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Research Paper

The role of leucaena in cattle fattening and breeding production systems in eastern Indonesia

El rol de la leucaena en los sistemas de producción de cría y engorde de ganado en el este de Indonesia

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Abstract

Cattle farming in West Nusa Tenggara province, Indonesia (NTB) is essential to support the high demand for beef cattle in Indonesia. Leucaena was introduced to smallholders as a high-quality feed to increase cattle production in NTB. A survey was conducted with both leucaena-using and non-leucaena-using smallholder cattle farmers in Sumbawa and West Sumbawa districts, NTB to understand the role of leucaena in NTB smallholder cattle enterprises (mixed breeding/fattening) and the effects of leucaena toxicity on cattle performance, especially cow-calf production. We found that farmers using leucaena feeding systems were able to keep more cattle than farmers using a traditional feeding system (9.1 vs 6.1 head/household). Many leucaena-using farmers (50.1 %) use leucaena for fattening cattle only. Other cattle classes (growers, breeding cows and bulls) were fed leucaena strategically, such as during the dry season (59 % of leucaena-using farmers) and at specific stages of pregnancy and lactation (41 % of leucaena-using farmers). Leucaena-using farmers in rainfed areas planted more leucaena (4,500 vs 1,984 trees) and fattened more bulls (5.8 vs 3.5 head/household) than farmers in high-rainfall areas. Transmigrant Balinese farmers planted significantly more leucaena trees (7,500 vs 2,354 trees) and raised more fattening bulls (7.8 vs 3.7 head/household) than the local Sumbawanese farmers. Most Balinese farmers had been practising leucaena feeding systems since they migrated to Sumbawa, for as long as 3 decades. Most leucaena-using farmers (74 %) had observed symptoms of illness associated with leucaena toxicity in their cattle such as hair loss and salivation. Few farmers feeding leucaena to breeding cows (5 %) reported instances of reproductive failure. Almost all non-leucaena-using farmers (93 %) reported symptoms of illnesses associated with plant toxicities (among other potential causes), most commonly skin lesions, diarrhoea, cataracts, and listlessness. It was concluded that the priority use of leucaena in Sumbawa was for fattening cattle rather than breeding cattle. Leucaena supports smallholder farmers in Sumbawa to have more intensive, productive and income-earning cattle enterprises, but questions remain over whether it should be used for feeding breeding cows.

Keywords: Breeding enterprises, leucaena users, toxicity.

Resumen

La ganadería en la provincia de West Nusa Tenggara, Indonesia (NTB) es esencial para respaldar la alta demanda de ganado vacuno en Indonesia. La leucaena se presentó a los pequeños agricultores como un alimento de alta calidad para aumentar la producción de ganado en NTB. Se llevó a cabo una encuesta con pequeños ganaderos que usaban y no usaban leucaena en los distritos de Sumbawa y West Sumbawa, NTB para comprender el papel de la leucaena en las empresas ganaderas

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de NTB (cría/engorde mixtos) y el efecto de la toxicidad de la leucaena sobre el rendimiento del ganado, especialmente en la producción de vacas y terneros. Descubrimos que los agricultores que usaban sistemas de alimentación con leucaena podían mantener más ganado que los agricultores que usaban un sistema de alimentación tradicional (9.1 vs. 6.1 cabezas por unidad familiar). Muchos agricultores usuarios de leucaena (50.1 %) utilizan la leucaena solo para engorde de ganado. Otras clases de ganado (animales en crecimiento, vacas reproductoras y toros) fueron alimentados con leucaena estratégicamente, como durante la estación seca (59 % de los agricultores que usan leucaena) y en etapas específicas de gestación y lactancia (41 % de los agricultores que usan leucaena). Los agricultores que utilizan leucaena en áreas de secano plantaron más leucaena (4,500 vs. 1,984 árboles) y engordaron más toros (5.8 vs. 3.5 cabezas/hogar) que los agricultores en áreas de alta precipitación. Los agricultores Balineses transmigrantes plantaron significativamente más árboles de leucaena (7,500 vs. 2,354 árboles) y criaron más toros de engorde (7.8 vs. 3.7 cabezas/hogar) que los agricultores locales de Sumbawan. La mayoría de los agricultores Balineses habían estado practicando por tres décadas sistemas de alimentación con leucaena desde que emigraron a Sumbawa. La mayoría de los productores que utilizan leucaena (74 %) habían observado síntomas de enfermedades asociadas con la toxicidad de la leucaena en su ganado, como pérdida de pelaje y salivación. Pocos granjeros que alimentaban con leucaena a vacas reproductoras (5 %) reportaron casos de falla reproductiva. Casi todos los agricultores que no usaban leucaena (93 %) informaron síntomas de enfermedades asociadas con la toxicidad de las plantas (entre otras posibles causas), más comúnmente lesiones en la piel, diarrea, cataratas y apatía. Se concluyó que el uso prioritario de la leucaena en Sumbawa era para el engorde de ganado más que para la cría de ganado. Leucaena permite que los pequeños agricultores de Sunbawa tengan empresas ganaderas más intensivas, productivas y generadoras de ingresos, pero quedan dudas sobre si debería usarse para alimentar a las vacas reproductoras.

Palabras clave: Empresas de cría, usuarios de leucaena, toxicidad.

Introduction

Leucaena (*Leucaena leucocephala*) is an edible forage tree legume widely used as feed for cattle and other ruminants (buffalo, sheep and goats) in tropical and subtropical areas (Dalzell et al. 2012), especially Indonesia. It provides high nutritive value fodder for cattle. It is highly palatable, fast growing, able to be harvested for up to 40 years (Shelton and Dalzell 2007) and a potential source of timber and firewood (Shelton and Brewbaker 1994). The use of this tree legume can increase the growth rate by up to 0.83 kg live weight/day for Bali cattle (Panjaitan et al. 2014) and improve the meat quality (Dahlanuddin et al. 2019) of fattening bulls. It also has the potential to increase body condition score (BCS) and milk production when fed to breeding cows (Dahlanuddin et al. 2016). However, leucaena is not currently recommended as a feed for breeding cattle due to its concentration of the toxin mimosine and its metabolites in all parts of the plant (leaves, pods, seeds and bark) (Hegarty et al. 1964). These recommendations for breeders are based on a limited body of reported evidence from farmers in Australia and other countries, suggesting that leucaena toxins could reduce reproductive performance (Holmes 1980; Holmes et al. 1981; Jones et al. 1989).

