THE EFFECT OF SEASON, STOCKING RATE AND FRAME SIZE IN CATTLE SELECTING THE MARAMA PLANT (*Tylosema esculentum*) IN THEIR DIET IN EASTERN NAMIBIA

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ABSTRACT

Keywords: *Namibia, marama bean, cattle, frame size, season, stocking rate*

The study was conducted to measure the effect of season, stocking rate and frame size of cattle selecting the marama plant (*Tylosema esculentum*) in their diet while grazing the veld of the Sandveld Research Station in eastern Namibia. Eight groups, consisting of at least 24 head of cattle in each group, were used in the trial. The actual bites taken by the cattle from the veld were recorded in 40-minute intervals, repeated in the early morning and late afternoon per factorial treatment. The percentage of bites taken of the marama plant was calculated from the total bites and statistically analysed by the SPSS general linear model. The study concludes that season alone had a significant influence on the selection of the marama plant as a feed-stuff for cattle, and that this plant is indeed utilised by free-range beef cattle, but not preferentially. Stocking rate and frame size of cattle had no significant influence.

INTRODUCTION

Several studies have shown that marama beans have extensive nutritional potential for humans (Biesele and Murray, 1983), but little has been done to investigate the value of these plants as fodder for livestock.

The marama plant is a rich source of protein and energy in regions where few conventional crops can survive. It grows in some areas that receive up to 800 mm in rainfall, as well as in others where rainfall is so slight and erratic that in some years almost no rain falls at all (ECHO, 1999).

It is generally accepted that cattle depend predominantly on grasses, although utilising herbaceous dicots and woody plants at certain times and under certain conditions (Forbes, 1995). For example, countless experiments in the United States have indicated that season-long cattle diets average 75% grass, 15% forbs and 10% shrubs or browse (Merritt *et al*., 2001).

The demand for energy and protein sources for both animal and human consumption is on the increase and is likely to continue this trend (McDonald *et al*., 1988). Protein is likely to become increasingly scarce and costly. It is a necessity, therefore, that the nutritional potential of all plants that can possibly be used as food or feed is exploited, especially underutilised crops and indigenous plants that are adapted to the soil and climate of the region.

According to the National Academy of Sciences (1979), cattle in Africa "eagerly eat" the leaves and stems of the marama bean plants, although Watt and Breyer-Brandwijk (1962) reported that "the foliage of this species is apparently not browsed by stock". The only reported use as an animal feed supplement is by some local farmers who use it to fatten pigs (Starcher *et al*., 1985).

One animal study reported testing the nutritional value of the marama bean (Ripperger-Suhler, 1983). Young rats were fed raw or cooked bean meal, contributing 10% protein to a purified diet. Food consumption was very poor, resulting in an overall weight loss over the four-week test period. Mortality was not significant and pancreatic hypertrophy was minimal. Additional studies were conducted to isolate anti-nutritional factors that might cause the rats to refuse diets containing marama beans. No hemaglutinins were found in the blood samples that were taken from rats, rabbits, sheep and humans. On the other hand, trypsin inhibitors were found in extremely high levels – 239 trypsin inhibitor units (TIU) per milligram of protein, which is close to twice that reported for soya beans (Kakade *et al*., 1973). Whether these high levels of trypsin inhibitor contributed to the rats' refusal to consume the diet could not be determined. However, diets containing roasted beans, which no longer contained anti-trypsin activity, were also not consumed.

Powell (1987) initiated studies to test the use of the marama plant as forage under rangeland conditions. The plants are known to tolerate drought, but the main problem is to get them established initially under range conditions characterised by unpredictable rainfall and periodic droughts.

MATERIALS AND METHODS

Experimental field design

The botanical and dietary abundance of the marama plant were determined in the course of a farm-scale, long-term systems trial started in 1987 at the Sandveld Research Farm in eastern Namibia, in the Camel Thorn tree savanna of the central Kalahari. The study investigated the effect on cattle productivity and veld condition of four systematically increasing stocking rates of free-range beef cattle, as well as two cattle frame sizes. Since 2001, this systems trial served to elucidate the dietary preferences of cattle during six seasons, namely three hot–wet (March 2001, 2002 and 2003), two cold–dry (June–July 2001 and 2002) and one hot–dry season (October 2002), and data concerning the dietary and botanical abundance of the marama plant were obtained during this period.

