultra. Cocoa-pods were initially mixed with water and fed as a slurry or mixed with rice bran to encourage intake by animals. Animals readily consumed the cocoa-pods within two weeks and there was no difference in adaptation to diet between untreated and treated cocoa-pods. There was no significant difference in the average daily live weight gain of yearling Bali cattle, more mature than those cattle used in section 7.1.2, fed 15 g DM/kg W/d of untreated or treated cocoa-pods (0.28 ± 0.04 vs. 0.33 ± 0.04 kg/d, respectively), with no significant difference in live weight at the end of the 84 day monitoring period (Figure 4). There was no significant difference in live weight gain between male and female yearling Bali cattle in this study.

All of the farmers involved in the study grew cocoa and harvested between May and July. However, only 41% of the farmers fed cocoa-pods to cattle. Of the farmers that fed cocoa-pods, 50% fed it fresh and chopped and 50% fed it dried and ground. The farmers who didn't feed cocoa-pods indicated they did not know it could be successfully fed to cattle and simply left the cocoa-pods in the plantation, thereby providing a potential reservoir for infestation by the cocoa-pod borer. All farmers indicated they would be likely to use a simple, cheap cocoa-pod chopping method to process cocoa-pods as a cattle feed if it was available in the village.

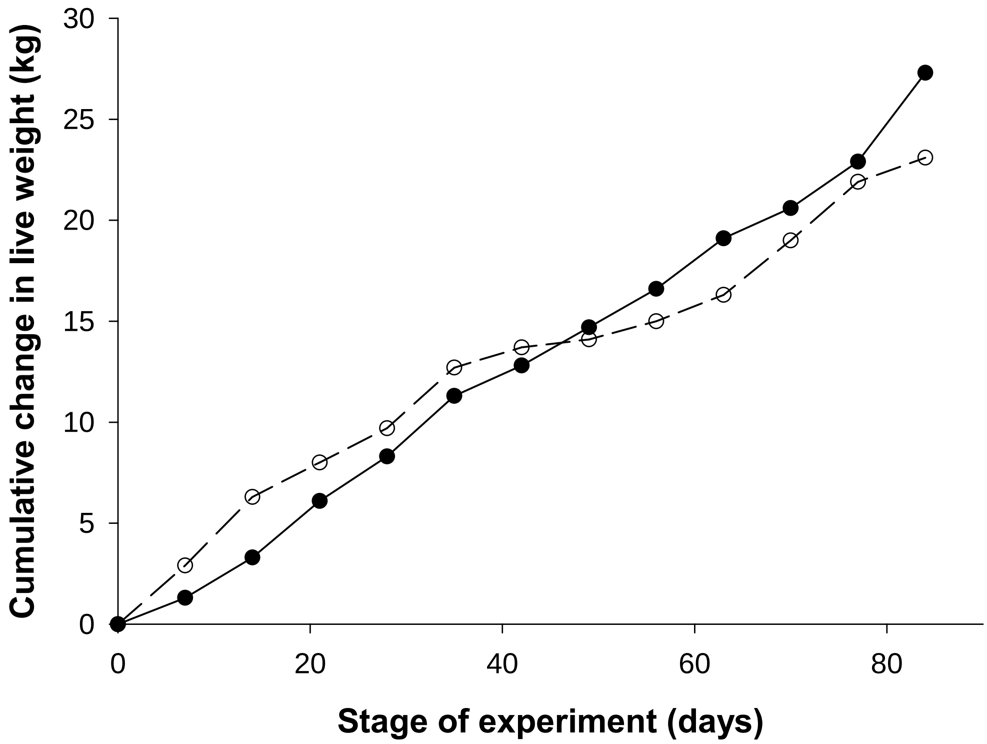

Figure 4. Cumulative live weight change of Bali cattle fed untreated (–○–) or treated (–●–) cocoa-pods at 15 g DM/kg live weight in villages in Ladongi sub-district, South East Sulawesi.

7.1.4 Implementation of a simple cocoa-pod chopper in Ladongi sub-district, South East Sulawesi

Two choppers, one manual and one electric operated, were sourced from Toko Mesin Engineering Company, Malang, East Java and established in villages in Ladongi sub-district, Sultra during the main cocoa harvest in 2008. The ability of these choppers to process cocoa-pods was evaluated and compared with the existing cocoa-pod grinder. For the manual and electric choppers, cocoa-pods must be processed within two to three days of harvest and should be clean of other litter before feeding through the machine. The chopped cocoa-pods can then be dried in the sun for three days, or treated with *Aspergillus niger* for three days followed by sun drying for three days. The dried cocoa-pods can be stored in bags for at least 12 months. For the existing large scale petrol operated grinder the pods may be dried before grinding. The ground cocoa-pods can then either be stored in bags or treated with *Aspergillus niger* for three days, followed by sun drying for three days. The dried cocoa-pods can be stored in bags for at least 12 months.

The characteristics of the two new choppers and the original petrol operated grinder are described in Table 4. The comparative advantages and disadvantages of the three processors are described in Table 5. The three processors are shown in Figure 5. The manual and electric choppers produced a larger size end-product than the existing petrol operated grinder (Figure 6). It is not expected that the difference in chop size would greatly affect acceptance and intake by cattle, however it is likely that the larger chopped product will not lend itself to being fed as a slurry, so this does warrant investigation. It is speculated that the larger sized end products could be soaked in water to encourage intake, however the ability of cocoa-pods to rehydrate is currently unknown and also warrants investigation. Alternatively the cutting blade could be modified to producer a smaller product, similar to the ground product from the larger grinder.

Table 4. Characteristics of cocoa-pod choppers and a grinder evaluated in villages in Ladongi sub-district, South east Sulawesi

Characteristic	Manual	Electric	Grinder
Operation	Manual (hand); chain and gear rotates blade	Electric;110/220V, 11/5.5A;1400 rpm	Diesel
Construction	Steel	Steel	Iron / Steel
Dimensions (cm)	60 x 36 x 90	60 x 36 x 90	180 x 60 x 150
Weight (kg)	22.6	42.8	100.0 (without engine)
End-product	Slices	Slices	Meal
Through-put (kg/h)	70-90	100-120	20-25
Safety features	Manual operation is easily stopped; minimal moving parts exposed; protective chute for inserting cocoa-pods; no noise; no dust.	Minimal moving parts exposed; protective chute for inserting cocoa-pods; no noise; no dust.	Strong construction
Labour requirements	2 people	1 person	2 people
Maintenance and running costs (rupiah/year)	200,000	500,000	1,700,000
Purchase price (rupiah) (excludes delivery)	1,500,000	2,000,000	20,000,000

Table 5. Advantages and disadvantages of cocoa-pod choppers and grinder evaluated in villages in Ladongi sub-district, South East Sulawesi

Manual	Electric	Grinder
	Advantages	
Cheap No petrol or electricity required for operation Low maintenance costs and requirements Safe to use Portable (light weight and small) Potential for modification electric motor can be added could be adapted to bicycle to run axle and wheels could be attached to assist portability	Cheap Low maintenance costs and requirements Low labour requirement and no manual grinding High throughput Portable (light weight and small) Potential for modification electric motor can be removed to revert to manual operation axle and wheels could be attached to assist portability	Versatile, can be used to chop cassava, maize grain, soybean, etc. Fine, consistent final product Dried cocoa-pods are acceptable for grinding
	Disadvantages	
Low throughput Manual operation Limited versatility, can be used to chop cocoa-pods, cassava, only Two people required for operation Final product may require further grinding if small particles are required Fresh cocoa-pods only	Electricity source required Heavier than manual chopper Limited versatility, can be used to chop cocoa-pods, cassava, only Not as safe as manual chopper with more moving parts exposed and operating at quicker rotor speed Final product may require further grinding if small particles are required Fresh cocoa-pods only	Expensive to purchase, operate and maintain Petrol required Dangerous to use (noisy, dusty, slow to stop in emergency) Heavier and less portable than other choppers Requires specialist training. Two people required for operation. Slow throughput

Farmers indicated they were interested in the new choppers evaluated, due to lower purchase price and operating cost, ease of operation and versatility to chop other products. They felt that the manual chopper could be modified to be pedalled by feet rather than operated by hand. Further, the limited range of products that can be chopped in the manual and electric choppers could be addressed through the design of other blades which could be interchangeable, depending on the feed source to be chopped. The mounting of the choppers on axles would allow them to be towed by motorcycle between farmers and villages. If the new choppers are to be adopted they should be circulated between the villages for farmers to assess for themselves. The local manufacture of these machines in Sultra would also facilitate adoption by reducing transportation costs. In conclusion, the low-input cocoa-pod choppers evaluated in this study successfully chopped cocoa-pods. A local source of production and slight modifications to the cocoa-pod choppers would facilitate adoption by farmers. The adoption of these cocoa-pod choppers would facilitate the removal of cocoa-pods from the cocoa plantations to reduce the chance of cocoa-pod borer attack and to provide an alternative cattle feed resource.

Figure 5. Electric (upper, left) and manual (upper, right) cocoa-pod choppers and the original cocoa-pod grinder (middle) evaluated and farmers using the new manual chopper in Ladongi sub-district, South East Sulawesi.