The demand for beef in Indonesia cannot currently be met by local cattle, therefore, cattle and beef are imported (Deblitz et al. 2011). The Indonesian Government has promoted programs to increase the number of breeding cattle so as to improve domestic self-sufficiency in beef production. The West Nusa Tenggara (NTB) Province (comprising Lombok and Sumbawa Islands) in eastern Indonesia has been identified as an area with high potential for increasing the production of beef cattle in Indonesia. However, the majority of beef cattle in NTB are kept by smallholder farmers with small-scale cattle ownership (5-10 head/household) and managed under a traditional cut-and-carry feeding system with poor nutritional feed, such as crop residues (rice straw and corn stover) or free-grazing on low-quality native pastures. Consequently, efficiency of cattle production is low, with low calving rates (~65 %), high calf mortality (10–20 %) and low growth rates (0.15–0.25 kg live weight/d) (Dahlanuddin et al. 2019). Therefore, improving the supply and quality of feed with forage tree legumes, such as leucaena, is a promising strategy to overcome these productivity problems. The adoption of leucaena-based feeding systems for cattle in Sumbawa Island is increasing, with recent reports of more than 2,500 smallholder farmers using leucaena for feeding cattle (Dahlanuddin et al. 2019).

Most studies on leucaena-based cattle production systems in NTB (Panjaitan et al. 2014; Dahlanuddin et al. 2017; 2018) and globally (Buck et al. 2019; Pachas et al. 2019) focus on the use of leucaena for fattening cattle only. This emphasis has arisen because of the profit and income implications of increased growth rate and sale

weight of fattening cattle (Cowley et al. 2020). There are knowledge gaps remaining as to whether leucaena should also be used as feed for breeding animals and whether leucaena affects reproductive performance when fed to breeding bulls and cows. There is little information regarding the utilisation of this legume for breeding cattle by leucaena-using farmers in Indonesia or elsewhere. Providing this information is important to improve understanding regarding feeding leucaena to breeding cattle safely.

This study aimed to understand the role of leucaena in NTB smallholder mixed breeding/fattening cattle enterprises, the use and effects of leucaena in cow-calf production systems and incidence, knowledge and farmer management strategies for alleviating leucaena toxicity issues, with specific attention to effects on cattle breeding and reproduction. As a comparison, non-leucaena-using farmers were surveyed to provide a control reference to determine whether problems experienced by leucaena-using farmers are attributable to the use of leucaena.

Materials and Methods

Farmer recruitment

A survey was conducted from December 2019 to March 2020 in Sumbawa and West Sumbawa districts, Sumbawa Island, NTB Province, Indonesia (Figure 1), through face-to-face interviews of leucaena-using and non-leucaena-using smallholder cattle farmers. The survey methodology and questionnaire were approved by the Human Research Ethics Committee, University of New England (HE19-040).

Farmer participants and survey areas were selected with a purposive sampling method. The criteria for inviting leucaena-using farmers from these districts to participate in the research were that they had been feeding leucaena to fattening and breeding cattle for more than 1 year. Non-leucaena-using farmers from the same districts were invited to participate in the research on the proviso that they had been raising either fattening or breeding cattle for more than 1 year, had never fed leucaena to their cattle, and there was no leucaena growing near their property accessible to their grazing cattle.

Farmer recruitment to the survey was facilitated by the Consortium for Large Ruminant Research - University of Mataram (for leucaena-using farmers), and Dinas Peternakan (Department of Animal Husbandry) NTB (for non-leucaena-using farmers), using their own farmer records. Initial contact and recruitment were made by letter and phone call to all cattle farmers from these databases in the study districts. Farmers who responded positively to the invitation to participate (112 leucaena-using farmers and 54 non-leucaena-using farmers) were visited at their homes for a face-to-face interview. Participating farmers were classified by water management, either irrigated lands (2 or 3 crops per year in irrigated systems) or rainfed areas (1 crop per year in rainfed systems) and by ethnicity (either local Sumbawanese or transmigrant Balinese).

Questionnaire and survey implementation

Questionnaires were developed for leucaena-using farmers and for non-leucaena-using farmers. The questionnaires consisted of multiple-choice and Yes/No questions where a particular response was expected, and open-ended questions where the farmer could respond freely. Leucaena-using farmers were asked questions on the following topics:

1. Farm scale (e.g. property size, number of cattle owned);
2. Growing leucaena (e.g. area of leucaena planted, number and cultivar of leucaena trees planted on their property);
3. Cattle management and leucaena use for their cattle (when, why and how they feed leucaena to their herd);
4. Farmer observations of symptoms of leucaena toxicity, e.g. hair loss, skin lesions (Jones et al. 1978) salivation (Megarrity and Jones 1983), and reduced reproductive performance of breeding cow/bull (Holmes 1980; Holmes et al. 1981);
5. Farmer knowledge of leucaena toxicity and its prevention;
6. Supplementary feeding; and
7. Cattle performance.

Non-leucaena-using farmers were asked questions 1, 4, 5, 6 and 7 above, but were not asked questions specific to growing and feeding leucaena to their cattle.

The interviews were conducted in Indonesian by Indonesian enumerators and each took approximately 15 minutes to complete. An information sheet was presented to target farmers and a consent form was signed before the interview commenced.

Statistical Analyses

All statistical analyses were conducted in R (R Core Team 2020). Chi-square tests were used for testing

Figure 1. Map of Sumbawa Island, NTB Province of Indonesia showing the survey locations. ▲ rainfed; ● irrigated land (Google 2020).

equality of proportions between groups. T-tests were used for comparison of the means between groups. Univariate linear regressions were used to analyze correlations between continuous variables.