At Sandveld, two types of cattle were evaluated, namely the relatively large-framed Afrikaner x Simmental rotational crossbreed and the small-framed, purebred Sanga. These two widely divergent cattle frame sizes were chosen to elucidate the argument that "big is not always best" (Dickerson, 1978; Els, 1998). Stocking rate was kept relatively constant by fixing the number of animals in treatment. It increased from "Low" (targeted animal mass: 15 kg/ha, equivalent to 30 ha/large stock unit [LSU]) to "Low–medium" (25 kg/ha or 18 ha/LSU) to "Medium–high" (35 kg/ha or 12.9 ha/LSU) and, ultimately, to "High" (45 kg/ha or 10 ha/LSU). Treatment herds consisted of 18 to 78 animals, depending on the targeted stocking rate, and resembled stocking rates in use by commercial ranchers – at least in respect of the rates. Routine cattle management activities were identical across all eight treatments and included a set programme of preventive health measures, mating, weaning, replacement, supplementation, and water provision.

Each of these 2 x 4 factorial treatments was allocated six grazing camps of, in total, 689$\pm$4.4 ha. Herds were rotated through their allocated grazing area on a fixed cycle of 7–10 days' occupation per camp during the hot–wet season and 10–14 days' occupation per camp during the two dry seasons (cold–dry and hot–dry). However, the diet selection trial was restricted to only one of the six available camps per treatment in order to prevent differences between camps influencing the experiment. The experimental plot (average size: 142$\pm$28.9 ha) was selected from the available six treatment camps to be as similar in soil (deep red Kalahari sands of the Hutton soil type) and vegetation type (fairly open savanna dominated by perennial grasses and the Camel Thorn tree, *Acacia erioloba*) as possible. Wild herbivores roamed the whole farm freely, and no distinction could be made between their impact on plants and that of livestock.

Shortly before the treatment, the herd of cattle was put out to graze the experimental plot, and its botanical composition was determined by 474$\pm$72.1 step-points that were placed every 3 m along its diagonal transect. Botanical abundance of all plant species was calculated based on point strikes on their canopy. Multiple plants were recorded at one strike point when it struck one plant growing beneath the canopy of another. Herbaceous yield before grazing was determined by clipping the yield, at ground level, in 40 x 1 m^2 equidistant quadrats along the diagonal transect. During clipping, the yields were sorted into 10 different fractions, of which one contained all dicotyledonous plants, including the marama. The biomass produced by this plant was, thus, not measured separately, but only in a group containing all the other herbs of the veld.

While the treatment cattle herd was grazing the experimental plot, but still in the first half of their period of occupation during which utilised plants were still clearly recognisable, six head of cattle from each of the eight factorial treatments were selected at random and observed for an uninterrupted period of ten minutes per head. All bites taken were counted and all forage plants utilised were identified in order to calculate the dietary abundance of each forage plant. Plant parts or organs (including seeds, pods and tuber parts) that were utilised were also recorded. This procedure was repeated on two early mornings and two late afternoons per factorial treatment. At these times, cattle – being crepuscular – feed most actively (Albright & Arave, 1997). Each time, six head of cattle were randomly selected from the treatment herd, enabling statistical analysis of the data by simple Analysis of Variance (ANOVA), rather than by repeated-measure ANOVA.

The advantages and disadvantages of the various methods available to determine the diet selection of free-range cattle have been extensively reviewed at Sandveld (Rothauge, 2004a; 2004b). However, as Forbes (1995) – an eminent expert in this field – states, there is no ideal method, and the choice of method eventually depends on the operator and the circumstances of the experiment. At Sandveld, the cattle were tame enough for the operator to approach them closely for reliable bite counting and forage identification and the operator had sufficient botanical knowledge to identify forage plants accurately. Given the difficulty of obtaining reliable information from fistulated animals in such an environment, the choice of the latter method was obvious. In addition, direct observation of cattle diet selection avoids the confounding effect that free-range wild herbivores, which occur at Sandveld in considerable numbers, have on the utilisation of forage plants.

To evaluate the effect of cattle frame size on the cattle's diet selection, the botanical composition of the veld, and the nutritive value of the diet from all 24 head of cattle, within a frame size treatment, were pooled. The same was done in respect of the 12 head belonging to a fixed stocking-rate treatment. To establish dietary preference, the dietary abundance of a forage species was compared with its botanical abundance. A ratio larger than 1.0 (dietary abundance: botanical abundance) indicated preference of the species concerned (Petrides, 1975).