Figure 6. End-product of the cocoa-pod grinder (left) and the manual cocoa-pod chopper (right) evaluated in Ladongi sub-district, South East Sulawesi. The manual and electric cocoa-pod choppers produced a similar consistency of chopped cocoa-pods.

General discussion of cocoa-pod studies

The removal of cocoa-pods from cocoa plantations will be one means to improve cocoa yield and quality by controlling the amount of litter which could potentially harbour the cocoa-pod borer. Despite being of modest nutritive value, cocoa-pods should be considered as an important cattle feed resource in areas where cocoa plantations exist.

Fresh cocoa-pods will be readily consumed by cattle, however this does not allow for long-term storage to utilise cocoa-pods in times of inadequate feed supply. Dry, unprocessed cocoa-pods are unpalatable to cattle. It is therefore essential that for the cocoa-pods to be conserved for feeding when needed some form of processing is required. While it does appear that treatment with *Aspergillus niger* will improve the nutritive value of cocoa-pods, the inputs (cash and labour) and technical skill required are likely to be major impediments to adoption by small-holder farmers. However, simple choppers are likely to be adopted by farmers, provided purchase, operating and maintenance costs are low. These can be readily utilised to process cocoa-pods (either untreated or treated) for long term storage.

The impact of *Aspergillus niger* on cocoa-pod quality was evident in the three studies, conducted by different organizations. In the two feeding studies, the response was variable and appears to be dependent on the level of inclusion in the diet and the age of the animal. No response was evident when *Aspergillus niger* treated cocoa-pods were fed to more to mature Bali cattle (~150 kg live weight) in villages, when offered at 15 g DM/kg W/d. However, a response was apparent when *Aspergillus niger* treated cocoa-pods were offered to young, growing calves (~120 kg live weight), where calves fed treated cocoa-pods had a higher average daily live weight gain than those fed untreated cocoa-pods, offered at 10 g DM/kg W/d (0.232 vs. 0.136 kg/d). The young calves initially lost live weight when fed untreated and treated cocoa-pods *ad libitum*, although this live weight loss occurred during the first few weeks of the study and stabilised thereafter. This suggests that live weight will be maintained on high levels of cocoa-pods for a short period (eight weeks) after an appropriate induction period. The calves fed treated cocoa-pods *ad libitum* loss less live weight than those fed the untreated cocoa-pods *ad libitum*.

It is recommended that chopped and dried cocoa-pods be fed without *Aspergillus niger* treatment as maintenance feed for mature cattle (greater than 150 kg in live weight) in periods of inadequate feed supply. Based on the laboratory and feeding studies conducted within this project, feeding levels of approximately 10 g cocoa-pod DM/kg W/d in conjunction with other feeds such as native grasses or Gliricidia, is expected to maintain body condition of non-lactating, mature female cattle. The inclusion of cocoa-pods into the feed resources used by small-holder farmers will make available other higher quality forages for growing calves and lactating cows and reduce labour inputs of farmers over the long-term, albeit with an increased labour requirement during cocoa-pod collection and processing. It is not recommended that untreated cocoa-pods be included at high levels in the diets of growing calves or lactating cows.

7.2 To establish and assess the value of forage and shrub legumes as supplements in the diet of cattle.

7.2.1 Biomass production of forage legumes on dryland and lowland areas in Ladongi sub-district, South East Sulawesi

Legumes were successfully established in small plots in both dryland and lowland areas of Ladongi sub-district, Sultra (Figure 7). In both dryland and lowland areas biomass production peaked at approximately 120 days after sowing. In both areas *Lab lab purpureus* appeared to produce the greatest amount of biomass (Figures 8 and 9). Generally there was little difference in biomass production of the different species evaluated under dryland or lowland conditions. It should be noted that the lowland area was attacked by rats during the monitoring period (between days 70 and 100) and this may have reduced biomass production, particularly of *Centrosema pascuorum*. It appears that any of the legumes evaluated will provide an additional source of high quality feeds on either lowland or dryland areas. Therefore opportunities exist for a wider scale evaluation of these legumes as either ley crops during the rice fallow period, small plantings in gardens or other unused dryland areas. None of the legumes evaluated are likely to persist under heavily shaded cocoa plantations. The greatest opportunity exists for the establishment of legumes in the fallow rice fields during the dry season. During this time cattle generally graze weeds and rice straw stubble on the rice fields. The establishment of legumes would provide a supply of higher quality forages and improve soil fertility, potentially reducing subsequent fertiliser inputs. The legumes could be grazed by tethered animals, cut and carried to the kandang or conserved as fodder reserves for the feed shortages which occur in the subsequent wet season, when rice fields are prepared for the subsequent rice crop. This approach would require careful management to restrict access of cattle to areas planted with legumes until they are established. The selection of which legumes to plant on fallow rice fields will need to consider their persistence and ease of removal when farmers prepare fields for the subsequent rice crop. In this regard *Lab lab purpureus* may be the most useful option. It will produce a large biomass relatively quickly (albeit with a somewhat higher stem content than the other species evaluated), it can either be grazed or conserved as hay and is easily removed from the fields during preparation for the subsequent rice crop.

a. *Centrosema pascuorum*

b. *Clitoria ternatea*

c. *Lab lab purpureus*

d. *Macroptilium bracteatum*

Figure 7. Forage legume plots on a lowland area in Ladongi sub-district, South East Sulawesi, February 2008 (82 days after sowing).

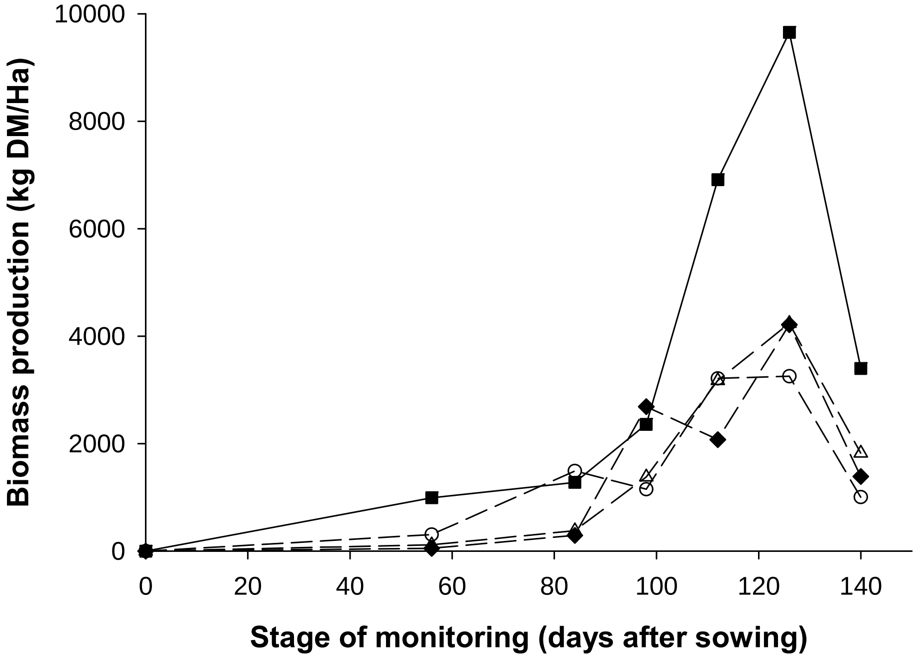

Figure 8. Biomass production of *Centrosema pascuorum* ( ), *Clitoria ternatea* ( ), *Lab lab purpureus* ( ) and *Macroptilium bracteatum* ( ) sown on a dryland area in Ladongi sub-district South East Sulawesi in mid-November, 2007.

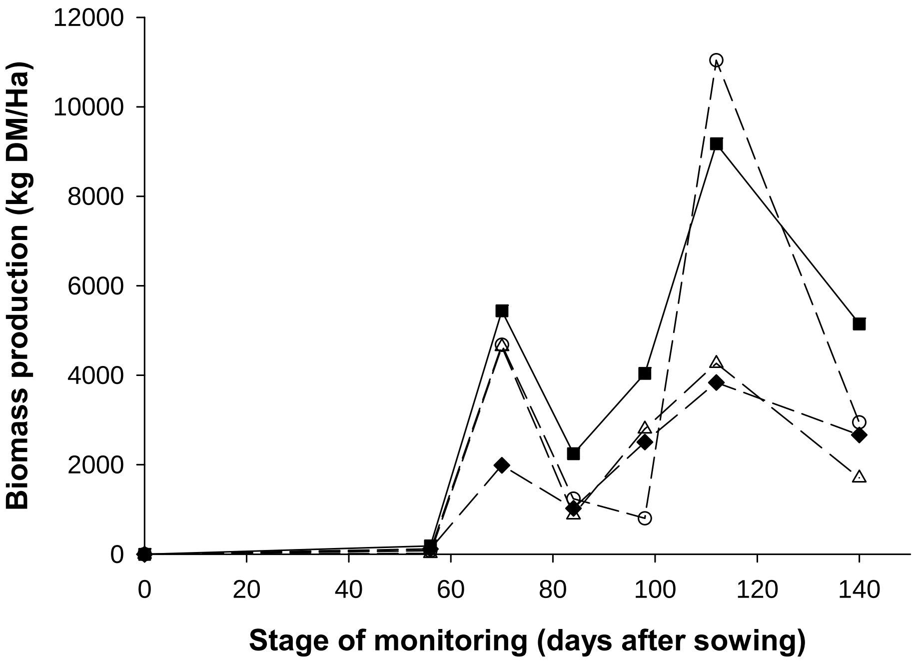

Figure 9. Biomass production of *Centrosema pascuorum* ( ), *Clitoria ternatea* ( ), *Lab lab purpureus* ( ) and *Macroptilium bracteatum* ( ) sown on a lowland area in Ladongi sub-district South East Sulawesi in mid-November, 2007.

