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Productive performance of three tropical legumes for protein banks in the dry tropics of Colima, Mexico

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Abstract

The aim of this study was to evaluate the productive performance of mucuna (*Mucuna pruriens*), lablab (*Lablab purpureus*) and clitoria (*Clitoria ternatea*) for protein banks in Colima, Mexico, with irrigation used prior to the rainy season. Fifteen plots were allocated in a complete randomized block design with 5 replicates. Dry matter production, crude protein, calcium and phosphorus concentrations and leaf:steam ratio were evaluated. The highest dry matter production was recorded for clitoria and lablab (9.80 and 8.93 t/ha, respectively, over 240–260 days), while mucuna produced 5.5 t DM/ha in 120 days. Leaf production in clitoria (4.73 t/ha) exceeded that in lablab (3.23 t/ha) and mucuna (2.69 t/ha), while leaf:stem ratio was 0.94 for clitoria, 1.0 for mucuna and 0.58 for lablab. Crude protein concentrations in all species were high (21.7–27.8%) as were concentrations of Ca (1.17–1.64%) and P (0.38–0.67%). Use of the 3 forages is discussed. Studies in the absence of irrigation in a range of seasons would determine how relevant these findings are in those situations. Feeding studies with animals would provide additional information on which to decide the appropriate species to plant in different situations.

Resumen

El objetivo del estudio fue evaluar el desempeño productivo de las leguminosas frijol terciopelo (*Mucuna pruriens*), lablab (*Lablab purpureus*) y clitoria (*Clitoria ternatea*) cuando se utilizan como bancos de proteína con aplicación de riego controlado después de la época de lluvias en Colima, México. Las leguminosas fueron establecidas en un diseño experimental de bloques completos al azar con cinco repeticiones para un total de 15 parcelas. Se midieron la producción de materia seca (MS), los contenidos (%) de proteína cruda (PC), calcio (Ca) y fósforo (P), y la relación hoja:tallo. Clitoria, 240 días después de la siembra (dds), y lablab, 260 dds, mostraron las mayores producciones de MS (9.80 y 8.93 t/ha, respectivamente); mientras que mucuna, 120 dds, produjo 5.5 t/ha de MS. La producción de hoja de clitoria (4.73 t/ha) superó a la de lablab (3.23 t/ha) y a la de mucuna (2.69 t/ha). La relación hoja:tallo fue 0.94 en clitoria, 1.0 en mucuna y 0.58 en lablab. Las especies mostraron un alto contenido de PC entre 21.7 y 27.8%, Ca (1.17 y 1.64%) y P (0.38 y 0.67%). Se discute el uso de las 3 especies y se sugieren estudios adicionales sin aplicación de riego.

Introduction

The state of Colima is located in the seasonally dry tropical region of Mexico, which is characterized by frost-free temperatures and rainfall of about 900 mm/yr, but also a pronounced seasonal arid pattern. This region provides a challenging environment for beef production owing to heat, disease and pest factors common to tropical areas, plus the added burden of a 7- to 8-month dry season, when forage quantity and quality are low (Peel et al. 2010).

Smallholder livestock production in the seasonally dry tropical areas is based on traditional dual-purpose systems (Macedo et al. 2003; Guevara et al. 2013),

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which provide only about 80 and 68% of the dry matter and protein requirements, respectively, of cattle. These systems have traditionally been based on feeding low-quality roughage sources and/or crop residues, mainly maize stover, during the dry season (Macedo et al. 2008; Guevara et al. 2013). The low protein concentration in these forages limits microbial activity in the rumen, resulting in depressed feed intake, low dry matter digestibility and suboptimal animal production, whether measured in terms of milk yield, draught power or growth rate (McDonald et al. 1996).

The integration of well-adapted protein bank legumes to supplement crop residues and grasses in animal production systems has the potential to improve forage quality in the dry season, and this strategy is being adopted much more widely by smallholders in many tropical countries (Pengelly et al. 2004; Rootman et al. 2004). In Zimbabwe, supplementing maize stover with lablab hay has significantly increased milk yields from 4–6 L/day to 6–17 L/day (Thorpe 1999). Milk yield and protein, lactose and non-fat solids from cows fed a ration with mucuna hay were similar to those from cows eating commercial feed concentrates (Murungweni et al. 2004).

