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# Pod availability, yield and nutritional characteristics from four fruit bearing tree species dispersed in pastures as a complementary feed for animal production in the dry tropics

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## Abstract

The objective of this study was to determine the annual pod availability, yield and nutritional characteristics of four fruit bearing tree species (FBTS) from which pods are more readily consumed by cattle, as reported by farmers. Tree density and abundance were estimated by conducting a complete inventory of all individual trees larger than 10 cm in diameter at breast height (DBH) on sixteen traditional livestock farms in a dry tropical ecosystem. All fallen pods from seven individual trees of each FBTS were collected as they fell on the ground. A total of 1402 trees were found dispersed in 614 ha of pastures with an overall mean tree density of 2.28 trees/ha.

Pod availability started on the final days of January and ended in May. *Acrocomia aculeate* (Jacq.) Lodd. ex Mart. produced pods during most of all of the collection period compared to the other tree species. *Enterolobium cyclocarpum* (Jacq.) Griseb and *A. aculeate* were the FBTS that produced the most and the least pod yields respectively. Pod nutritional quality ranged between 5 to 16% for crude protein, between 25 to 42.5% for neutral detergent fiber, and between 63 to 72 % for *in vitro* dry matter digestibility among the four FBTS. It is concluded that leguminous tree species were present at low densities despite the fact that they produce the higher nutritional quality pods. However, pastures containing a FBTS combination with different fruit pattern distributions during the dry season could provide a more stable overall fodder nutritional value available to cattle during the dry season than monoculture pastures. But more research is needed to determine the level that pod production will compensate for pasture availability decline as tree density increases.

***Key words:*** *abundance, dry tropics, livestock, pods*

## Introduction

In the dry tropical areas, livestock production systems are based mainly on the extensive grazing of native or improved monoculture grasses as a principal source of feed. In such environments, nutritional quality from most tropical grasses during the dry season is too poor (DM digestibility <380 g/Kg and protein content <70 g/Kg) to meet livestock nutritional requirements. Consequently, dry-season supplementation has long been recognized as necessary to support livestock performance (Maphosa et al 2009).

Traditionally, most farmers use commercial concentrates to supplement livestock during the dry season however, with the constant increase of grain price, this seems unprofitable nowadays (Rueda et al 2003) forcing farmers to look for alternative feed resources. Pods (whole fruits, seeds plus husk) from bearing tree species are potential feed resources to improve livestock performance in dry tropical ecosystems (Mlambo et al 2007) since they generally contain higher crude protein (>120 g/Kg) and *in vitro* dry matter digestibility (540 – 800 g/Kg) than grasses (Durr and Rangel 2002; Ku 2005).

Many studies have documented the use of pods in animal production (Alvarez-Morales et al 2003; Mahgoub et al 2004; Koenig et al 2007; García-Winder et al 2009; Maphosa et al 2009). Cattle supplemented with *Samanea saman* (Jacq.) Merr pods at 150 g/Kg of dry matter intake level increased live weight by 142 g/day. In the same sense, dual purpose milking cows consuming 2, 4 and 6 kg/day of *S. saman* dry pods increased milk production by 26, 32 and 64 % L/day respectively compared to dual purpose cows without access to pods (Baquero et al 1999). Feeding does with 200 g/day of *Dichrostachys cinerea* pods increased milk production, their kids growth at higher rates and reduced kids mortality compared with not supplemented does (Maphosa et al 2009). Studies feeding sheep with *E. cyclocarpum* (Alvarez-Morales et al 2003), *Prosopis cineraria* (L.) Druce (Mahgoub et al 2004) and *Acacia farnesiana* (L.) Willd (Garcia-Winder et al 2009) pods reported dry matter intakes ranging from 70 to 95 g/day and gained weight from 60 to 120 g/day suggesting that at least part of the sheep diet can be substituted with pods. Collecting pods to feed livestock during the dry period is a common practice among small scale and commercial farmers in dry tropical areas (Timberlake et al 1999; Garcia-Winder et al 2009; Maphosa et al 2009; Harvey et al 2011), but this practice has not been widely adopted due to the difficulty involved in collecting the pods.