7.2.2 Establishment of *Sesbania grandiflora* on rice paddy field bunds in Ladongi sub-district, South East Sulawesi

Sesbania seedlings were planted on bunds of rice fields and at schools in Ladongi sub-district and at BPTP-Sultra research farm nurseries at Kendari and Wawotobi during the late dry season in 2008. The survival of seedlings was higher in nurseries and schools than on rice field bunds (Table 6). The higher survival of trees in the nurseries and schools is attributed to more intensive management of a smaller number of trees, compared with on the rice field bunds. Given the lower survival rates on bunds, it is recommended that seedlings be planted at 1-2 m spacings to successfully establish a larger number of trees. Despite the lower survival on the rice field bunds, the surviving trees have grown well (Figure 10). Unfortunately, in late April 2009 the collaborating farmers in Ladongi sub-district cut down the Sesbania trees on the rice field bunds, without consultation with the project team. The reason given was that several bird nests had appeared in the Sesbania trees and farmers were concerned that the trees would attract more birds which would reduce their rice yields. This is despite the entire rice growing area being surrounded by Gliricidia and cocoa plantations with similar opportunities for nesting. Given the successful establishment of Sesbania in this study and its potential role in addressing feed gaps there is a strong requirement for farmer demonstration sites in Sultra regarding the potential impact Sesbania could have on their cattle production systems and the minimal effects it is likely to have on rice yields. An alternative strategy would be to initially establish Sesbania in non-productive areas of land, away from the rice fields.

Table 6. Survival of *Sesbania grandiflora* seedlings planted at various sites in South East Sulawesi during October and November, 2008

Site	Total seedlings planted	Seedling survival January 2009 April 2009 No. %[1] No. %[1]			
BPTP nursery, Wawotobi	100	80	80	80	80
BPTP nursery, Kendari	100	90	90	90	90
Rice field bunds, Ladongi sub-district	350	250	71	62	2.4
High school, Ladongi sub-district	30	30	100	30	100
Muslim school, Ladongi sub-district	20	20	100	20	100

[1]*As a percentage of the total number of seedlings originally planted.*
[2]*In early April 2009 all 250 trees present in January had survived. However, in late April several birds nests appeared in the Sesbania and the farmers chopped down the majority of the Sesbania on the rice field bunds out of concern that more birds would be attracted which would destroy the rice crop.*

a. b. c.

Figure 10. *Sesbania grandiflora* established on rice field bunds in October 2008 (a.), after three months growth in January 2009 (b.) and after 5 months growth in March 2009 (c.) in Ladongi sub-district, South East Sulawesi.

7.2.3 Establishment and grazing of best-bet forage legumes on rice paddy fields after the rice harvest in Ladongi sub-district, Sulawesi Tenggara

Excessive rainfall in Sultra in 2008, particularly in May, June, July and August, resulted in poor establishment and survival of forage legumes on paddy fields after the rice harvest in May and June. The rainfall during this period in Kendari was higher in 2008 compared with the average rainfall over the years 2001 to 2007 (Figure 11).

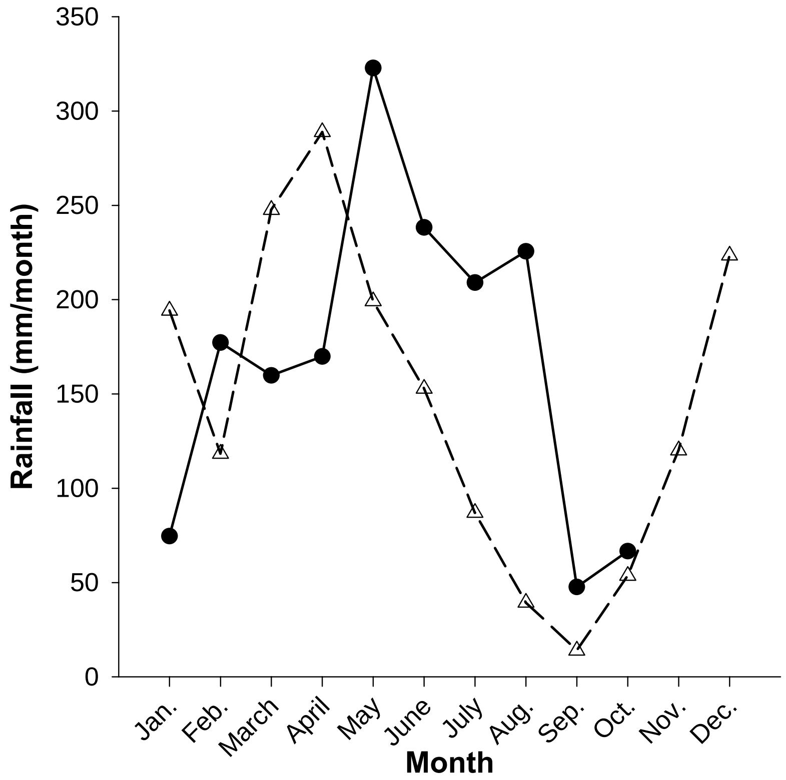

Figure 11. Rainfall distribution in South East Sulawesi in 2008 (–●–) compared with average rainfall for the years 2001 to 2007 (–△–). Data was recorded at the BPTP-Sultra weather station at Kendari; no data was available for November and December 2008 due to a weather station malfunction.

The failure to establish a large area of forage legumes on rice paddy fields was due to excessive rainfall and poor drainage. Despite the excessive rainfall, areas of *Lab lab purpureus* did establish but did not persist (Figure 12). Attempts were made to drain paddy fields however this had little or not impact on the establishment and survival of forage legumes (Figure 12). Only in those areas which were elevated and better drained did any legumes establish (Figure 13). Small-holder farmers indicated they had never previously experienced a similar rainfall pattern as that of 2008; many took the opportunity to plant a second rice crop. The lack of forages meant that the grazing study was not conducted as planned. A shorter study for two months in duration, demonstrated that growing Bali cattle could be successfully grazed on forage legumes if climatic conditions permitted establishment on paddy fields (Figure 13). There were no detrimental effects on cattle from grazing the forage legumes and average daily live weight gains of 0.20 ± 0.01 kg/d were recorded. This average daily live weight gain was comparable to gains recorded for animals fed native grass and forage legumes in on-station and village studies described elsewhere in this report and in the LPS 2004 023 final report.

a. *Lab lab purpureus* (July 2008)

b. *Lab lab purpureus* (October 2008)

c. Waterlogged *Macroptilium bracteatum* field (October 2008).

d. Attempts were made to drain surface water from fallow rice fields (October 2008).

Figure 12. Establishment of legumes on fallow rice paddy fields after excessive and persistent rainfall during the typical dry season in Ladongi sub-district, South East Sulawesi.

a.

b.

Figure 13. Establishment (a.) and grazing (b.) of *Clitoria ternatea* on elevated, well drained fallow rice paddy field in October and December 2008, respectively, in Ladongi sub-district, South East Sulawesi.

While the approach of establishing forage legumes on paddy fields after the rice harvest ultimately failed in the present study, it is an approach that warrants re-evaluation due to the uncharacteristic rainfall conditions during the 2008 dry season. There are several other issues which need to be resolved before this approach could be scaled up; these include restricting access of other animals to the legumes established on the rice fields and weed and pest control. Other potential options such as growing legumes on dryland areas, rice paddy field bunds or near to houses and kandang's warrant consideration however they do not provide the additional benefits to soil fertility through nitrogen fixation of legumes on the paddy fields and from urinary nitrogen and the breakdown of organic matter in the faeces of cattle tethered and grazing legumes in the fields. In contrast, the conservation of forages and feeding in the kandang as required will reduce overall labour inputs, despite the higher requirement during harvest and baling, and will still allow for the collection, composting and storage of faeces for more strategic use immediately prior to preparation of the subsequent rice crop.

7.2.4 Village study and demonstration of Gliricidia feeding to Bali cattle in Ladongi sub-district, South East Sulawesi

Bali cattle fed Gliricidia *ad libitum* grew significantly faster than Bali cattle fed native grass *ad libitum* (0.35 ± 0.03 vs. 0.22 ± 0.03 kg/d, respectively; $P<0.05$) in Ladongi sub-district. At the end of the 84 day monitoring period, Bali cattle fed Gliricidia were 10.8 kg heavier than Bali cattle fed native grass (Figure 14). There was no significant difference in live weight gain between male and female Bali cattle in this study. Bali cattle readily consumed Gliricidia in the current study (Figure 15).