Among the legume species being used or with potential as forage, lablab (*Lablab purpureus*) and mucuna (*Mucuna pruriens*) are annual legumes capable of producing large quantities of high-quality, above-ground biomass for livestock feed (Murungweni et al. 2004; Peters et al. 2010). In addition, clitoria (*Clitoria ternatea*) is a perennial climbing, strongly persistent, herbaceous legume with good potential under irrigation, yielding good quality forage (Villanueva et al. 2004; Cabrera et al. 2010). These 3 legumes are some of those recommended for the seasonally dry tropical areas of Mexico. Since the rainy season is so short, irrigation is normally used either before or after the rainy season to ensure that crops grow satisfactorily.

This study aimed to evaluate the productive potential of the above legumes for protein banks in Colima, Mexico, when irrigation was used prior to onset of the rainy season.

Materials and Methods

The trial was carried out in Armería, Colima, Mexico (19°00’56’’ N, 104°00’05’’ W; 91 masl), where the climate is warm, subhumid with summer rains (Figure 1). The average annual temperature and rainfall are 26.5 ºC and 790.8 mm, respectively (SEFOME 2012).

A complete randomized block design with 5 replications was used. Legumes were sown on 2 March 2007 in 9.60 m^2 plots, on a Eutric Regosol, at sowing rates of 15 kg/ha for mucuna (González 2007), 30 kg/ha for lablab (Martínez et al. 1987) and 20 kg/ha for clitoria (Villanueva et al. 2004). The area was irrigated prior to sowing, with drip irrigation applied every 10 days after sowing until the rains began (30 June 2007). Seeds were immersed for 5 minutes in water at 80 °C before sowing and urea, superphosphate and potassium chloride fertilizers were applied to the experimental plots to provide 100 kg N/ha, 80 kg P/ha and 80 kg K/ha. Weed control was done manually.

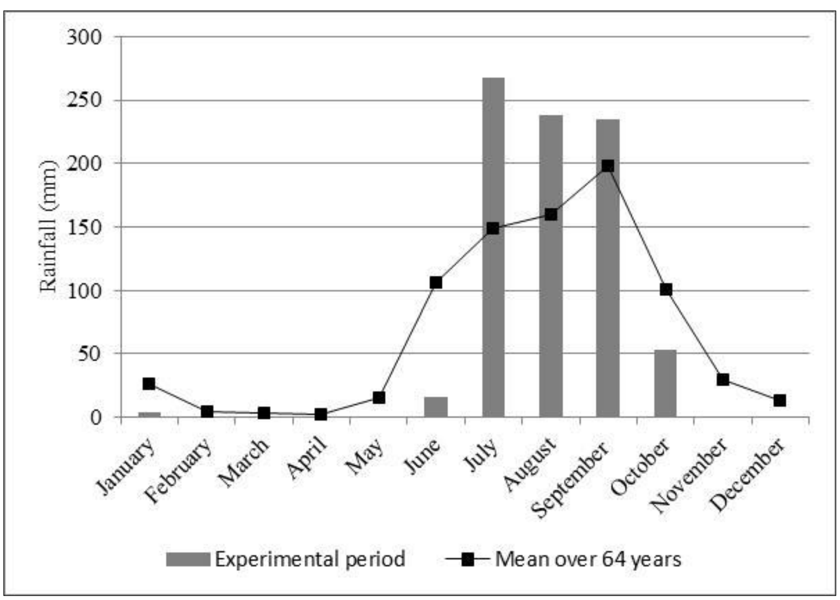

Figure 1. Rainfall during the study and the average of the last 64 years.

The legumes were harvested from an area of 4.80 m^2 in the center of the plot at a uniform height of 10 cm above ground. Mucuna (first harvest) and lablab (first and second harvests), were cut at 120 d of age, while clitoria was harvested at early flowering (10%), which occurred at 70 d for the first cut and at 47 d average for the 4 subsequent cuts.

At each harvest, an 800 g sample of fresh forage from each plot was selected, bagged and dried at 60 ºC for 48 h for estimating dry matter production. Following drying, leaves and stems were separated and weighed. Leaf and stem yields and leaf:stem ratio were calculated. The dried samples were bulked over all harvests and mean crude protein, calcium and phosphorus concentrations were determined (Goering and Van Soest 1970; AOAC 1990). In the case of clitoria, the only one that behaved as a perennial, plant height, stem length and cover were evaluated before each harvest. To assess plant cover, a 1 m^2 metal frame was used, with a single sample per plot. Plant height and length of stem were measured with a 1 m ruler on 5 randomly selected plants per plot.