Results

Farmers interviewed

One hundred and sixty-six farmers were interviewed in this survey. Sixty-seven percent (112 of 166) of farmers practiced leucaena feeding in their cattle production system, while the remaining farmers were not using leucaena, instead raising cattle under the traditional cut-and-carry feeding system, with grasses and crop residues, or free-grazing native pastures. Leucaena was fed as a cut-and-carry fodder (Figure 2). Fifty-one percent (57 of 112) of leucaena-using farmers and 27 % (15 out of 54) of non-leucaena-using farmers were categorized as wetland farmers, using irrigation for crop production. The majority of leucaena-using farmers interviewed (81 %) were local Sumbawanese farmers, and the remainder (19 %) identified as Balinese ethnicity. All non-leucaena-using farmers were Sumbawanese.

Leucaena users vs non-leucaena users

There were substantial differences in the systems of cattle management by the 2 farmer groups. All leucaena-using farmers managed their cattle intensively with a cut-and-carry feeding system (Figure 2). With this system, cattle were kept in a pen or cattle house (*kandang*) and hand-fed fresh leucaena (leaves, small branches and pods) harvested from the farmer's own land, roadsides and riversides or bought from other farmers. They also provided other feedstuffs such as Gliricidia (*Gliricidia sepium*), crop residues and by-products (rice straw, corn stover, peanut haulms and rice bran) to supplement the diet when leucaena was not fed as 100 % of the diet, especially for non-fattening cattle classes, and during the dry season. Conversely, all non-leucaena-using farmers managed their cattle extensively with a low-input system.

a. Leucaena harvested by a farmer.

b. Leucaena being fed to fattening bulls.

Figure 2. Leucaena feeding systems for cattle in Sumbawa.

Leucaena-using and non-leucaena-using farmers had a similar (P>0.05) land size (Table 1). On average, land ownership was 2 ha/household with cattle, rice and maize as the primary enterprises. Typically, about half of leucaena-growing farmers' land (0.9 ± 1.0 ha/household) was planted to leucaena (Table 1). Most of these farmers initially started planting leucaena between 2010 and 2019. The number of leucaena trees planted per farm ranged from 100 to 50,000 trees (Table 1), mostly of cultivar 'Tarramba'. The majority (81 %) of non-leucaena-using farmers were unaware that leucaena could be fed to cattle and had never obtained any information from local extension services about its benefits in cattle production systems. The remaining non-leucaena-using farmers said that the animals did not like to eat leucaena leaves.

At the time of the interview, leucaena-using farmers had cattle herds 50 % larger than non-leucaena-using farmers (9.1 ± 0.7 vs 6.1 ± 0.5 total cattle/household, respectively) (Table 1). However, 92 % of leucaena-using farmers and all non-leucaena-using farmers had similar numbers of breeding cows (3.8 ± 0.2 vs 3.3 ± 0.2 cows/household) (Table 1). Thus, the main difference between the groups in the cattle production system was the number of bulls fattened. The majority of leucaena-using farmers (71 %) fattened bulls, with an average of 4.7 ± 0.8 fattening bulls/farmer at the time of interview (Table 1). On average, each leucaena farmer could fatten 8.9 ± 10.0 bulls/year (range 2–60 head) under the leucaena feeding system. In contrast, only 12 % of non-leucaena-using farmers kept bulls for fattening, with an average of 2.9 ± 0.3 bulls per year for non-leucaena-using farmers (Table 1).

Leucaena feeding systems in different land types

Total area of land of leucaena-using farmers in irrigated areas was not different from that of leucaena-using farmers in the rainfed area (Table 2), means being 2.2 and 2.0 ha/household, respectively. However, in the irrigated area, leucaena-using farmers allocated 1.3 ± 0.2 ha (65 %) of their land for leucaena planting, whereas in the rainfed area only 0.7 ± 0.1 ha (35 %) of land was allocated for leucaena planting (P<0.05). However, farmers in the rainfed area planted more (P<0.05) leucaena trees (4,500 trees ± 1,151/household) than the farmers in the irrigated area (1,984 ± 595 trees/household). Leucaena-using farmers typically split their land between broadacre crop

Table 1. Farm-scale comparison between leucaena users and non-leucaena users at research sites in Sumbawa Island, NTB, Indonesia, at the time of the interviews.

Items	Leucaena users *(n=112)*		Non-leucaena users *(n=54)*		P-value
	Mean ± s.e.	*n*	Mean ± s.e.	*n*	
Land size (ha)	1.9 ± 0.2	110	2.0 ± 0.2	50	0.34
Total number of cattle currently raised (head)	9.1 ± 0.7	112	6.1 ± 0.5	54	0.0003
		Cattle production systems			
Fattening bulls (head)	4.7 ± 0.8	80	2.9 ± 0.3	7	0.003
Breeding cows (head)	3.8 ± 0.2	104	3.3 ± 0.2	54	0.141
Breeding bulls (head)	1.0 ± 0.0	12	1.8 ± 0.4	5	0.04
Growers (head)	1.2 ± 0.1	38	1.3 ± 0.1	21	0.217

Table 2. The comparison of farming scale between leucaena-using farmers in irrigated and rainfed areas.

Items	Irrigated		Rainfed		P-value
	Mean ± s.e.	*n*	Mean ± s.e.	*n*	
Land ownership (ha)	2.2 ± 0.2	55	2.0 ± 0.1	57	0.166
Land planted to leucaena (ha)	1.3 ± 0.2	50	0.7 ± 0.1	51	0.005
Number of leucaena trees planted	1,984 ± 595	51	4,500 ± 1,151	52	0.040
Total number of cattle raised currently (head)	7.7 ± 0.7	55	10.5 ± 0.9	57	0.012
		Cattle production systems			
Fattening bulls (head)	3.5 ± 0.9	39	5.8 ± 0.5	41	0.013
Breeding cows (head)	4.0 ± 0.2	54	3.4 ± 0.3	56	0.120
Breeding bulls (head)	1.0	5	1.0	7	
Growers (head)	1.5 ± 0.1	13	1.3 ± 0.1	23	0.245

planting areas and leucaena areas, but some farmers integrated broadacre and leucaena crops in an alley cropping configuration (Figure 3).

a. Farmer's land planted with leucaena.

b. Leucaena integration with peanuts.