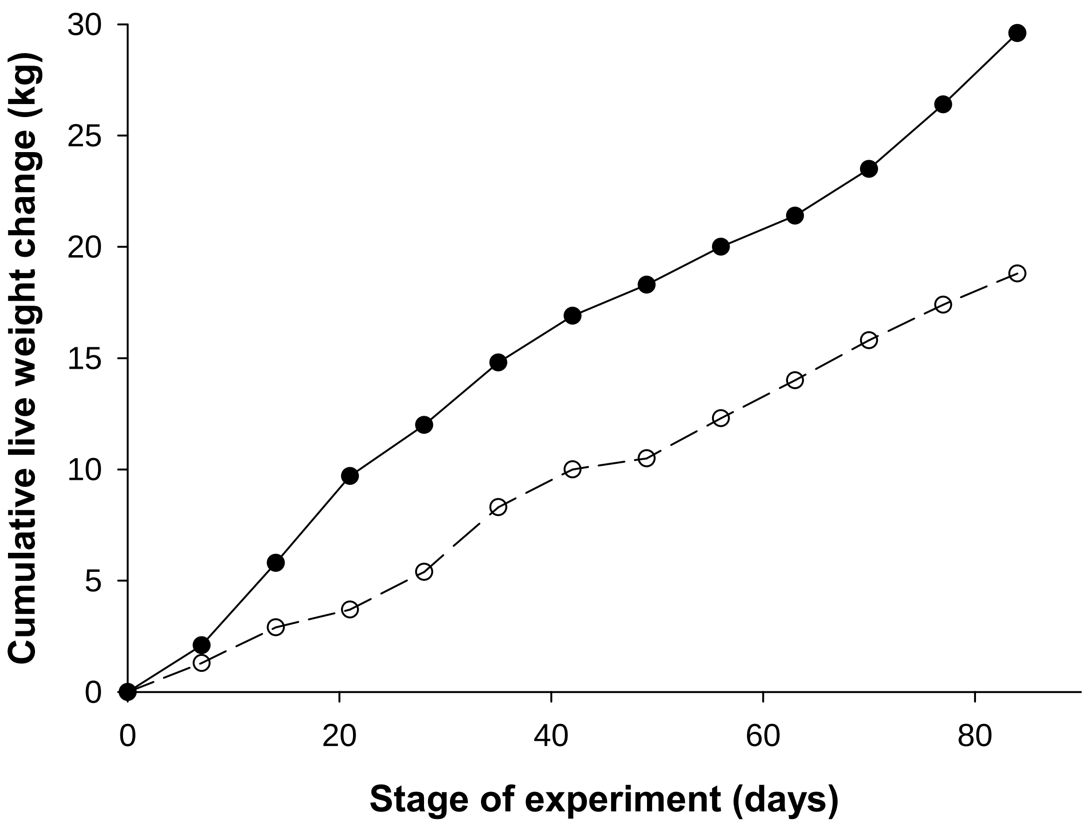

Figure 14. Cumulative live weight change of Bali cattle fed native grass (–○–) or *Gliricidia sepium* (–●–) *ad libitum* in villages in Ladongi sub-district, South East Sulawesi.

Figure 15. Cattle readily consuming fresh *Gliricidia sepium ad libitum* in a household kandang in Ladongi sub-district, South East Sulawesi.

7.2.5 Evaluate feed value of forage legumes and Gliricidia for young Bali cattle

The growth response of eight to 12 month old weaned Bali cattle to native grass, Gliricidia and forage legumes was evaluated. The nutritional composition of the feedstuffs evaluated in the two on-station experiments conducted at the University of Haluoleo were within the range of values expected for each of the feedstuffs investigated (Table 7).

Table 7. Nutrient composition of native grass (NG), *Gliricidia sepium* and rice bran fed to young Bali cattle in experiment 1

Parameter	NG	Gliricidia	Rice bran	Forage legume
Dry matter (g/kg)[1]	204 ± 2	257 ± 1	939 ± 3	225 ± 3
Organic Matter (g/kg DM)[1]	903 ± 3	901 ± 8	881 ± 7	N/M[2]
Crude Protein (g/kg DM)[1]	71 ± 2	223 ± 4	97 ± 2	N/M
NDF (g/kg DM)[1]	598 ± 7	412 ± 4	471 ± 5	N/M

[1]*values are mean ± standard error of the mean.*
[2]*N/M, not measured.*

In experiment 1, animals fed Gliricidia with rice bran supplementation had a significantly higher average daily live weight gain during the eight week experimental period than animals fed native grass, native grass supplemented with Gliricidia or Gliricidia alone (Table 8; Figure 16). There was no difference in average daily gain between the other three treatments. Animals solely fed Gliricidia *ad libitum* had a lower total feed intake than animals fed all other treatments, while cattle offered 10 g rice bran DM/kg W/d with Glircidia *ad libitum* had the highest intakes. Dry matter and organic matter digestibility were lowest for native grass and highest when Gliricidia was supplemented with rice bran. Total digestible organic matter intake and estimated metabolisable energy intake were both lowest for animals consuming Gliricidia alone and highest for animals fed Gliricidia supplemented with rice bran. Animals fed Gliricidia supplemented with rice bran drank more water each day than animals fed fresh feeds (native grass and Gliricidia); however the estimated total water intake (consumed from the feed and the drinking water) was greater for animals fed native grass and native grass supplemented with Gliricidia.

In experiment 2, average daily live weight gain was lowest for animals fed the forage legumes and highest for animals fed Gliricidia supplemented with rice bran (Table 8; Figure 16). Total feed intake and digestibility were highest for animals fed Gliricidia supplemented with rice bran (Table 8). There was little difference between the other three treatments for all parameters measured, although native grass had the lowest digestibility and the highest estimated total water intake (consumed from feed and drinking water).

Table 8. Average daily live weight gain, feed and water intake and digestibility of eight to 12 month old weaned Bali calves fed different diets in two experiments conducted at South East Sulawesi[1]

Parameter	Treatments				
	Experiment 1				
	NG[2]	NG + Gliricida[3]	Gliricidia	Gliricidia + RB[4]	SEM[1]
Live weight gain[5] (kg/d)	0.156^{a}	0.153^{a}	0.134^{a}	0.268^{b}	0.03
Feed intake (kg DM[6]/d)	2.55^{c}	1.60^{a}	2.20^{b}	1.80^{a}	0.13
Supplement intake (kg DM/d)	-	0.99	-	0.95	0.03
Total intake (kg DM/d)	2.55^{b}	2.59^{b}	2.20^{a}	2.75^{b}	0.12
Total intake (g DM/kg W/d)	25.1^{ab}	26.2^{b}	23.4^{a}	28.4^{c}	1.0
DM digestibility (g/kg)	541.2^{a}	561.1^{b}	567.3^{b}	596.9^{c}	6.7
DOMI[7] (g/kg W/d)	13.1^{ab}	14.3^{b}	13.0^{a}	16.89^{c}	0.6
Drinking water intake (kg/d)	2.23^{a}	2.09^{a}	2.10^{a}	3.25^{b}	0.3
Total water intake[8] (g/kg W/d)	119.7^{b}	115.7^{b}	93.4^{a}	90.72^{a}	4.4
	Experiment 2				
	NG	Gliricidia	Forage legumes	Gliricidia + RB4	SEM
Live weight gain (kg/d)	0.207^{b}	0.182^{ab}	0.168^{a}	0.257^{c}	0.02
Feed intake (kg DM/d)	2.73^{b}	2.64^{b}	2.67^{b}	2.20^{a}	0.17
Supplement intake (kg DM/d)	-	-	-	1.17	0.04
Total intake (kg DM/d)	2.73^{a}	2.64^{a}	2.67^{a}	3.36^{b}	0.17
Total intake (g DM/kg W/d)	22.4^{a}	22.3^{a}	22.8^{a}	28.7^{b}	1.1
DM digestibility (g/kg)	524.1^{a}	551.8^{b}	559.5^{b}	595.2^{c}	7.1
DDMI (g/kg W/d)7	11.7^{a}	11.9^{a}	11.5^{a}	17.3^{b}	0.1
Drinking water intake (kg/d)	1.17	1.14	1.21	1.09	0.17

[1]Values are means; SEM is standard error of difference of means; alphabetical superscripts across the rows indicate significant difference between treatments (P<0.05).
[2]Native grass ad libitum, NG.
[3]Gliricidia fed at 10 g DM/kg W/d before feeding basal diet.
[4]Rice bran fed at 10 g DM/kg W/d before feeding basal diet.
[5]Average daily gain over the experimental period (8 weeks experiments 1; 4 weeks experiment 2).
[6]Dry matter (DM).
[7]Digestible organic matter intake (DOMI); Digestible dry matter intake (DDMI).
[8]Estimated total water consumed from drinking water and feed intake.