The effects of legume and harvest on dependent variables were analyzed with ANOVA and Tukey´s test (P=0.05) using the SAS general model procedure (SAS Institute Inc. 2009).

Results

Dry matter (DM) production of mucuna and lablab at the first harvest was greater than that of clitoria, while lablab and clitoria had greater total production than mucuna (P<0.05) (Table 1). Dry matter production of lablab decreased significantly from the first to the second harvest, while production of clitoria remained unchanged over the 5 harvests (Table 1).

Table 1. Dry matter production (t/ha) and leaf:steam ratio of 3 legumes in Colima, Mexico.

	Harvest							
	1	2	3	4	5	Total	s.e.	Sig. level
Whole plant								
Mucuna pruriens	5.50A†					5.50B		
Lablab purpureus	5.89Aa†	3.04Ab‡				8.93A	0.59	0.00
Clitoria ternatea	1.40Ba†	2.15Aa†	1.92a§	2.12a§	2.21a§	9.80A	0.11	0.11
s.e.	0.65	0.21				0.68		
Sig. level	0.00	0.09				0.01		
Leaf								
Mucuna pruriens	2.69A†					2.69B		
Lablab purpureus	2.39Aa†	0.84Ab‡				3.23B	0.28	0.00
Clitoria ternatea	0.71Ba†	1.08Aa†	0.84a§	1.03a§	1.07a§	4.73A	0.05	0.07
s.e.	0.27	0.07				0.30		
Sig. level	0.00	0.24				0.01		
Stem								
Mucuna pruriens	2.81A†					2.81B		
Lablab purpureus	3.50Aa†	2.21Aa‡				5.71A	0.37	0.17
Clitoria ternatea	0.69Ba†	1.08Ba†	1.08a§	1.09a§	1.14a§	5.08 A	0.06	0.16
s.e.	0.40	0.21				0.45		
Sig. level	0.00	0.14				0.00		
Leaf:stem ratio								
Mucuna pruriens	1.00AB†					1.00 A		
Lablab purpureus	0.75Ba†	0.38Bb‡				0.58 B	0.08	0.01
Clitoria ternatea	1.05Aa†	1.07Aa†	0.79a§	0.95a§	0.95a§	0.94 A	0.04	0.10
s.e.	0.06	0.13				0.06		
Sig. level	0.04	0.01				0.00		

Values within columns and parameters followed by different upper-case letters and within rows followed by different lower-case letters are significantly different according to Tukey's test (P≤0.05).
†Irrigation; ‡Irrigation–rainy season; §Rainy season.

Table 2. Crude protein, calcium and phosphorus concentrations (%) of 3 legumes in Colima, Mexico.

Species	Crude protein	Calcium	Phosphorus
Mucuna pruriens	27.8	1.48	0.38
Lablab purpureus	21.6	1.64	0.67
Clitoria ternatea	22.1	1.17	0.41