Figure 3. Leucaena planting systems for cattle in Sumbawa.

Rainfed farm also had more cattle (P<0.05) than irrigated farms with the difference lying in the number of bulls fattened (Table 2). Meanwhile the number of cattle in other classes (breeding cows and bulls plus growers) did not differ (P>0.05) between land types.

Leucaena feeding systems in different ethnic groups

The use of leucaena cattle production systems differed slightly between local Sumbawanese farmers and transmigrant Balinese farmers, particularly in the number of fattening bulls and the number of leucaena trees planted (Table 3). On average, Balinese farmers held more fattening bulls at the time of the interview (7.8 ± 1.9 bulls/household) than local farmers (3.7 ± 0.4 bulls/household). The maximum number of bulls able to be fattened in a fattening period (the duration of bulls being fattened from purchase to sale) by a Balinese farmer was 36 head. The greater cattle fattening focus by Balinese farmers was supported by increased leucaena plantings (7,500 trees/household) compared with Sumbawanese farmers (2,354 trees/household).

On average, Balinese farmers had 7.3 years (range 3–15 years) of experience using leucaena in cattle production, especially for fattening bulls. In contrast, most Sumbawanese farmers were new to the leucaena feeding system, with an average of 3.8 years (range 1–5 years) experience, where they were previously practicing a traditional cut-and-carry feeding system using poor nutritional quality feed sources.

Table 3. Comparison of farming scale between leucaena-using local Sumbawanese farmers and transmigrant Balinese farmers in Sumbawa Island.

Items	Local		Balinese		P-value
	Mean ± s.e.	*n*	Mean ± s.e.	*n*	
			Farming area		
Land ownership (ha)	2.1 ± 0.1	91	2.0 ± 0.2	21	0.46
Land area of leucaena planted (ha)	1.0 ± 0.1	82	0.9 ± 0.3	19	0.45
Number of leucaena planted (tree)	2,354	82	7,500	19	0.04
Number of cattle currently held (head)	8.6 ± 0.6	91	11.5 ± 2.0	21	0.05
Number of cattle fed leucaena per year (head)	7.2 ± 1.3	87	16.3 ± 1.4	19	0.01
Experience with leucaena feeding system (years)	3.8 ± 0.1	91	7.3 ± 0.9	21	0.00
% Irrigated land farmer	60	55	0	0	0.00
			Cattle production systems		
Fattening bulls (head)	3.7 ± 0.4	62	7.8 ± 1.9	18	0.02
Breeding cows	3.7 ± 0.3	90	3.6 ± 0.4	20	0.44
Breeding bulls	1.0	12	1.0	1	
Growers	1.2 ± 0.2	35	1.0 ± 0.1	2	0.00

Seasonal leucaena feeding

There was consistently an average of 50 ± 10 % of leucaena-using farmers feeding leucaena to fattening bulls in most months, even in the wet season (Figure 4a). The exception was in the early wet season (December) when leucaena-using farmers supplemented fattening cattle diets with crop residues and other tree legumes. During the dry season, farmers reported that supplies of leucaena decreased because they had to feed leucaena to other cattle classes in addition to fattening cattle at the time when other forages were not available (Figure 4 b–d). During the wet season, leucaena-using farmers fed breeding cows and grower bulls fed stock crop residues, native grasses and other forage tree legumes (*Gliricidia sepium* and *Sesbania grandiflora*).

For breeding and growing cattle, fewer leucaena-using farmers fed leucaena to these animals year-round (31 ± 34 % and 17 ± 19 %, for breeding cows and grower bulls, respectively (Figure 4). The majority (59 %) of leucaena-using farmers fed leucaena to breeding cows and growers during the dry season (between July and October), when other forages were not available (Figure 5). During this period the percentage of farmers feeding leucaena to breeding cows increased progressively and significantly (P<0.05) from 7 % to a peak of 80 % in September-October, and the percentage of farmers feeding leucaena to growers increased from 3 % to 45 % in September-October (P<0.05).

In comparison, there was no change (P=0.12) in the percentage of farmers who fed leucaena to fattening bulls between the wet and the dry seasons. In addition to filling seasonal feed gaps, some leucaena-using farmers fed leucaena to breeding cows during the lactation period, expecting their cows would be able to produce more milk for their calves.

Incidence of leucaena toxicity

There was a significant difference between leucaena and non-leucaena-using farmers regarding knowledge of leucaena toxicity (Table 4). The majority of both leucaena-using farmers and non-leucaena-using farmers (75 and 93 %, respectively) reported they had no knowledge of leucaena toxicity, despite the majority of leucaena-using farmers having had long experience with leucaena. These farmers were unfamiliar with the terms "plant toxicity" and many expressed surprise when asked questions about this topic, as their herds had shown good performance when fed leucaena.