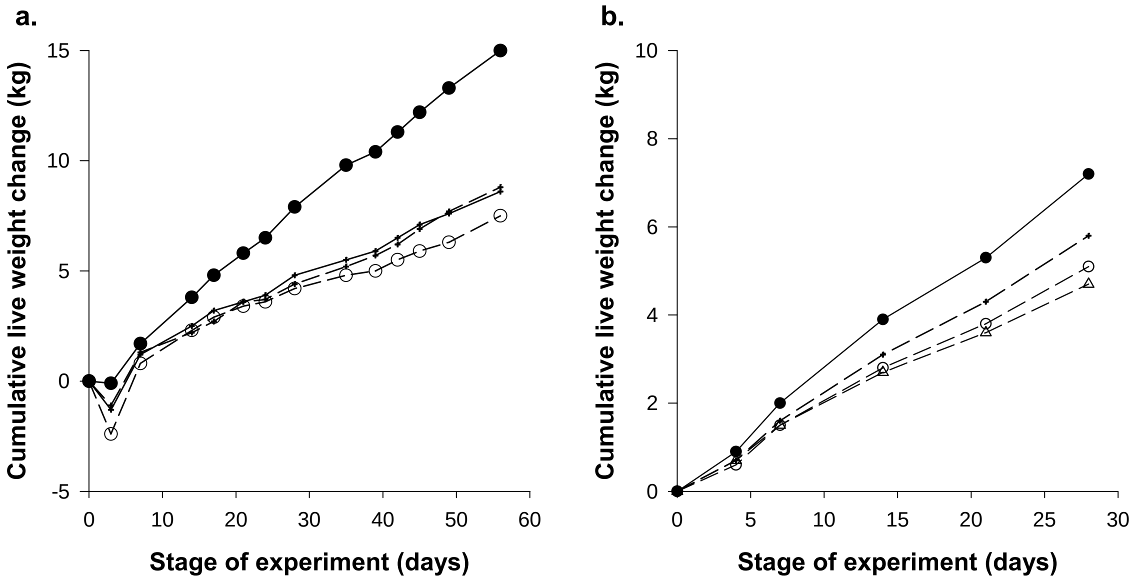

Figure 16. Cumulative live weight change of young Bali cattle offered native grass *ad libitum* ( ), native grass *ad libitum* plus 10 g Gliricidia DM/kg W/d ( ), Gliricidia *ad libitum* ( ), Gliricidia *ad libitum* plus 10 g rice bran DM/kg W/d ( ) in experiment 1 (a.) and native grass *ad libitum* ( ), forage legume *ad libitum* ( ), Gliricidia *ad libitum* ( ), Gliricidia *ad libitum* plus 10 g rice bran DM/kg W/d ( ) in experiment 2 (b.).

7.3 To build the capacity of BPTP-Sultra and University of Haluoleo staff to undertake feed evaluation research.

The project developed the capacity of BPTP-Sultra and UNHALU staff to conduct farmer relevant nutritional and feed evaluation research.

- Researchers from LPS 2004 023 acted as mentors for BPTP-Sultra and UNHALU project staff in Sultra. Prof. Marsetyo (University of Tadulako, Central Sulawesi) provided guidance to BPTP-Sultra and UNHALU staff in the conduct of on-station and village feeding trials and survey data collection. Dr Esnawan Budisantoso (BPTP-Nusa Tenggara Timur / ANTARA) provided guidance in forage legume evaluation studies conducted in villages and the establishment of larger areas of forage legumes for feeding studies.
- Australian scientists regularly visited activities in progress in Sultra and provided guidance on experimental design, activity planning and logistics, sample collection, data entry and communication.
- Sultra project scientists attended joint project meetings with LPS 2004 023 project staff and visited activities and sites involved in LPS 2004 023.
- Project team members from BPTP-Sultra and UNHALU were presented with opportunities to develop their knowledge and skills through attendance at a range of seminars, conferences, workshops and meetings. These are detailed in section 8.2.1.

- 6 undergraduate students from the University of Haluoleo were involved in the on-station experiments conducted within the project as part of their Honours program and submitted a thesis based on these studies. Students gained experience in the conduct of feeding, digestibility and live weight gain studies, as well as the applied relevance of on-station activities to the crop-livestock systems in eastern Indonesia. This provided the next generation of livestock scientists with an opportunity to receive training in ruminant nutrition research from experienced Indonesian and Australia researchers. One of these students prepared an abstract in English and was presented with a non-award certificate from the University of Queensland.
- By the end of the project, BPTP-Sultra and UNHALU staff were trained in all aspects of the project activities and were conducting all activities to a high standard with minimal inputs from the LPS 2004 023 project mentors.

7.4 To establish lifetime growth paths of male and female Bali cattle under ideal nutrition and management conditions.

Live weight of male Bali calves was significantly less than female calves at the commencement of the study, although there was no difference in live weight between male and female cattle at 12 and 18 months of age (Table 9). There was no difference in average daily live weight change between males and females from approximately 6 to 12 months of age. Entire males had greater average daily live weight gain than females from 12 to 18 months of age, and than females and castrated males from 18 to 27 months of age. Upon completion of the study, at approximately 27 months of age, male cattle were approximately 71 kg heavier than female cattle (Figure 17). It is interesting to note that average daily live weight change of males remained relatively constant at approximately 0.4 kg/d from 12 months of age onwards, whereas there was a sharp decrease in average daily live weight change of females after 18 months of age compared with growth rates from 6 to 18 months of age.

Daily dry matter intake, measured when the average live weight of the animals was 103, 163 and 215 kg, was 27.6 ± 0.5 g DM/kg W/d and was not different between the stages of development (28.5 ± 0.5, 27.5 ± 0.5 and 26.8 ± 0.5 g DM/kg W/d, respectively) or between males and females at each of the different stages of development. The plasma glucose concentration was 3.25 ± 0.09 mmol/L and did not vary with stage of development, or between males and females at any stage of development. Plasma urea concentration was significantly higher in younger animals (9.13 ± 0.31 mmol/L, 100 kg live weight) than in older animals (7.41 ± 0.32 and 7.48 ± 0.33 mmol/L, 190 and 260 kg live weight, respectively). There was no difference in plasma urea concentration between male and female Bali cattle at 100 and 190 kg live weight, however females had an elevated plasma urea concentration (8.97 ± 0.56 mmol/L) compared to entire males (5.99 ± 0.56 mmol/L) at 260 kg live weight.

Circumference at the chest and height at the withers both predicted live weight of growing Bali cattle from approximately 6 to 27 months of age (Figure 18). Males became progressively darker as they matured, while females remained a red / brown colour throughout the experiment (Figure 19). Interestingly, males castrated at puberty reverted from black to a red / brown colour, suggesting that circulating sex steroids are involved in the regulation of coat colour in Bali cattle.

A large variation in cumulative live weight change existed between individual animals. For example, Figure 20 illustrates the mean cumulative live weight change of entire male Bali cattle from approximately 6 to 27 months of age (n=10 from 6 to 18 months of age; n=6 from 18 to 27 months of age) with the cumulative live weight change of the fastest and slowest growing individual entire males, from within the mean population. At approximately 27 months of age, after 21 months of management within the same kandang and offered the same feeds, there was a difference in live weight of 69 kg. Over the 21 month period the mean cumulative live weight gain of entire males was approximately 250 kg at approximately 0.39 kg/d; while the fastest growing entire male gained 283 kg at 0.43 kg/d and the slowest growing entire male gained 214 kg at 0.33 kg/d. This suggests there may be potential for genetic selection to improve Bali cattle performance, once other management issues (nutrition, reproduction and health) are addressed.

Table 9. Live weight and average daily live weight change of male and female Bali cattle at different stages of development[1,2]

Stage of development (age in months)	Entire male[3]	Female[4]	Castrated male[5]
	Live weight (kg)		
6	69.6 ± 2.1[a]	78.6 ± 2.7[b]	N/A6
12	132.3 ± 5.5	133.0 ± 7.1	N/A
18	199.7 ± 6.5	188.8 ± 8.4	N/A
27	320.7 ± 11.5[b]	249.3 ± 14.1[a]	292.5 ± 14.1[ab]
	Average daily gain (kg/d)		
6 to 12	0.335 ± 0.03	0.291 ± 0.03	N/A
12 to 18	0.404 ± 0.02[b]	0.334 ± 0.03[a]	N/A
18 to 27	0.412 ± 0.02[c]	0.206 ± 0.02[a]	0.291 ± 0.02[b]

[1]Values are treatment means; SEM is standard error of the mean; alphabetical superscripts across the rows indicate significant difference between treatment means (P<0.05).
[2]Based on anecdotal evidence puberty was estimated to occur at approximately 18 months of age and 180-200 kg live weight.
[3]Number of entire males included in statistical analysis was 10 at 6, 12 and 18 months and six at 27 months of age.
[4]Number of females included in statistical analysis was six at 6, 12 and 18 months and four at 27 months of age.
[5]Number of castrated males included in statistical analysis was four at 27 months of age.
[6]N/A, not applicable; castration was conducted at approximately 18 months of age.