Fortunately, complete deforestation for agricultural practices hardly ever occurs. Farmers tend to leave scattered trees in pastures during the slash-and-burn process (Muchagata and Brown 2003) some of which produce pods during the dry period that are readily eaten by livestock directly from the ground. With respect to this, dispersed trees in pastures are a feasible and available resource that can contribute to reducing the dependency on external inputs to feed cattle (Souza de Abreu 2000; Betancourt et al 2003). However, despite the large body of literature that exists regarding the use of pods as animal feed, little information is known about the FBTS dispersed in pastures and their production patterns. Knowledge of density, abundance and production patterns of existing FBTS composition in pastures is therefore necessary to provide insight to develop feeding strategies using non-conventional feed resources (such as pods).

Therefore, the objective of this study was to determinate pod availability throughout the year, yield and nutritional characteristics of four FBTS most commonly reported by farmers to provide pods that are consumed by cattle.

The FBTS studied were:

*Acrocomia aculeate* (Jacq.) Lodd. ex Mart. , a fire resistant palm (Photo 1) widely found in tropical areas from Mexico to Argentina with a small canopy composed of 20-30 pinnate, plumose leaves up to 10 feet long (3 m). It produces smooth fruits generally favoured by cattle that are about 2 inches (5.1 cm) in diameter with a fragile epicarp that cracks easily on maturation whereas the mesocarp is fibrous and yellow (Scariot and Lleras 1995).

*Enterolobium cyclocarpum*(Jacq.) Griseb, a large canopy leguminous tree (Photo 2) found from Mexico to Brazil from 700 to 1100 meters above sea level. It produces highly digestible (>70%) edible pods of high protein content (>12%) avidly eaten by animals (Zamora 2001; Ku 2005).

*Guazuma ulmofilia (*Malvaceae*)*, considered a multipurpose tree (Photo 3) whose main use has been reported as being an important fodder source for livestock. It produces round or elliptic 3-5 mm diameter pods containing 8-9% of crude protein and around 79 % of fiber with a pleasant smell, making them appetizing to cattle (Zamora 2001; Ku 2005).

*Samanea saman* (Jacq.) Merr, a large canopy leguminous tree (Photo 4) commonly found as a shade tree dispersed in pastures of cattle farms from México to northern South America. It produces twisted pods, 10 to 20 cm long with high crude protein content (130 to 150 g/kg) and in pasture lands cattle are avid *Samanea saman* pod eaters (Durr 2001; Zamora 2001; Ku 2005).

**Photo 1.** *Acrocomia aculeate*

**Photo 2.** *Enterolobium cyclocarpum* (Jacq.) Gri

**Photo 3.** *Guazuma ulmofiliaLam* (Sterculiacea)

**Photo 4.** *Samanea saman* (Jacq.) Merr

## Materials and methods

### The Study area

The study was conducted in 614ha of active pastures on sixteen traditional livestock farms in Cañas, Guanacaste, Costa Rica (10º 11 ´ N; 84 º15´W). Farm size ranged from 18 to 241 ha, with an average of 67.0 ha whereas paddock size varied from 0.1 to 39.5 ha. Most of the pasture area (72 %) contained improved or introduced grass species, among which, Urochloa brizantha (Hochst. ex A. Rich.) R.D. Webster and Urochloa decumbens (Stapf) R.D. Webster were the most frequent, while *Hyparrhenia rufa* and *Paspalum* spp were the most frequent naturalized/native grass species. The study area is classified as a tropical dry forest (Holdridge 1978) with elevations ranging from 60 to 250 m above sea level (Arauz 2001). Annual rainfall ranges between 1000 to 2500 mm, with > 95 % falling from May to November. Average temperature varies between 23 and 31 ºC. Relative humidity fluctuates between 62-88 % and 52–77 % in the wet and dry seasons, respectively. Soils in the lowlands are of volcanic origin and mainly vertisols, with an average depth of 100 cm. In the uplands and sloping areas soils are mainly inceptisols with rock formations on the soil surface. Soils are well drained, texture varies from fine to medium and fertility goes from medium to very high (Arauz 2001).