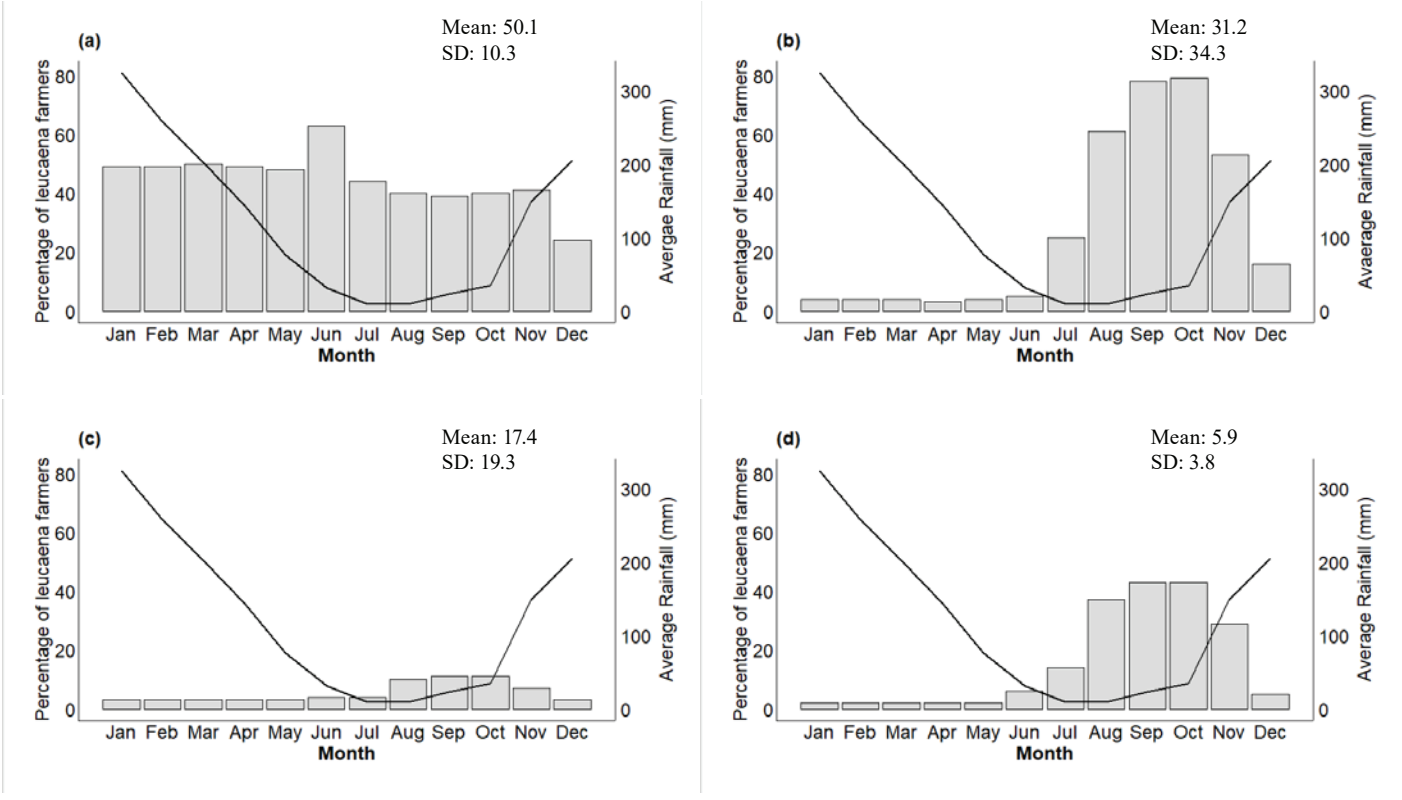

Figure 4. Percentage of leucaena-using farmers reporting leucaena use for each class of cattle in each month; (a) Fattening bulls, (b) Breeding cows, (c) Breeding bulls, (d) Grower bulls. Bar (▭) Percent of farmers; line (—) Average rainfall.

Eighteen percent of leucaena-using farmers and the remaining 7 % of non-leucaena-using farmers reported that they knew a little about leucaena toxicity from vets and extension staff. Very few farmers (7 % of leucaena-using farmers and no non-leucaena-using farmers) reported that they had good knowledge of leucaena toxicity and its prevention.

Table 4. Farmer knowledge of leucaena toxicity and its prevention.

Knowledge of leucaena toxicity and its prevention	LU[1] (*n*=112)	NLU[2] (*n*=54)	Chi-Square P-value
Good knowledge	7	0	0.008
Little knowledge	18	7	0.028
No knowledge/ awareness	75	93	0.165

[1]LU= Leucaena users (%); [2]NLU= Non-leucaena users (%).

Figure 5. Lack of forage during the dry season in Sumbawa. Grasses and herbaceous forages are limited during this time, but trees, including forage tree legumes such as leucaena, retain green growth.

Despite having no knowledge of toxicity, when prompted the majority (74 %) of leucaena-using farmers agreed that they had observed symptoms associated with leucaena toxicity in their herd. The most common signs observed were alopecia (43 %) and excess salivation (37 %) (Table 5). These symptoms occurred more frequently in newly purchased cattle naïve to leucaena, but disappeared within 2–3 weeks. Some leucaena-using farmers reported abortions and stillbirths in breeding cows fed leucaena. There were no reports of these reproductive problems among non-leucaena-using farmers (Table 5), indicating that leucaena may have a negative side effect on breeding cows.

Cattle performance

Leucaena-using farmers reported that their bulls could be fattened to finishing weight in 5.9 ± 0.4 months on average, which is much faster than bulls fattened under the traditional system (8.0 ± 3.1 months); however, participant response rates to this question were low. There was a positive relationship between the numbers of leucaena trees planted and the number of fattening cattle raised (Figure 6). Farmers reported that the inter-calving interval of breeding cows fed leucaena was 11.8 ± 0.3 months, whereas the inter-calving interval of cows managed under a traditional feeding system was 12.1 ± 0.3 months.

Table 5. Symptoms of plant toxicities observed by leucaena-using and non-leucaena-using cattle farmers in Sumbawa.

Item	LU[1] (*n*=112)	NLU[2] (*n*=54)
Farmers reporting symptoms	74	15
	P<0.05	
Toxicity symptoms reported	(*n* = 115)	(*n* = 14)
Hair loss	43	7
Skin lesion	1	14
Salivation	37	0
Unexpected performance	2	0
Cataract	0	36
Reproductive failure	5	0
Unexplained cattle death	4	0
Chronic diarrhoea	5	14
Listless	2	29

[1]LU= Leucaena users (%); [2]NLU= Non-leucaena users (%).

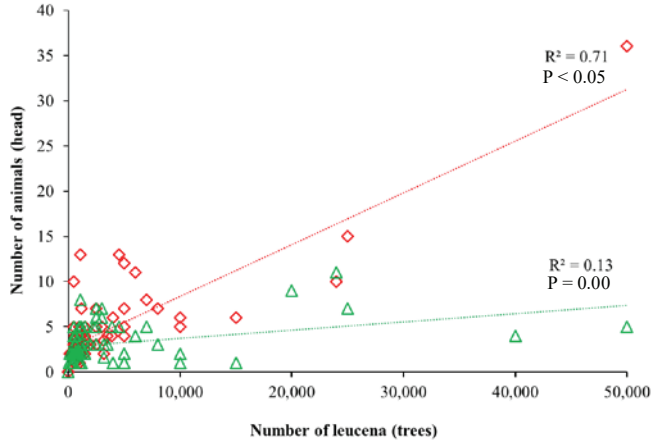

Figure 6. Relationship between numbers of leucaena trees planted and fattening bull (◆) and breeding cow (▲) herd size.