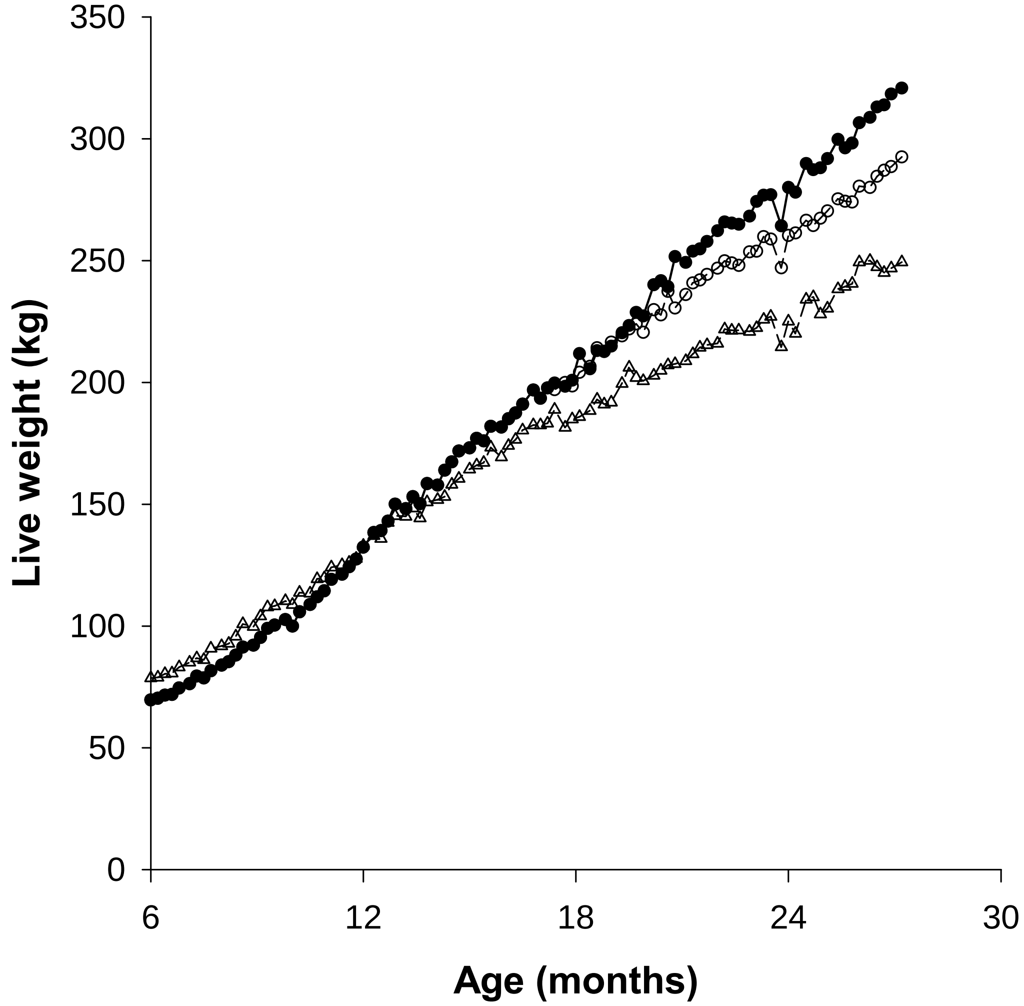

Figure 17. Live weight of entire male (—●—), female (– ▵ –) and castrated male (– ○ –) Bali cattle fed a *Sesbania grandiflora* based diet from approximately 6 to 27 months of age. Castration was conducted at puberty at approximately 18 months of age.

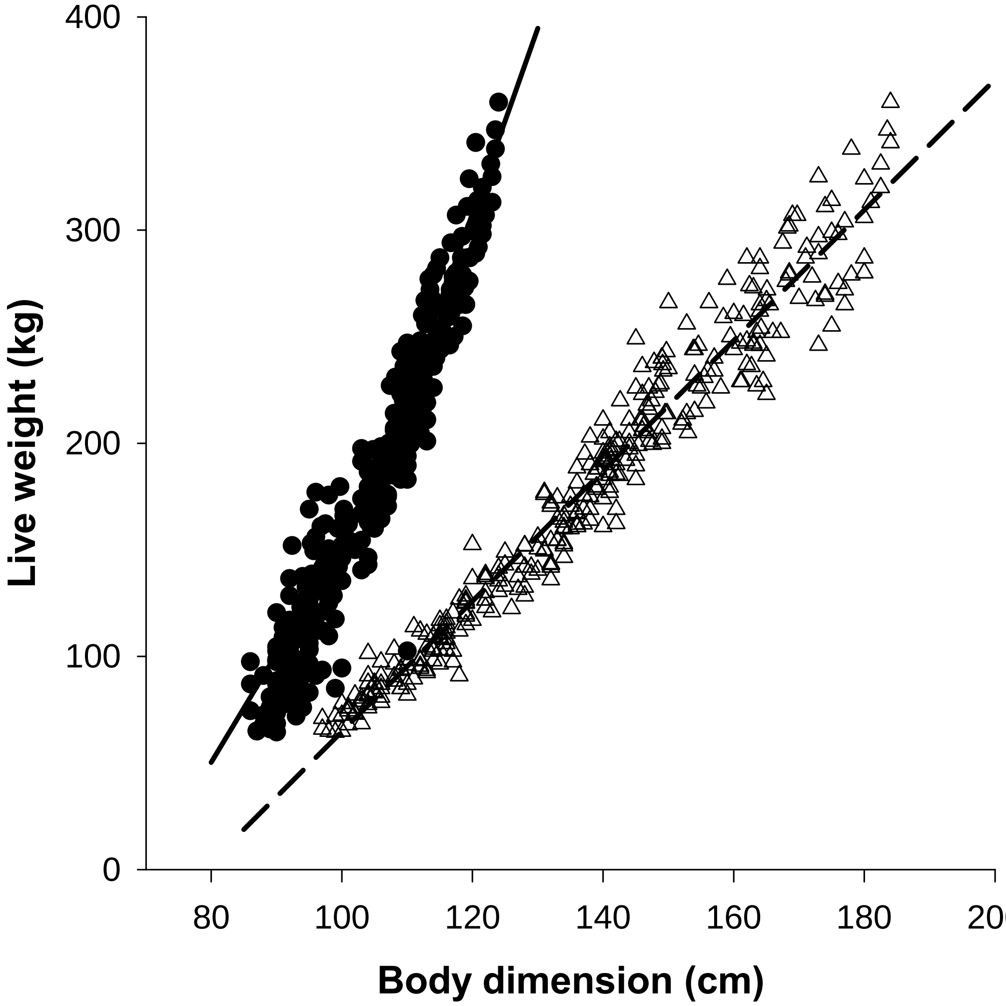

Figure 18. Relationship between wither height and live weight (●) and chest girth and live weight (△) for male and female Bali cattle from approximately 6 to 27 months of age. Equations: live weight (kg) = 245 - 8.17 x wither height (cm) + 0.0717 x wither height (cm)^2 (— ; *P*<0.001; R2=0.93); live weight (kg) = -241.23 + 3.0592 x chest girth (cm) (––– ; *P*<0.001; R2=0.96).

Entire male (Animal No. 2)	Castrated male (Animal No. 1)[1]	Female (Animal No. 14)

Figure 19. Male and female Bali cattle photographed at approximately 6 (top row), 18 (middle row) and 27 (bottom row) months of age.

[1] *Animal 1 was castrated at approximately 18 months of age, one week after the photograph in the middle row was taken.*