### Data collection

Tree density and abundance were estimated by conducting a complete inventory of all individual trees larger than 10 cm in diameter at breast height (DBH) of the four FBTS most commonly reported by farmers as producing pods consumed by cattle.

Pod availability throughout the year, yield, and nutritional characteristics were estimated from seven individual trees of each FBTS dispersed in pastures. Individual trees were selected based on farmer´s permission to collect the pods and on accessibility to trees and were fenced around with barbed wire (3 m outside of the canopy) to prevent cattle from consuming pods. For each individual tree (n=28) all fallen pods were collected weekly directly from the ground and weighed in the field until pod production stopped. Pod production was pooled weekly for each tree species, mixed, and a sample of 200 g was taken and sent to the laboratory to determine pod quality.

### Laboratory analysis

Pod DM content was estimated by drying samples in a forced-air oven at 60 ºC for 48 h. Crude protein (CP) was determined by micro Kjeldahl procedure (AOAC 1990). Neutral detergent fiber (NDF) was determined according to the method described by Van Soest et al (1991) without the use of amylase, and results are reported including residual ash. *In vitro* dry matter digestibility (IVDMD) was determined following the Tilley and Terry (1963) procedure.

### Data analysis

Data on tree species density, abundance, pod availability, yield and their nutritional quality were analyzed by descriptive statistical analysis procedures using InfoStat 4.1 (2004).

## Results

### Trees dispersed in pastures

A total of 1402 trees of these four FBTS were found dispersed in 614 ha of active pastures within the sixteen livestock farms with an overall mean tree density of 2.28 trees/ha.

Mean tree densities were 1.3, 1.1, 0.14 and 0.12 trees/ha for G. *ulmifolia, A. aculeata, S. saman* and *E. cyclocarpum* respectively.

The non leguminous tree species *G. ulmifolia* and *A. aculeate* represented more than 90% of individuals found and were almost 10 times more abundant than the leguminous tree species (Table 1).

**Table 1.** Abundance of four fruit bearing tree species dispersed in 614 ha of active pastures on sixteen livestock farms in a dry tropical ecosystem.

| Tree species | Family | Abundance # | | |
|---|---|---|---|---|
| | | Trees, n | Relative, % | Absolute, % |
| *Guazuma ulmifolia* | Malvaceae | 695 | 49.6 | 49.6 |
| *Acrocomia aculeata* | Arecaceae | 586 | 41.8 | 91.4 |
| *Samanea saman* | Mimosaceae | 69.0 | 4.90 | 96.3 |
| *Enterolobium cyclcarpum* | Mimosaceae | 52.0 | 3.70 | 100 |

*# Out of total number of trees (n = 1402)*

### Pod availability and nutritional quality

Pod collection lasted for 15 weeks; from January 27 to May 12. During this period, pod availability of *A. aculeate* was consistent throughout all of the collection period, whereas pod availability for *G. ulmifolia, S. saman* and *E. cyclocarpum* was higher during February, March, and April, respectively (Figure 1).