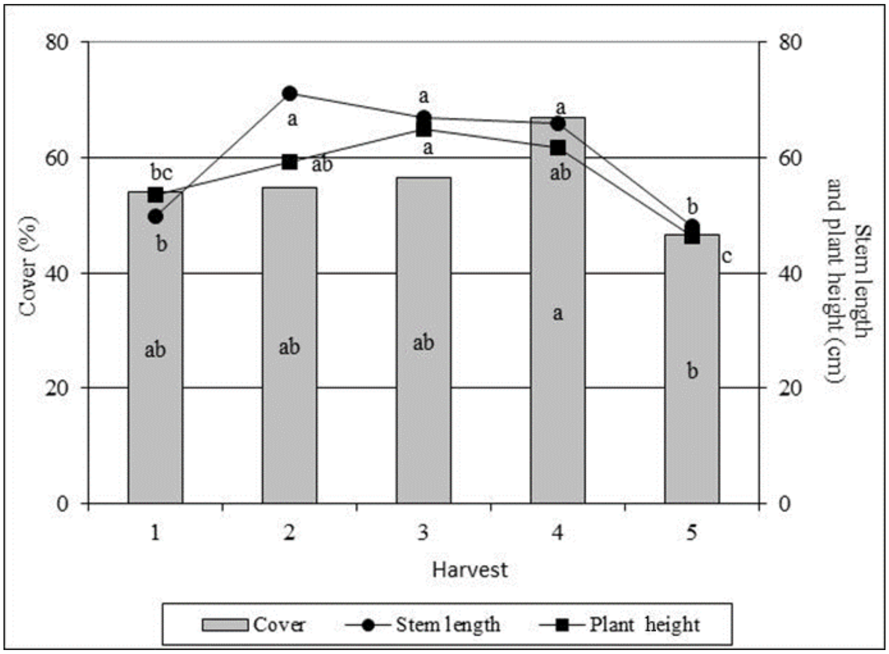

Figure 2. Evolution of cover, stem length and plant height of clitoria (*Clitoria ternatea*) in Colima, Mexico. Different letters in columns or on lines denote significant differences (P<0.05).

The production of leaf and stem of mucuna and lablab at the first harvest and stem production of lablab at the second harvest were greater than those from clitoria (P<0.05) (Table 1). While total leaf production for clitoria was greater than for mucuna and lablab, lablab and clitoria produced more stem than mucuna (P<0.05). As a result, leaf:stem ratio for mucuna and clitoria was greater than for lablab (P<0.05). Leaf production and leaf:stem ratio of lablab decreased significantly from the first to the second harvest, while these parameters did not vary over the 5 harvests for clitoria (Table 1).

At 120 days of age, mucuna and lablab had average crude protein concentrations of 27.8 and 21.6%, respectively. Average concentrations of calcium and phosphorus in mucuna and lablab were 1.48 and 1.64%, and 0.38 and 0.67%, respectively. At 47 days of age, average concentrations of crude protein, calcium and phosphorus in clitoria were 22.1, 1.17 and 0.41%, respectively (Table 2).

Ground cover of clitoria was similar at the first 4 harvests, decreasing significantly at the final harvest, while height peaked at the 4th harvest. The stems showed maximum length from the second to the fourth harvest, and decreased towards the end of the study (Figure 2).

Discussion

This study has provided useful information on the potential of mucuna, lablab and clitoria as legumes for use as protein banks in the seasonally dry tropics of Mexico. All 3 legumes produced good yields of forage of high quality and could have a role in improving nutritional levels for ruminants, especially during the dry season. It is important to realize that the data in this study are for 1 year only and seedlings were irrigated for the 4 months until the rains started to ensure survival. Harvesting of mucuna, the first harvest of lablab and the first 2 harvests of clitoria occurred before the wet season started, so the growth was produced by drip irrigation. Rainfall during the rainy season was well above the long-term mean, so yields obtained and survival of the species, especially clitoria, might be better than would be obtained under non-irrigated situations and in average or below average rainfall conditions.

The total DM yield of clitoria over the 5 harvests compared favorably with yields reported by Bakhashwain and Elfeel (2012) in Saudi Arabia, when it was drip-irrigated and heavily fertilized. Average DM production of clitoria under irrigation per harvest was lower than that reported in Sudan (2.95 t/ha) by Mohamed-Osman et al. (2013). While in our study DM production of clitoria remained unchanged over the 5 harvests, other authors in Mexico found that, owing to low rainfall and no irrigation, the greatest DM production occurred at the first harvest, with significant decreases subsequently (Carvajal and Lara 2005). A similar trend was observed in clitoria under irrigation (Bakhashwain and Elfeel 2012). In the present study, irrigation followed by adequate rainfall favored vigorous regrowth, while in other studies in the absence of irrigation, DM production varied significantly between the rainy and dry seasons (Sosa et al. 2008).

DM yield of the primary growth (first harvest) of lablab in this study was greater than the yields reported by Barnes (1996) in Ghana, who harvested less than 2.89 t/ha at 2 sites in consecutive years. In addition, total DM yield of lablab was greater than the 5.9 t/ha reported by Jingura et al. (2001) in Zimbabwe. However, Nworgu and Ajayi (2005) reported DM yields of 19.98–20.82 and 44.58–48.66 t/ha/yr in Nigeria[1], harvesting at 8 and 12 weeks, respectively. The DM yield of mucuna in this study was lower than the 8.2–11.6 t/ha reported by Kaizzi et al. (2004), but greater than the 2.61 t/ha of Jara (1997). Factors like soil moisture (rainfall), temperature, soil type, plant density, cutting height, cutting interval and fertilizer application affect DM production of legumes (Jingura et al. 2001; Njarui et al. 2004; Sosa et al. 2008; Ogedegbe et al. 2011).