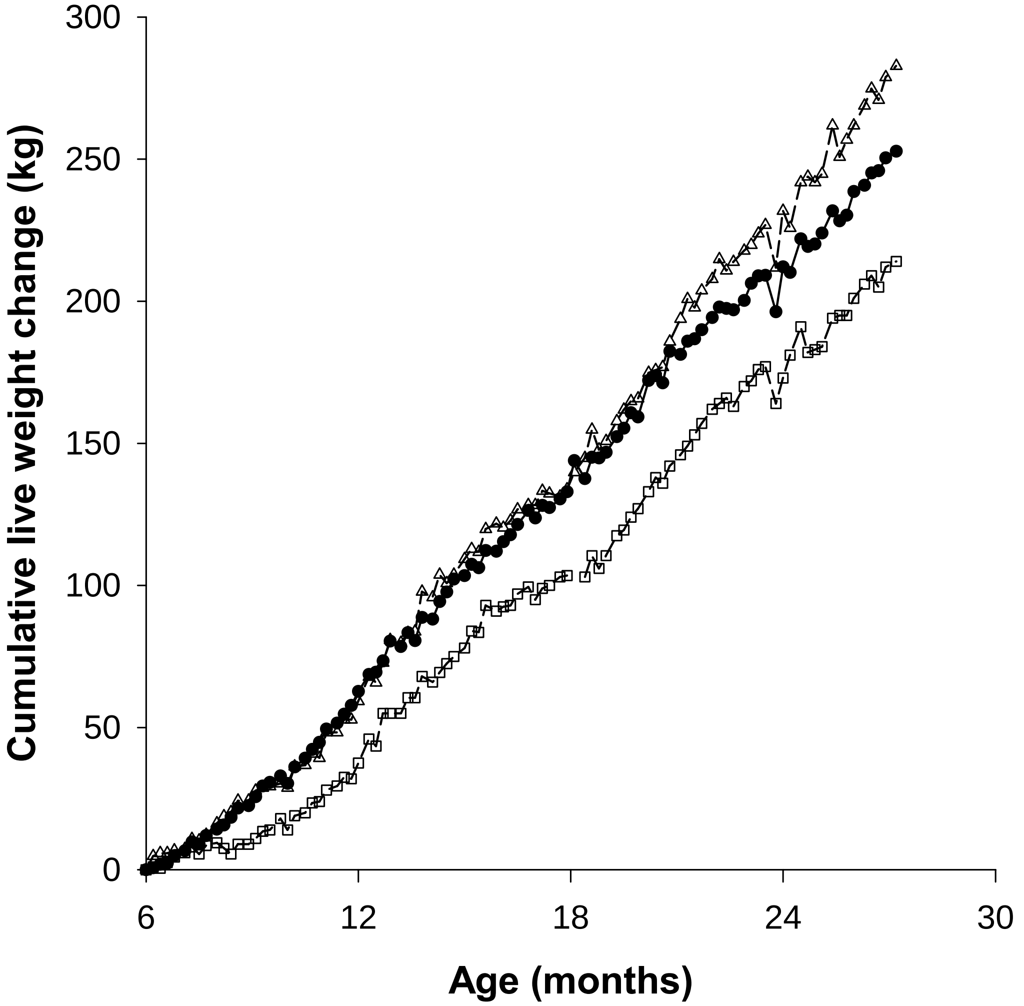

Figure 20. Variation in cumulative change in live weight of entire male Bali cattle fed a *Sesbania grandiflora* based diet from approximately 6 to 27 months of age (—●— , mean of entire males, n=10 from 6 to 18 months, n=6 from 18 to 27 months; –△– , entire male with greatest change in live weight; –□– , entire male with least change in live weight).

8 Impacts

8.1 Scientific impacts – now and in 5 years

The project has generated information on the use and treatment of cocoa-pods as a feed resource for Bali cattle. The information generated regarding treatment of cocoa-pods with *Aspergillus niger* provides information on the nutritive value and animal responses, which previously did not exist. The information generated warrants further investigation of the biological processes by which *Aspergillus niger* improves the quality of cocoa-pods and its potential use on other low quality feeds and agro-industrial by-products, including those used in Australia. The long-term growth study conducted at the University of Mataram also describes, for the first time, differences in growth rate of male and female Bali cattle of similar ages under controlled experimental conditions. The information generated in this study will be used in the development of growth and nutrition models for Bali cattle and provides a point of reference for all future studies conducted with growing Bali cattle. This study was also the first to characterise the sexual dimorphic regulation of growth and coat colour in Bali cattle under experimental conditions and provides data to support the previously untested anecdotal evidence which existed. The project established protocols for the successful collection and processing of blood and tissue samples from Bali cattle for laboratory analysis, either in Indonesia or Australia.

The project provided an opportunity for scientists and technicians at BPTP-Sultra and UNHALU to conduct ruminant nutrition research activities. The project introduced quality control programs in the conduct of pen studies, field work and laboratory work to both groups. This has included an appreciation of biological and technical variation in the design of experiments, training in experimental protocols and data management. These changes have extended to other projects and other scientists and technicians, not directly involved in the ACIAR project, who have adopted the experimental design and protocols introduced.

The present project has developed an openness of discussion and debate, while maintaining respect, between partner organisation scientists at annual project meetings and via email and other forms of communication, regarding research issues, methodology, results and ideas. This has resulted in project scientists sharing information, experiences, ideas and resources between groups. This is also occurring between projects, where team members from LPS 2004 023 are acting as mentors for team members in SMAR 2007 013.

8.2 Capacity impacts – now and in 5 years

8.2.1 Staff capacity

All staff have been given the opportunity to develop their skills and experience by attendance at a range of conferences and seminars, training workshops and meetings and through postgraduate study.

Conferences / Seminars

- 2007. International Symposium on Energy and Protein Metabolism. Vichy, France. Quigley (University of Queensland). (Australian Academy of Sciences funded).
- 2007. International Seminar on Nutrition of Herbivores. Beijing, China. Marsetyo (University of Tadulako). (ACIAR funded).

- 2008. Australian Society of Animal Production. Brisbane, Australia. Quigley, Isherwood, and Poppi (University of Queensland). (ACIAR and MLA funded).
- 2008. International Seminar on Bali Cattle Production. Kupang, Indonesia. Dahlanuddin (University of Mataram). (Indonesian committee funded).
- 2008. Pengembangan Sapi Potong Menuju Percepatan Pencapaian Swasembada Daging Sapi Nasional. Palu, Indonesia. Dahlanuddin (University of Mataram) and Marsetyo (University of Tadulako) (Indonesian committee funded).

Training / Workshops

- Scientific Communication workshop. Jakarta, Indonesia. 2006 and 2007. Marsetyo (University of Tadulako) Takdir Saili (UNHALU) and Dahlanuddin (University of Mataram). (ACIAR funded).
- Statistical analysis and experimental design workshop. Makassar, Indonesia. 2007. Takdir Saili and La Ode Nafiu (UNHALU) and Marsetyo (University of Tadulako). (ACIAR funded).
- Laboratory analysis of soil and forage samples workshop. Naibonat, Indonesia. 2007. Rusli (UNHALU), Rusdi (BPTP-Sultra), Sitti Marwiah (University of Tadulako) and Sri Sulastri (University of Mataram). ATSE Crawford Fund funded.
- Delivering quality extension services. AIT Thailand. 2007. Muhammad Rusman (BPTP-Sultra).
- Research priority setting, planning and activity management workshop. Bogor, Indonesia. 2008. Muhammad Rusman (BPTP-Sultra).
- Technology assessment and knowledge exchange workshop. Nusa Tenggara Barat, Indonesia. 2008. Muhammad Rusman (BPTP-Sultra).
- Program linkage ACIAR-SMAR on Beef Cattle Management. Pasuruan, Indonesia. 2008. Takdir Saili and La Ode Nafiu (UNHALU), Muhammad Rusman and Miftah Hidayat (BPTP-Sultra), Baiq Susmarita (Rita) Ningsih (University of Mataram). (SADI-SMAR funded).
- John Dillon Fellowship. Melbourne / Wagga Wagga / Canberra / Brisbane / Armidale, Australia. 2009. Marsetyo (University of Tadulako). (ACIAR funded).

The greatest capacity development of staff (scientists, technicians and students) at Sultra has been through their interaction with other scientists involved in LPS 2004 023. The staff in SMAR 2007 013 were included in all forms of communication with the LPS 2004 023 staff. Staff from LPS 2004 023 travelled to Sultra on several occasions to assist with the establishment of experimental protocols and the management of the project. This sharing of knowledge between Indonesian staff demonstrated the collaborative nature of the teams involved in both projects. It is anticipated that the skills developed and linkages formed between organisations will be maintained in the future. The involvement of Australian scientists in all stages of the experimental activities of the project has demonstrated the need for a ‘hands-on’ approach to conducting research. This effect has been reciprocal as the Australian scientists gained a greater understanding of the issues that arise with implementing a research program in sometimes difficult conditions, as well as the social issues in conducting and extending research findings within the complex crop-livestock systems of eastern Indonesia; the capacity of the Australian scientists to conduct intensive research activities in Indonesia has also been developed. This resulted in Indonesian and Australian scientists learning from each other.

The appointment of a ‘junior scientist’ within each organisation and the involvement of honours students in the project activities at UNHALU contributed to the capacity development of the next generation of researchers to conduct farmer relevant research. The honours student who submitted an abstract of his thesis, in English, to the University of Queensland, received a certificate acknowledging his contribution to the project. It is hoped that this certificate will assist the graduate to find employment upon completion of his studies. The continued capacity development of junior scientists will require continued engagement, either through ongoing involvement with ACIAR projects or opportunities for further training, in the form of postgraduate study programs.

8.2.2 Infrastructure capacity

Both BPTP-Sultra and UNHALU have used project funds to develop their infrastructure in some way. In some cases this has involved upgrades of animal research facilities, including the animal pens and feed and water troughs, both on-station and on-farm. In other cases laboratory related equipment such as freezers, drying ovens, laboratory, feed and animal balances, laptops for data entry and communication and digital cameras for video and photographic recording of project activities have been purchased. BPTP-Sultra purchased low-cost cocoa-pod grinders which are simple to operate and maintain and established a forage nursery at Kendari. These infrastructure improvements will allow research activities to be conducted in the future.

8.2.3 Institution capacity

The improved capacity of staff and infrastructure has not only had a direct impact on the institutional capacity to conduct research. The involvement of partner organisations in the project has also been of benefit where such international collaboration can assist them in their own national recognition and classification and improve their national ranking score, which provides greater opportunities for funding and development in the future. The reputation of all partner organisations to provide service to cattle development programs at a regional level has been enhanced.