Discussion

Leucaena users vs non-leucaena users

In general, leucaena-using and non-leucaena-using farmers had a comparable farm size with cattle, rice and maize being the primary enterprises. This finding is in

agreement with data previously reported by Hilmiati et al. (2017) and Hilmiati et al. (2017; 2019) regarding land area and usage of farmers in Sumbawa. The differences in area planted to leucaena on irrigated and rainfed farms is partly attributed to integration of limited numbers of trees in strips within cropping land on irrigated farms while trees were planted at high density in the absence of crops on rainfed farms. Leucaena cultivar 'Tarramba' was the common cultivar planted by the farmers, and shows that the introduction and development of this cultivar has been highly successful in eastern Indonesia since it provides a large quantity of high quality forage for cattle (Nulik et al. 2019) during both wet and dry seasons (Sutaryono et al. 2019). Tarramba leucaena has the advantages of greater biomass production and increased psyllid tolerance and drought tolerance (Nulik et al. 2013) and is preferred by cattle in Indonesia over other varieties (Nulik et al. 2019).

In contrast, non-leucaena-using farmers use their land only for cropping activities, which are their primary income source, while planting leucaena was new to them. Most of them had no knowledge of the benefits of leucaena for cattle production systems. This suggests that, despite numerous local and internally-funded projects focussed on leucaena integration in NTB cattle production systems over several decades, there is still work to be done in extending this information to farmers. Deficits in farmer knowledge are not limited to leucaena specifically. Dahlanuddin et al. (2019) reported that many smallholders in Sumbawa had little knowledge of the nutritional needs of the animals and did not understand the nutritional differences of the various feed sources available to them. For example, they were unaware of the nutritional superiority of leucaena over other feedstuffs, such as native grass, rice straw and maize stover.

The low-input farming practices of the non-leucaena-using farmers coincided with cattle being a secondary income source for these farmers, to be sold whenever they required extra money. These farming systems require significantly lower labour input than the cut-and-carry leucaena farming systems. Given the low levels of awareness of leucaena among non-leucaena-using farmers, it is possible that cattle remained a secondary income source for these farmers because they lacked awareness of leucaena as a high-quality and quantity, locally available feed source. Therefore, their cattle productivity remained low because of reliance on low quality native pastures and crop residues. It is also possible that these farmers chose to keep their farming enterprise (and returns) focussed on crop production, and preferred not to commit the time required by intensive cut-and-carry leucaena feeding systems. According to Hilmiati et al. (2019) farmers can potentially earn profits up to IDR 21 million per year from leucaena-based fattening systems, compared with around IDR 3 to 4 million per year from cropping systems. Research in East Java smallholder cattle production systems found that use of leucaena in weaned Bali cattle diets increased farmer by more than 100 % compared with income on farms without leucaena (IDR 1,914,336 vs IDR 704,076 gaps/head/period) (Priyanti et al. 2010).

With the leucaena feeding system, farmers were able to keep more cattle than the non-leucaena feeding system, with fattening bulls forming the majority of the household herd. The greater number of fattening bulls raised by leucaena-using farmers aligns with cattle raising being a primary income source for these farmers. Waldron et al. (2016) found that increasing the number of bulls fattened increased household income significantly due to an increase in the revenue from extra cattle sold, whilst the marginal cost to labour and feed remained low. For example, increasing the number of fattening bulls from 4 to 5 head increased feed demand by 20 % and labour costs by 10 %, while farmer income increased from IDR 61,463 to IDR 77,848/day (Waldron et al. 2016). These results are supported by other research showing that bull fattening is the most common enterprise in intensive cattle production systems in NTB, where cattle are put in the pen year-round with a cut-and-carry feeding system, while breeding and backgrounding are more common enterprises for traditional cattle production systems (Hilmiati et al. 2019).

This means that the inclusion of leucaena into cattle feeding systems offers great potential to improve the cattle productivity and income of smallholder farmers. Therefore, expanding current leucaena extension and adoption programs may be of benefit for farmers who currently do not use leucaena. According to Dahlanuddin et al. (2019), the most effective aspect in the NTB leucaena extension strategy was the establishment of on-farm demonstration sites, which are used for farmer cross-visits to teach best management practices (such as leucaena establishment, harvesting and feeding strategies) to non-leucaena-using farmers.

Kana Hau et al. (2014) identified several barriers to adopting intensive cattle management systems with leucaena feeding in eastern Indonesia that need to be overcome for further extension of the system. These include:

1. The ready availability of communal grazing areas for cattle, so that farmers do not need to allocate resources, labour, pens and feed;

2. Farmers preferring to let the cattle graze in communal grazing areas, roadside or hills with a herder, perceiving that they are safer from thieves than when tethered or put in a pen;
3. Farmer beliefs that newly planted leucaena will be ruined by free-grazing animals (cattle, goats and buffalo); and
4. Limitations of skills and knowledge of farmers regarding tree establishment and limited access to leucaena planting material.

Our results demonstrate that lack of farmer knowledge of animal nutrition and awareness of the benefits of feeding leucaena are also significant barriers to adoption

Leucaena feeding systems in different land types

In general, the total land area of leucaena-using farmers in the irrigated area was no different from those of leucaena-using farmers in the rainfed area. Differences in number of leucaena trees planted is because most farmers in rainfed areas used the land allocated to plant only leucaena at a high density, while the irrigated land farmers use their land to plant leucaena integrated with crops, e.g. maize, peanuts and beans, in alley cropping systems. The integration of forage legumes with crops in the more secure cropping land is one of the best strategies to inspire farmers to grow and provide high-quality feed for cattle (Supriyadi et al. 2014). With this system, farmers can earn greater profits from combined fattening cattle and crops (maize grain and cassava), up to IDR 107 million/yr, compared with cropping only (IDR 43 million/yr) (Supriyadi et al. 2014).