Sampling

After grazing at a treatment plot was terminated, samples from every utilised forage plant species, including the marama plant, were collected. A total of 1 017 forage samples were collected, of which 280 (27.5%) were collected in a random manner while 730 (71.7%) were collected in a manner imitating the diet selectivity observed and recorded in cattle while their bites were counted ("Imitated" samples). A further seven samples (0.6%), representing other matter such as moribund herbaceous matter and lick, were also collected. Random samples were only collected from the six ecological indicator grass species and from the total herbaceous bouquet on offer by reconstituting, on a mass basis, the ten individual yield fractions (pers. comm., Rothauge, 2003). Thus, the reconstituted random sample is a real entity and not an average of other samples. Imitated forage samples were collected from every plant species utilised by cattle in such a manner that the principal forage species were sampled more often than those less important to the cattle. The average grass, woody and dicotyledonous plant sample is, in contrast to the reconstituted random sample, only an arithmetic average of grass, woody and dicotyledonous plant samples, respectively.

Immediately after collection, all samples were sealed in plastic to retain their natural or field moisture content, and were weighed, dried, ground and subjected to standard chemical analysis to determine their nutritional content, which was presumed to indicate the nutritional content of the selected diet.

Proximate analysis

ADF acid detergent fibre
Ca calcium
CF crude fibre
CP crude protein
DM dry matter
DOM digestibility of organic matter
ME metabolisable energy
NDF neutral detergent fibre
P phosphorus

Crude protein (CP), crude fibre (CF), crude fat (fat), ash, calcium (Ca) and phosphorus (P) content were determined as per the Association of Official Analytical Chemists International (AOAC, 1990; 1995), Acid detergent fibre (ADF) was determined as per Goering and Van Soest (1970). Neutral detergent fibre was determined as per Robertson and Van Soest (1981). *In vitro* digestibility of the organic matter (DOM) and metabolisable energy (ME) content were determined as per Menke *et al.* (1979). All analyses were conducted by the Agricultural Laboratory at the Ministry of Agriculture, Water and Rural Development in Windhoek, using the Agri Laboratory Association of South Africa (ALASA) methods.

Minerals

Phosphorus

The phosphorus concentration in the solution of digested samples is determined spectrophotometrically as the yellow phospho-vanado-molybdate complex (Cavell, 1955).

Calcium

Calcium was determined by atomic absorption flame spectroscopy (Price, 1972).

In vitro digestibility of organic matter/metabolisable energy content

Digestibility of organic matter was determined with the Hohenheim Gas Test (Menke *et al.*, 1979). The relationship between digestibility *in vivo* and gas production (carbon dioxide and methane) *in vitro*, when the plant/feed is incubated with rumen liquor for 24 hours, is used to estimate the digestibility of organic matter.

STATISTICAL ANALYSIS

Statistical analysis utilised the general linear model of the SPSS computer program (Bryman and Cramer, 1997), with prior arcsin transformation of all relative abundance data. Relative abundance is typically skewed, with only a few high and many low abundances (Zar, 1999).

RESULTS AND DISCUSSION

Nutrient content of diet selection

Laboratory analyses yielded information on 11 different nutrients within the total diet selections can be seen in Table 1.

Table 1. Nutrients of major importance in all random and imitated forage samples collected during the diet selection trial at the Sandveld Research Farm*

Details of sample and test	Random samples	Imitated samples	Statistical parameters
Number	280	730	
Field dry matter (%)	76.8±15.09	65.1±22.6	$P < 0.01$; $r^2 = 0.06$
CP (%)	4.5±1.63	7.7±3.67	$P < 0.01$; $r^2 = 0.16$
Ca (%)	0.37±0.24	0.70±0.78	$P < 0.01$; $r^2 = 0.05$
P (%)	0.03±0.02	0.05±0.03	$P < 0.01$; $r^2 = 0.09$
CF (%)	37.9±3.21	33.7±7.38	$P < 0.01$; $r^2 = 0.08$
ADF (%)	45.1±3.74	40.8±6.17	$P < 0.01$; $r^2 = 0.11$
NDF (%)	72.7±5.50	64.0±13.55	$P < 0.01$; $r^2 = 0.10$
Fat (%)	1.4±0.37	2.1±1.28	$P < 0.01$; $r^2 = 0.08$
Ash (%)	8.2±2.41	9.3±5.90	$P < 0.01$; $r^2 = 0.01$
DOM (%)	44.9±8.49	50.3±9.23	$P < 0.01$; $r^2 = 0.07$
ME (MJ/kg)	6.2±1.03	7.2±1.17	$P < 0.01$; $r^2 = 0.14$