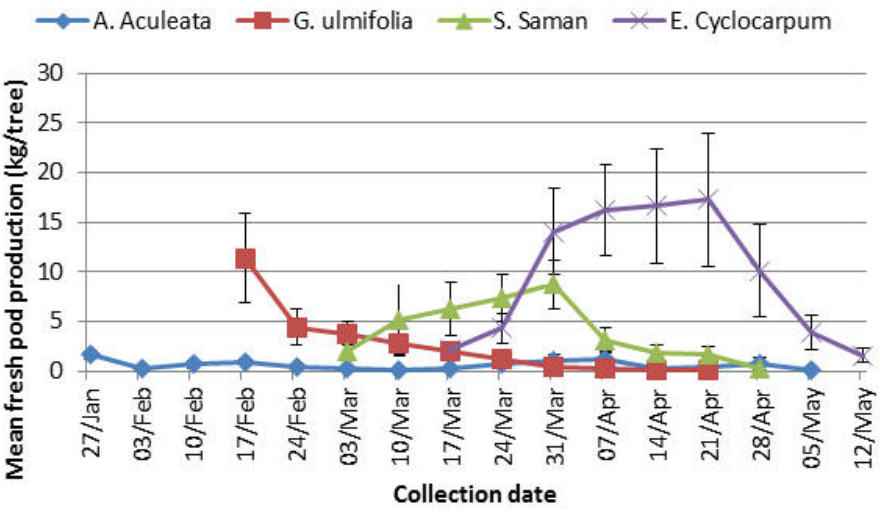


**Figure 1**. Weekly mean fresh pod production (kg/tree) of four fruit bearing tree species dispersed in 613.6 ha of active pastures on sixteen livestock farms in a dry tropical ecosystem.

Mean fresh pod availability (kg/tree) was 3 to 10 times higher for *E. cyclocarpum* than the other tree species. *Guzuma ulmifolia* and *S. saman* produced 3 to 4 times more pods than *A. aculeate*, which produced only 8.6 kg in 15 weeks (Table 2).

**Table 2** . Mean fresh pod availability, yield and nutritional characteristics of four fruit bearing tree species dispersed in 613.6 ha of active pastures on sixteen livestock farms in a dry tropical ecosystem

| | Tree species | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | ***Acrocomia aculeata*** | | ***Guazuma ulmifolia*** | | ***Samanea saman*** | | ***Enterolobium cyclocarpum*** | |
| Sample size, trees | 7 | | 7 | | 7 | | 7 | |
| Tree density, trees/ha | 1.30 | | 1.10 | | 0.14 | | 0.12 | |
| Pod availability in weeks[a] | 15 | (8-15) | 10 | (7-10) | 9 | (5-9) | 9 | (6-9) |
| Pod yield kg/tree | 8.6 | (5.9) | 26.4 | (20.8) | 36.1 | (21.6) | 86.0 | (60.9) |
| Pod yield kg/ha[b] | 11.2 | (7.7) | 29.0 | (22.8) | 5.1 | (3.0) | 10.3 | (7.3) |
| Pod dry matter content g/kg | 805.8 | (102.6) | 832.8 | (27.9) | 819.3 | (39.6) | 865.4 | (30.5) |
| Pod crude protein g/kg | 55.6 | (6.1) | 75.0 | (15.0) | 156 | (8.0) | 131 | (14.0) |
| Pod NDF g/kg | 424.3 | (65.3) | 363 | (121) | 247 | (89.0) | 293 | (49.0) |
| Pod IVDMD g/kg | 663.7 | (47.1) | 633 | (107) | 711 | (30.0) | 678 | (29.0) |

*a = mean standard error is presented in parenthesis except of pod availability which present the range;*
*b = calculated by multiplying pod yield by tree density*

Pod CP of the leguminous trees (*S. saman* and *E. cyclocarpum*) was higher than that of the non-leguminous tree species (*G. ulmifolia* and A. *aculeata*). *Samanea saman* produced pods with the highest CP followed by *E. cyclocarpum*, *G. ulmifolia* and *A. aculeate* respectively. Pods of S. *saman* trees also had higher IVDMD than the other tree species and lower NDF than the non-leguminous trees but similar to that of *E. cyclocarpum*. In contrast, *A. aculeata* pods had the lowest nutritive value among the four FBTS studied (Table 2).

## Discussion

One of the key problems that livestock farmers face in tropical areas is the lack of forage of high nutritional value during the dry period. To overcome this problem, agroforestry, particularly fruit-based agroforestry systems, is one possible option due to their pod availability during the dry season when grass is scarce and of low nutritional quality for the animals to meet their nutritional requirements.

Pods from the tree species studied here, except that of *A. aculeate*, are capable of supplying the recommended (or higher) nutrients established for sheep and cattle by the National Research Council (1985) for maintenance. Additionally, they have also been shown to be an excellent source of available nutrients, particularly protein and energy as shown in diverse studies in which livestock supplemented with pods during the dry season are more productive and lose less weight compared to non supplemented livestock (Alvarez-Morales et al 2003; Mahgoub et al 2004; Garcia-Winder et al 2009; Maphosa et al 2009).