These results suggest that leucaena-using farmers in the rainfed area are focused on increasing feed resources for cattle production. Subsequently, they are able to keep more cattle and to increase their income. These farmers have only 1 cropping season each year (BPS-Sumbawa 2020) and are therefore more reliant on other income sources than farmers in the irrigated area, who are able to triple-crop. Overall, the intensity of leucaena plantings, total cattle herd size and number of fattening cattle suggest that rainfed leucaena-using farmers were more focused on cattle production and more reliant on leucaena to support this than the irrigated land leucaena-using farmers.

Leucaena feeding systems in different ethnic groups

The use of leucaena cattle production systems differed slightly between local Sumbawanese farmers and transmigrant Balinese farmers, particularly in number of fattening bulls and number of leucaena trees planted. Hilmiati et al. (2019) reported that a hectare of planted leucaena was able to feed 8–10 head of fattening bulls during the wet season and 4–5 head of fattening bulls during the dry season. With these leucaena resources, the transmigrant farmers are able to keep at least twice as many cattle annually as local farmers, showing that leucaena plays an essential role in increasing the income of Balinese farmers. Indeed, one Balinese farmer had a herd size of 60 head. Further, all Balinese farmers being interviewed in this survey were located in rainfed areas with 1 cropping season, so they were reliant on cattle fattening as the main income source to support their families.

The Balinese transmigrant farmers also had long experience with leucaena feeding systems, having been practicing this feeding system since they migrated to Sumbawa utilizing their previous experience of feeding leucaena to cattle in Bali (Dahlanuddin et al. 2019). Meanwhile, the local Sumbawanese farmers are relatively new to the leucaena feeding system, having previously practiced traditional cut-and-carry and free-grazing feeding systems with poor nutritional feed resources. Balinese farmers were one of the main drivers of the adoption of leucaena feeding systems by more than 1,000 local farmers in Sumbawa, who observed and replicated the successes of Balinese farmers in fattening cattle under the leucaena feeding system (Dahlanuddin et al. 2019).

Role of leucaena in cattle production systems in NTB

Sumbawa Island is a tropical area where the average annual rainfall is 1,466 mm, of which 85 % falls during the wet season from November to May (Figure 4) (BPS-Sumbawa 2020). The seasonal rainfall affects the capacity of traditional smallholder farmers to provide feed for their herds since the production and the availability of grass and herbaceous forages fluctuates during the year (Sutaryono et al. 2019). In the dry season, forages other than leucaena or other tree legumes are rare (Figure 5). The herd sizes reported in the present research were recorded during the wet season, and so possibly may represent an annual peak in cattle ownership, if the dry season prompts farmers to reduce herd size by selling off fattening cattle. However, our results suggest that the leucaena-using farmers were less affected by the seasonality of rainfall, since leucaena was always available for cattle during the year. Most

leucaena was used for fattening cattle only, while other cattle classes were fed leucaena only during the dry season. The present survey asked farmers only whether they fed leucaena or not each month; however, Panjaitan et al. (2014) recorded the proportion of leucaena fed in the diet on a seasonal basis, and reported that the greatest proportion of leucaena (up to 100 %) in the diet for fattening cattle occurred at the end of the wet season, while the lowest proportion of leucaena in the diet of fattening cattle (50 %) occurred in the dry season.

Evidence from this survey that some farmers feed leucaena to breeding cows at specific stages of the breeding cycle shows that some smallholder farmers in Sumbawa have an appreciation of changing nutritional requirements with breeding cycles, and of how leucaena use can support these. Dahlanuddin et al. (2016) reported that feeding leucaena to cows increased body condition score and milk yield compared with cows fed King grass only (2.1 ± 0.1 vs. 1.0 ± 0.1 kg milk/day). Feeding a high-quality forage at key points is essential to improve reproductive performance, such as improving conception rates and milk production. Improving cow BCS around parturition and early lactation is crucial since it determines their reproductive performance and overall productivity (Herd and Sprott 1986).

Cattle Performance

Leucaena-using farmers preferred fattening rather than breeding because fattening is more profitable than breeding cattle. The provincial agencies of NTB also encourage farmers to fatten cattle as a way to increase smallholder incomes in rural areas. Fattening enterprises under leucaena feeding systems reduced labour and feed cost (Halliday 2018). The finding from the present survey that leucaena-feeding accelerated fattening from 8.0 to 5.9 months agrees with Dahlanuddin et al. (2017) and Hilmiati et al. (2019) who reported that the mean duration of fattening with leucaena was 5.5 months. However, Panjaitan et al. (2014) reported that Balinese farmers in Sumbawa experienced with using leucaena were able to complete 3 fattening periods each year, by feeding leucaena at a rate of 80 % of the diet or more. Together with the greater year-round consistency in feed supply afforded by leucaena, this means that leucaena-using farmers can fatten more than twice as many cattle per year as non-leucaena-using farmers, using the same infrastructure and labour resources. Reducing the fattening period duration and thus fattening more bulls per year by feeding a higher quality diet results in greater gross margins for smallholders (Cowley et al. 2020). This current research did not capture data on growth rates, sale weights or prices of fattening cattle. Nevertheless, some evidence shows that fattening bulls under leucaena diets can double the growth rate compared with bulls fattened under the traditional system. Panjaitan et al. (2014) reported that the overall average daily gain (ADG) recorded for Bali bulls fattened with leucaena in Jatisari Village in Sumbawa was 0.42 kg/d. Similarly, Dahlanuddin et al. (2014) with a controlled experiment reported that the ADG of Bali cattle fed dried leucaena was greater (0.47 kg/d) than that of Bali bulls fed native grass only (0.2 kg/d). As a comparison, in Australia, the ADG of steers grazing leucaena pastures was higher than those of steers grazing grass pasture only (0.48 vs 0.06 kg/d) (Rolfe et al. 2019). By increasing growth rates and minimising the proportion of dietary energy going to maintenance requirements, the gross margin of smallholder forage tree legume fattening systems is comparable with high-input concentrate feeding systems (Cowley et al. 2020).