* *Systems trial (Rothauge 2004c)*

The imitated samples consistently had a more advantageous nutrient content than the random samples, as indicated by their higher field moisture (50% difference), protein (71% difference), calcium (89% difference), phosphorus (67% difference), fat (50% difference), ash (13% difference), and metabolisable energy content (16% difference), their greater digestibility (12% difference) and lower fibre content (9–12% difference).

Table 2. Content of major nutrients of random and imitated§ samples of the principal forage species of free-range beef cattle at the Sandveld Research Farm*

Species	No.	CP (%)	NDF (%)	DOM (%)
Schmidtia pappophoroides	48 *(58)*	4.4±1.47 *(5.6±1.98)*	69.8±3.93 *(70.3±3.08)*	50.3±7.67 *(55.5±8.39)*
Anthephora pubescens	30 *(73)*	5.9±2.04 *(7.3±2.64)*	65.7±3.85 *65.6±3.09*	53.2±9.25 *55.7±8.40*
Eragrostis lehmanniana/E trichophora	0 *(76)*	*(6.1±1.82)*	*(73.5±2.57)*	*(48.1±7.32)*
Stipagrostis uniplumis	48 *(59)*	4.0±1.09 *(5.2±1.50)*	75.7±3.99 *(75.1±2.62)*	40.1±5.80 *(45.2±8.07)*
Melinis repens repens	0 *(54)*	*(6.0±2.03)*	*(70.2±3.90)*	*(50.1±7.09)*
Eragrostis rigidior	48 *(65)*	4.1±1.10 *(5.7±2.28)*	75.2±4.11 *(73.9±2.66)*	40.9±5.68 *(44.3±7.73)*
Grewia flava/G flavescens	0 *(16)*	*(15.4±3.12)*	*(42.2±3.80)*	*(46.3±10.06)*
Tarchonanthus camphorates	0 *(15)*	*(10.1±2.06)*	*(47.6±5.58)*	*(47.7±5.58)*
Acacia mellifera	0 *(11)*	*(10.7±1.35)*	*(30.2±4.36)*	*(42.3±12.52)*
Terminalia sericea	0 *(12)*	*(7.2±1.72)*	*(48.0±9.37)*	*(41.4±3.24)*
Nidorella resedifolia	0 *(29)*	*(10.2±2.59)*	*(40.9±11.49)*	*(50.1±6.64)*
Hermannia tomentosa	0 *(8)*	*(12.9±2.67)*	*(46.7±4.01)*	*(55.9±8.84)*

§ In italics and between round brackets

* Systems trial (Rothauge 2004c)

According to Table 2, the nutritional properties of the random and imitated samples differed between the different species of grass ($P < 0.01$; except for the field dry matter (DM) content of random samples, for which $P > 0.05$), as well as between different species of woody plants ($P < 0.01$) and different species of dicotyledonous herbs and forbs $P < 0.05$; except for their field DM and ADF content, for which $P > 0.05$). As far as the grasses were concerned, the major nutritional difference between random and imitated samples was in their CP content and digestibility, with NDF content being less sensitive to manner of sampling. The CP content of the principal grasses, as utilised by cattle (imitated), varied roughly from 5% to nearly 8%. The CP content of the principal browse forages and dicots was twice as high as that of grasses. Despite the much lower NDF content of the woody forages, their digestibility was still lower than that of the grasses, while the dicots had a lower NDF content but higher digestibility in comparison with grasses.