The leaf fraction of forages generally has better nutritional value than more fibrous stems (Van Soest 1994). Since cattle select for the leaf fraction, the leaf:stem ratio is a very important parameter in determining the nutritional value of forages, including legumes (Hendricksen et al. 1981; Wood 1983). Legumes with high leaf:stem ratios would seem to be those of highest nutritional value (Norton and Poppi 1995). Clitoria maintained the same leaf:stem ratio throughout, in contrast with the results of Ramírez et al. (2003), who observed a decline in this parameter with progressive harvests. Leaf:stem ratio of clitoria was significantly lower than values of up to 7.3 reported by Abusuwar and Omer (2011), who suggested that leaf:stem ratio increased with the addition of 50 kg triple superphosphate/ha before planting. At the first harvest, leaf:steam ratio for lablab was similar to that found by Murphy et al. (1999) in Honduras (0.76) in plants of similar age (117 days), but the overall value (0.58) was slightly lower than the bottom of the range (0.63–6.0) reported by Abusuwar and Omer (2011). As normally occurs in most forages, with maturity lablab showed a decrease in leafiness, resulting in a decrease in leaf:stem ratio. With regard to mucuna, leaf:stem ratio was significantly lower than that indicated (2.94) in a previous study (Nyambati and Sollenberger 2003).

The crude protein concentrations in clitoria, lablab and mucuna were much higher than the minimum requirement (7%) for maintenance of beef cattle (NRC 1984). Juma et al. (2006) reported crude protein concentrations in clitoria and mucuna of 21.8 and 18.0%, respectively, while Aganga and Autlwetse (2000) reported a crude protein concentration in lablab of 16.4%.

Calcium and phosphorus concentrations in the 3 legumes were higher than the suggested critical levels of 0.30% Ca and 0.25% P, necessary to meet ruminant requirements in the tropics (McDowell and Arthington 2005). Legumes are good sources of Ca, and are higher in Ca content than grasses.

In clitoria, length of stem was higher than that reported for 2 genotypes, blue (28.2 cm) and white (31.7 cm) in Venezuela by Suárez et al. (2012). The coverage and height of clitoria were better than observed in another Mexican study, in which plant coverage decreased from 63 to 11% and the height from 67 to 41 cm, from first to fourth harvest (Carvajal and Lara 2005). Meanwhile, Adjei and Fianu (1985) mentioned that clitoria coverage declined during the first year after planting, from almost 60% to less than 15%. These studies show that, despite clitoria being a perennial plant which could be expected to remain productive for perhaps 5 years (Pengelly and Conway 2000), it often performs as an annual. Its lack of persistence is often due to grazing management, soil type, weed competition, drought and cutting interval (Adjei and Fianu 1985; Peck et al. 2012). The fact that our crops were irrigated from before planting until the start of the rainy season and the rainy season was wetter than normal could indicate that the results obtained were the best that might be expected on this soil type in this region.

While all 3 species grew well and produced high yields of high quality forage, their various attributes make them suitable for use in different situations. One

[1]Data presented without major methodological details.

needs to consider how the protein bank would function, i.e. would forage be harvested and stored for feeding livestock later in the year or would it be left to stand in the field for grazing off during the dry season? Issues like how well the species retain their leaves post maturity become important for stand-over forage. Owing to its perennial growth pattern, clitoria is more flexible in how the forage might be used. It could be used as green forage for several cuts, which could eliminate costs of hay making and storage. Some authors, e.g. Abreu et al. (2014), recommend feeding the forage fresh, either in a cut-and-carry system or under grazing. Annual legumes such as lablab and mucuna can provide a large quantity of forage within a short period, which can be conserved and used as hay for dry season livestock feeding. While this incurs additional costs for labor and storage, the area is freed up for growing other crops, especially under the conditions of our study, where growth of mucuna and most of the growth of lablab occurred before the start of the wet season. A major limitation for some producers with these annuals is that they might need replanting each year (Pengelly and Conway 2000).

Currently, it has been shown that using legume protein banks increases milk yield and weight gain, and improves household short-term income in tropical countries (Kabirizi et al. 2013; Nulik et al. 2013; Douxchamps et al. 2014).

Studies over a range of years in the absence of irrigation would provide a better understanding of how these legumes would perform under strictly rain-fed conditions.

Feeding studies with the forage produced by the 3 species would provide a sounder basis for decision making on which species to plant in different situations.

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