Leucaena feeding has previously been reported to have a positive impact in shortening the inter-calving interval (Mayberry et al. 2015, Wirdahayati et al. 1998). In the present study, however, farmer reports of typical inter-calving interval did not differ between leucaena users and non-leucaena users. Anecdotal farmer reports of inter-calving interval, such as those collected in the present survey, are likely to be less reliable than experimental observations of calving dates.

Although many farmers reported some symptoms related to leucaena toxicity, performance of both fattening and breeding enterprises was significantly improved by leucaena. This suggests that any toxicoses are short-lived, and that cattle become not only adapted to leucaena, but are able to be highly productive.

Incidence and farmer knowledge of leucaena toxicity

Although it has many benefits for animals, leucaena contains mimosine and its derivatives (3-hydroxy-4(1H)-pyridone and 3-hydroxy-2(1H)-pyridone, commonly mentioned as 3,4-DHP and 2,3-DHP, Halliday 2018) which are toxic and harmful for animals if they are not adapted to their consumption. In this study, the most common symptoms reported by leucaena-using farmers were alopecia and excess salivation, although farmers mostly did not understand that this was caused by leucaena toxicosis, and so, the vast majority of leucaena-using farmers reported no knowledge that leucaena was

toxic at first questioning. Hegarty et al. (1964) reported that hair loss is one of the most common signs of toxicity observed in animals fed 100 % leucaena diets. Previous studies have reported abortions and stillbirths in ewes and heifers fed a high level of leucaena (Hamilton et al. 1971; Holmes 1980), and a small number of leucaena-using farmers (5 %) also reported these issues in the present study. Jones et al. (1989) suggested that this could be caused by the anti-mitotic action of mimosine or goitrogenic action of DHP. However, most reports of an effect in cattle stem from early, unreplicated research on cattle with unclear leucaena inoculation or adaptation status (Klieve et al. 2002).

Non-leucaena-using farmers in this study reported symptoms of health disorders which were rare in leucaena-using farms such as cataracts, listlessness, chronic diarrhoea and skin lesions. All non-leucaena-using farmers relied on free-grazing of their cattle, which increases the risk of ingestion of toxic plants and weeds. The different suite of symptoms reported between the 2 groups suggests that if both were the result of toxicities, these could be caused by different plant toxins. Although there are many possible causes of these symptoms, other possible diagnoses consistent with these symptoms include Malignant Catarrhal Fever disease (MCF), which commonly occurs in cattle and other ruminants in Indonesia, including in NTB (Muthalib 1988; Damayanti 2016). There is a high incidence of MCF in NTB cattle (92 cases reported per year) (Wiyono and Damayanti 2018). Regardless of the precise cause of these symptoms, it is possible that pathogenic illness may be more common in non-leucaena farms since those cattle are managed under a traditional system where the cattle spent most of their time in communal grazing areas with other cattle, sheep and goats.

The recommended management strategies to prevent negative effects of leucaena toxicity on naïve ruminants' health include the transfer of the mimosine/DHP-degrading bacteria (including *Synergistes jonesii*) (Allison et al. 1992) to ruminants newly introduced to leucaena, either by passive transfer from adapted ruminants (Jones 1994) or by direct inoculation of DHP-degrading media (available as a commercial inoculum in Australia only) (Klieve et al. 2002) together with a gradual increase in the amount of leucaena in diets to promote the natural upregulation of detoxification pathways. However, none of the leucaena-using farmers with knowledge of toxicity in Sumbawa used these recommendations and all were unfamiliar with using feeding management to reduce the toxicity of leucaena. A few farmers (11 %) reported that "saltwater" and "tamarind water" (the extracted water of the tamarind fruit) were given to their herd when they observed any symptoms of toxicity, such as salivation. They claimed this strategy was successful in overcoming the symptoms within 2–3 weeks, which is also the time commonly reported for adaptation of naïve animals to leucaena due to up-regulation of microbial and hepatic leucaena detoxification pathways (Halliday 2018).

Although farmers in this survey did not use any method of transferring rumen fluid, there is evidence emerging that rumen microbe genera able to detoxify leucaena are naturally endemic in many, if not most, ruminant populations in Indonesia, and potentially worldwide (McSweeney et al. 2019). However, extensive detailed research on leucaena-fed bulls in Sumbawa reported high concentrations of DHP, suggesting that the bulls were not degrading all DHP in the rumen (Halliday et al. 2014). This phenomenon shows that *S. jonesii* alone is not able to totally protect the animals. Halliday (2018) reported more than 97 % of DHP in such animals was excreted in a conjugated form. The conjugation of many xenobiotic compounds, including DHP, commonly involves the hepatic process of glucuronication and sulfation (Lindsay et al. 1974) with much evidence of this occurring in leucaena-fed ruminants (Hegarty et al. 1979; Elliott et al. 1985; Halliday 2018). Conjugation of a compound increases water-solubility enabling it to more readily be excreted via the urine, and in the case of DHP, binds to and reduces the acute toxicity of the compound. Recent work has demonstrated that hepatic conjugation plays an important role in protecting cattle from DHP toxicity (Halliday 2018).

Conclusions

Leucaena plays an important role in providing a high-quality diet for cattle in Sumbawa, eastern Indonesia, to achieve better performance and to support more intensive, productive and income-earning cattle enterprises. However, the majority of leucaena use by farmers was focused on fattening cattle only, while other cattle classes were fed leucaena mostly as a strategic feed resource, during the dry season and at specific pregnancy stages. High levels of productivity in both fattening and breeding cattle fed leucaena were reported (e.g. high growth rate, reduced fattening interval of fattening bulls and inter-calving interval of breeding cows), even though several symptoms of leucaena toxicity such as hair loss, salivation and reproductive failure were reported by

those farmers. These findings confirm that leucaena has great potential to be used for fattening cattle. However, several reports of the incidence of reproductive issues among the cows of leucaena-using farmers highlight that knowledge gaps remain regarding the safe feeding of leucaena to breeding cattle. The confirmation by this survey of rare, but nevertheless present, reports of abortion and stillbirth by leucaena-using farmers compared with the absence of these symptoms on non-leucaena-using farms suggests larger-scale and empirical research is needed to determine and define the risks of feeding leucaena to breeding cattle.

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