Botanical and dietary abundance of the marama plant

Throughout all treatments and seasons of the diet selection trial, dicotyledonous plants contributed 15.0±10.95 g dry matter/m^2 to the total herbaceous yield of 172.1±39.51 g dry matter/m^2, or 8.7±5.70%. The marama plant contributed noticeably to dicotyledonous yield, but its yield was not quantified separately. The marama plant comprised 5.6±2.43% of all plants in the treatment plots (Table 3) and varied significantly according to the season of the year ($P \leq 0.01$, $r^2 = 0.81$), but its botanical abundance was not influenced significantly by cattle frame size ($P = 0.80$, $r^2 = 0.28$) and stocking rate of cattle ($P = 0.44$, $r^2 = 0.28$). It made up only a very small part of the cattle's diet, comprising 0.5±1.08% of all bites taken (Table 3). The season of the year had a significant effect on when cattle selected it ($P \leq 0.01$, $r^2 = 0.55$), but dietary abundance was not influenced by cattle frame size ($P = 0.93$, $r^2 = 0.13$) or the cattle stocking rate ($P = 0.40$, $r^2 = 0.13$).

Table 3. Relative abundance (%) and standard deviation of the marama plant in the natural vegetation and the diet of cattle at the Sandveld Research Farm

Treatment	Botanical abundance (%)	Dietary abundance (%)
Overall treatments	5.60±2.43	0.54±1.08
Large-framed cattle	5.57±2.699	0.45±0.69
Small-framed cattle	5.63±2.20	0.64±1.38
Low stocking rate	6.44±3.10	0.53±1.48
Low–medium stocking rate	5.57±2.19	0.23±0.60
Medium–high stocking rate	5.46±1.82	0.86±1.31
High stocking rate	4.93±2.50	0.56±0.72
Hot–wet season	6.83±1.79	0.98±1.38
Cold–dry season	5.14±2.56	0.15±0.36
Hot–dry season	2.83±0.80	0.00

The veld at Sandveld Research Farm was in good condition over all treatments, with grasses comprising at least 69% of all plants and more than 99% of all grasses being perennial. As could be expected, veld condition varied with treatment, but had not yet advanced towards bush-encroached veld dominated by annuals, or even bare veld, at the highest stocking rate treatment. The marama plant made up a sizeable proportion of the plants, more or less equal to the botanical abundance of a relatively common grass like *Eragrostis lehmanniana and E. trichophora*. Also, the marama's abundance was not influenced statistically by stocking rate treatment, but it did appear to become less abundant – decreasing by about 31% – as stocking rate increased. This tendency cannot be explained by its abundance in the cattle's diet, because it comprised only 0.5% of the diet, varying without tendency between stocking rate treatments. Its preference rating was very low throughout all treatments and seasons, i.e. around 0.10, indicating that cattle did not seek it out for consumption. In fact, the low preference rating indicates the opposite, namely that cattle refrained from eating it, failing to take a bite even if they came across the marama plant during their foraging forays. It did appear as though the small-framed Sanga cattle selected it 42% more readily than the large-framed Afrikaner x Simmental cross-breeds. This tendency was, however, not significant, mainly due to the tremendous variation in the selection of the plant amongst the eight factorial treatments. In fact, the standard deviation of the dietary abundance of the marama plant exceeded its average abundance in cattle diets in all treatments and seasons, indicating an extremely high variability in its contribution to cattle diet – due, most probably, to taste differences between individual animals or micro-site effects on individual plants, rather than a systematic treatment effect. Anecdotally, it was noticed that porcupines utilised the plant well, often digging up its enormous underground tubers and leaving them half-eaten, exposed to the elements in a hole, from which treatment the plant seemed to be able to recover very quickly.

The marama plant was, however, significantly more abundant in the veld during the hot–wet, vegetative growing season (Table 3) when it sprouted new leaves from its prostrate vines, than during the cold–dry or hot–dry dormant season when it lost most or all of its leaves due to its semi-deciduous nature. As a result, it was selected by cattle significantly more often during its growing than during its dormant season (Table 3). This happened because cattle usually selected only individual, young leaves from the distal ends of the prostrate vines for consumption, sometimes taking the distal portion of the vine as well, but generally avoiding mature leaves and the vine itself. In the dormant season, cattle occasionally took dry, brown leaves from the vines, avoiding leaves that had already fallen off. At no stage did cattle take the tubers or parts of tubers – even if they had been completely or partially exposed by porcupines. Similarly, cattle were never seen to take flowering parts, or the fruit (seedpod) or seed.