Pods of leguminous tropical tree species studied contain higher amounts of CP than tropical grasses, thus supplying readily fermentable nitrogen for the rumen microbes and counterbalancing the low supply of N at the rumen arising from tropical grasses in extensive cattle systems throughout the tropics. The study revealed that the two non-legume tree species are much more abundant than the leguminous tree species. This can be primarily explained by farmer`s preference to leave or remove particular tree species from pastures.

Commonly, farmers maintain trees in pastures based on tree canopy size and foliage density and on the dependence on products and services that particular tree species provide to cattle farms (Augusseau et al 2005; Kosaka et al 2006; Esquivel-Mimenza et al 2011). *Acrocomia aculeate* and *G. ulmifolia* are two species considered by farmers being of low and moderate crown size respectively from which livestock fed although the first species is also widely used to make an alcoholic drink whereas the second species is commonly used as firewood too (Harvey et al 2011). These might mean that these two tree species are grown in large numbers. On the other hand, the low abundance of the two leguminous tree species found might be explained by the fact that these species are characterized by large canopy size and dense foliage and generally farmers clear tree species with these characteristics from pastures in order to minimize impacts on pasture productivity caused by canopy shade, (Esquivel-Mimenza et al 2011; Harvey et al 2011), but apparently their decision does not consider the beneficial role (such as shade and pod production and quality) that large canopy FBTS have to livestock during the dry season.

Local knowledge studies in the study zone (Stokes 2001; Muñoz et al 2003) showed that livestock farmers had a wealth of knowledge regarding how large crown tree species reduces pasture availability but on the contrary, they did not have a good understanding of the least tangible (shade, forage, wellbeing) tree services that improve cattle productivity by maintaining large canopy tree species in pastures (Esquivel-Mimenza et al 2011; Harvey et al 2011). In this manner, farmers prefer to maintain large canopy tree species, such as *E. cyclocarpum* and *S. saman,* at low densities avoiding interference with pasture production. Therefore, including FBTS dispersed in pastures regardless of their dense crown cover will provide higher quality nutrients (energy and protein) than grasses. This implies that farmers can make decisions on combining large canopy tree species in pastures that supply higher quality nutrients with those of small crown in order to balance both positive and negative impacts of tree species to pastures. Adhering to this strategy may allow farmers to have a constant supply for feeding livestock during the dry season, having a more stable production all year round. This in consequence, may help them to make decisions as to how to design better silvopastoral systems incorporating large canopy FBTS into pastures.

It should be noted that pod availability measurements in this study were only carried out over one dry season and large variability occurred between individual trees within the same species. Previous studies have shown that large variations occur between individual trees within the same species with respect to the amount of pods produced (Janzen 1982; Nunez Pardo and Barros Henrriquez 2011). These variations are related to specific site conditions as well as to individual tree physiological factors such as genetics, age, provenance, and production pattern (Janzen 1982; Scariot and Lleras 1995; Nunez Pardo and Barros Henrriquez 2011). Nevertheless, *A. aculeate* and *G. ulmifolia* produced pods at the beginning of the dry season whereas *S. saman* and *E. cyclocarpum* produced pods in the middle and end of the dry season when standing herbage biomass is scarce and with lower nutritional quality as dry season advances. Thus, the inclusion of a mixture of FBTS with different fruit availability patterns in pastures will improve the use of the dry season pastures apart from providing higher nutritive quality that grasses ensuring a synchrony between pod production with that of the reduction in pasture availability and quality. This will allow livestock to select high quality feed contributing to the maintenance of live weight during the dry season when most animals suffer live weight losses due to limitations of both, forage availability and nutritional quality.

## Conclusion

- Leguminous tree species were present at low densities despite producing higher nutritional quality pods.
- Pastures containing a FBTS combined with different pod pattern distribution during the dry season could provide a more stable overall fodder nutritional value available to cattle during the dry season than monoculture pastures, but more research is needed to determine the level at which pod production will compensate for the decline of pasture availability as tree density increases.

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**Go to top**