8.3 Community impacts – now and in 5 years

8.3.1 Economic impacts

Given the short-term and preliminary evaluation nature of the current project it was unlikely that any immediate economic impacts resulted. While there was no component of economic analysis within this project it is anticipated that if the opportunities to address feed gaps evaluated in the current project were scaled up economic gains will be delivered to small-holder farmers through improved cattle production, decreased fertiliser costs, decreased requirements for labour, increased cocoa yields and potential to increase herd size.

8.3.2 Social impacts

At this stage it is not possible to ascertain any wider social impacts of the project than with those farmers directly involved. The greatest impact on farmers, from any possible nutritional management strategy introduced in villages, is through reduced labour inputs and increased cash-flow. Any feeding strategy which reduces a farmer’s time, or the time of wives and children, spent cutting and carrying forages will increase its chances of adoption. It will either allow time for other activities, including potential income generating activities, or it will allow time to raise more cattle for the same labour input. For example, some farmers have adopted the feeding of Gliricidia as it reduces the time required to cut and carry feeds, due to ease of cutting and proximity to kandang, compared to grass; this decision is made independent of the benefit of increased live weight gain.

Improvements in cattle and cocoa production and decreased reliance on purchased fertilisers may result in increased cash flow for small-holder farmers. It is likely this will lead to improved standards of living, as more cash will be available to meet food, health, education and other family and household requirements. The project is aligned with the

Indonesian government's policy of increased beef cattle production, from which increases in job creation and protein consumption and improvements in farmer welfare, will ensue.

8.3.3 Environmental impacts

This project was not expected to have any significant environmental impacts. Processing and feeding of cocoa-pods will remove potential reservoirs for pests and diseases and result in more hygienic conditions under plantations. Collection and composting of faeces to be used as an organic fertiliser on crops, use of forage legumes as ley crops and tethered grazing on fallow rice fields will provide nutrients to the soil and reduce the reliance on inorganic fertilisers, which may be environmentally and economically unsustainable.

8.4 Communication and dissemination activities

Given the geographical distribution of the project team, updates of activities at each site were compiled and circulated to all partners every month. This kept all project team members informed of activities and progress at each site and often acted as a means of stimulating discussion between partner organisations. While Australian team members visited Indonesia regularly, cross site visits and communication was encouraged between Indonesian project team members; this resulted in the sharing of ideas and resources between organisations which may not have previously had the opportunity to interact.

Project workshops

Project planning workshop. July 2007. BPTP-Sultra, University of Haluoleo and University of Tadulako. Sultra, Indonesia.

Project planning and review workshop, joint meeting for LPS 2004 023 and SMAR 2007 013. December 2007. University of Mataram. NTB, Indonesia.

Project review workshop, joint meeting for LPS 2004 023 and SMAR 2007 013. April 2009. Hotel B.J. Perdana, Pasuruan, East Java, Indonesia.

Farmer field days

Farmer field day, extension of village feeding studies. February 2008. Ladongi sub-district, South East Sulawesi.

Farmer field day, demonstration of new cocoa-pod choppers. July 2008. Ladongi sub-district, South East Sulawesi.

Newsletter articles

Sinar Tani, March 2008. Research legume adaptation for cattle feeds in Sultra.

Reports

SMAR 2007 013. ACIAR Annual report. 2007-2008.

Presentations

SMAR 2007 013 Project overview, ACIAR LPS project leaders meeting, Brisbane, August, 2007.

9 Conclusions and recommendations

9.1 Conclusions

Opportunities to use cocoa-pods and forage legumes to address feed gaps in the dry season in South East Sulawesi were evaluated in this project. The project went some way to developing a range of strategies to fill feed gaps and improve cattle production by using previously underutilised potential feed and land resources as well as attempting to introduce some new forages and grazing management systems.

Cocoa-pods were successfully fed to Bali cattle. Processing of cocoa-pods is required for the long-term storage of materials to fill feed gaps, however this needs to be cheap and simple to use for adoption by small-holder farmers. Simple, low-cost processing methods were successfully established in villages in Sultra. Treatment of cocoa-pods with *Aspergillus niger* increases the crude protein content and decreases the neutral detergent fibre content of cocoa-pods. Treatment of cocoa-pods with *Aspergillus niger* resulted in a slightly greater live weight gain response compared to untreated cocoa-pods when fed to growing Bali cattle but had no influence on animal response when fed to more mature animals. However, treatment requires additional financial, technical and labour inputs and is not essential for use of cocoa-pods as a ruminant feed resource. It is recommended that chopped or ground, dried untreated cocoa-pods be fed to mature animals (i.e. mature Bali cows) as a component of a maintenance diet but not as the sole component of the diet. The wide-scale uptake of cocoa-pod feeding in Sultra would address existing feed gaps while reducing the threat of cocoa-pod borer infestation of subsequent cocoa crops.

Unfavourable climatic conditions during 2008 resulted in poor establishment of forage legumes in the dry season, for both on-station and on-farm activities. However, given the results from the smaller plot studies and the successful establishment of *Clitoria ternatea* in well drained areas the strategy of planting forage legumes on fallow rice fields warrants further investigation. The successful establishment of forage legumes on fallow rice fields would provide high quality feed materials during the dry season or provide an opportunity to conserve forages for feeding during the subsequent wet season, when all available land is allocated to field and plantation crops. The approach of tethered grazing of legumes on rice fields should provide benefits in terms of supply of organic fertiliser directly to the rice field. Other approaches which could also be considered are the establishment of forage legumes on dry-land areas, around households and kandangs and on rice field bunds, although none of these have the additional benefit of nitrogen fixation of legumes into the rice field. It appears that *Lab lab purpureus* of all the legumes may provide the greatest benefit in terms of rate and total quantity of biomass production, ease of establishment under different conditions and ease of removal in preparation for the subsequent rice crop.

Potential exists for the feeding of tree legumes to cattle in Sultra. Gliricidia is widely available yet rarely used, apparently due to a lack of awareness by farmers that it can be successfully fed to cattle. Studies within this project demonstrated that feeding Glircidia either as a supplement or as the major component of the diet to Bali cattle will result in live weight gains greater than if Bali cattle were fed native grass. Greater responses were evident if Gliricidia was supplemented with a source of energy, such as rice bran. The successful establishment of Sesbania on rice field bunds and dry-land areas in the current project provides an additional opportunity for feeding tree legumes and also makes use of previously unused land resources. However, the potential benefits to cattle production and minimal effects on rice production need to be further demonstrated to farmers, as well as developing an understanding of the social and economic reasons that the farmers are reluctant to adopt this strategy in Ladongi sub-district.

There was no difference in growth rates of male and female Bali cattle from 6 to 12 months of age. Growth of female cattle was significantly reduced after puberty compared to growth prior to puberty and to growth of entire males after puberty. Growth of castrated males was intermediate between entire males and females, from 18 to 27 months of age. Some of the physiological mechanisms and the expression of genes involved in this sexual dimorphic regulation of growth are under investigation. These results suggest further work is required at understanding the growth and development of heifers, with the objective of increasing live weight gain to puberty and maturity, reducing the age at first calving and decreasing the inter-calving interval, with an overall output of increased lifetime reproductive performance.

9.2 Recommendations and future opportunities

It is recommended that simple and cheap cocoa-pod choppers are introduced to villages across Sultra to facilitate the removal of cocoa-pods from plantations and the processing and feeding to cattle. Further work may be required in regard to the form of processed cocoa-pods which is most palatable to cattle.

It is recommended that potential use of cocoa-pods as a feed resource is extended widely to small-holder farmers, along with instructions on processing and storage. The inclusion of *Aspergillus niger* treatment in this process is not recommended if cocoa-pods are to be fed to mature Bali cattle (i.e. to mature Bali cows as a component of the diet to maintain live weight and body condition). Level of inclusion in the diet should be set at approximately 10 to 15 g DM/kg live weight/d. It is recommended that further work is conducted in regard to the use of *Aspergillus niger* to improve the nutritive value of low quality feed resources, including those used in Australia.

It is recommended that monitoring of Sesbania plantations established within this project is ongoing. If the plantations continue to be successful it is recommended that this opportunity to utilise unproductive rice field bunds for Sesbania plantings be scaled up across Sultra. There appears to be an issue with the adoption of Sesbania establishment on paddy field bunds by farmers in Sultra and this will only be overcome by successful demonstration of the strategy and farmer to farmer transfer of experiences.

It is recommended that further work be conducted to evaluate the potential use of forage legumes within the crop-livestock system in Sultra, either on fallow rice fields or in other unproductive areas, such as around houses and kandang's. It is recommended that nurseries be established in Sultra for the production of seed and vegetative materials of new forage species and varieties.

It is recommended that future work be conducted on longer-term growth responses of Bali cattle, particularly females, to different feedstuffs at different phases of development. There appears to be a significant issue with the retention of potential breeding females within the herds of small-holder farmers and this may be restricting the potential of small-holders to increase their herd size. Best management practices for this class of cattle need to be developed, to ensure an appropriate age for first calving and a rapid subsequent re-conception. Future work could also investigate the potential for genetic selection to improve the performance of Bali cattle and compare Bali cattle growth paths with those of other breeds, such as Ongole.

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11 Appendixes

11.1 Project team members

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- Mr Syaiful Arief (Technical Officer - Lingsar)
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