The marama plant contributed disproportionately much to the nutrition of free-range cattle despite its very low abundance in their diet, especially in terms of its high CP content and, in summer, its high digestibility. Distal ends of vines, including young, fresh leaves, contained about four times as much crude protein as grass at the same time and place. Grass, the staple feed of cattle, contains crude protein in the range of 5–8%. It is unlikely that perennial, non-woody herbs contain a lot of tannins, so it can be assumed that most of this protein was also available to the ruminant digestive tract. Although their digestibility was poor, the crude protein content of dry leaves in winter was twice as high as that of dormant grasses in winter. The digestibility of young, distal vines in summer was only slightly higher than that of actively growing grasses. However, the crude fat content of distal vines was about four times higher than that of grasses at the same stage. The analyses of crude fat include lipids used as energy components as well as aromatic compounds that determine the taste of a plant. In

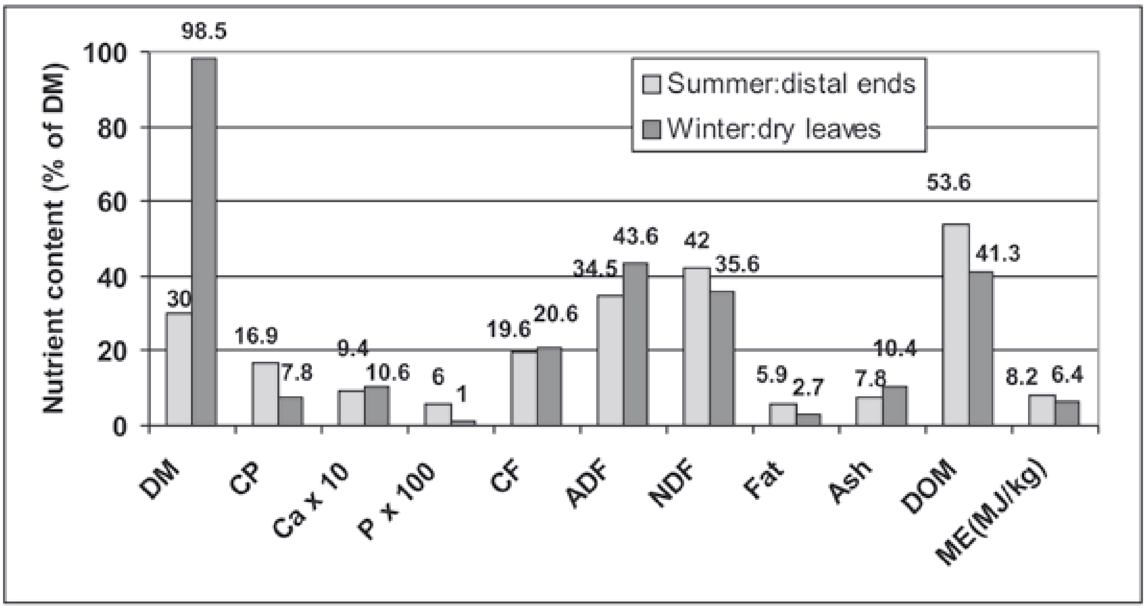

Figure 1. Nutritive value (%) of those organs of the marama plant that were selected by free-range cattle during the hot–wet season (summer) and the cold–dry season (winter).

the case of the marama plant, the high fat content of the distal, young vines (Figure 1) may indicate a high level of unpalatable aromatic oils, causing avoidance by foraging cattle. Although the cattle did not avoid it completely, some only took a bite and then went on to other fodder. It is suspected that when the leaves are old and leathery, it has more fibre and there is not much water content either, despite contributing to exceptionally high metabolisable energy content reminiscent of that of concentrated feed supplements. The crude fibre content of the selected organs was low irrespective of season, indicating the non-woody growth form of this dicot, while its high ash content was probably due to soil pollution of the prostrate vines.

CONCLUSION

This study indicates that the marama plant is indeed utilised by free-range beef cattle, but not preferentially, and that it forms only a very small part of their diet. Dietary abundance is sensitive to seasonal effects, probably because the plant is at different growth stages in different seasons. However, increasing the stocking rate did not entice cattle to consume more of this plant, although it appeared to decrease its botanical abundance, indicating that the plant may be sensitive to defoliation or pruning of its vines. It appears that different cattle types may select the plant more often than others, but it remains a minor dietary component only. The biggest value of the marama plant may be in the large amount of available crude protein it contains, especially during its growing season, typical of leguminous fodder plants. It is also possible that its high crude fat content contains unpalatable aromatic oils that discourage its utilisation by foraging cattle. Considering its low preference value by cattle, the plant does not warrant further investigation to turn it into a cultivated fodder plant, despite its apparent hardiness and high yield.

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