Biomass and Bioenergy 106 (2017) 38–42

Contents lists available at ScienceDirect

Biomass and Bioenergy

journal homepage: http://www.elsevier.com/locate/biombioe

Research paper

# Biomass and nitrogen content of fifteen annual warm-season legumes grown in a semi-arid environment

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ARTICLE INFO

*Article history:*
Received 1 December 2016
Received in revised form
7 August 2017
Accepted 11 August 2017
Available online 18 August 2017

*Keywords:*
Legumes for biofuels
Harvest
Single-harvest

ABSTRACT

Warm-season legumes can provide a low-input feedstock for biofuel, but research comparing the biomass and N content is lacking. The objective of this experiment was to evaluate and compare 15 annual, warm-season legumes in semi-arid climates as biomass feedstocks. A factorial randomized complete block design field experiment with four replications was conducted at sites near Beeville and Stephenville, TX, during the 2010 and 2011 growing seasons with an average 450 mm total rainfall and irrigation. Whole plot (1.5 m × 6 m; 25 cm row spacing) was legume species and subplot (1.5 m × 3 m) treatments included harvest every 30 d (initiated at first flower or canopy closure, whichever occurred first) or harvest once at the end of the season or plant death, whichever occurred first. 'Kauffman' and 'Tropic Sunn' (*Crotalaria juncea* L.) produced an average 8650 kg ha$^{-1}$ and was the most consistent across environments. 'Iron & Clay' and 'Red Ripper' cowpeas (*Vigna unguiculata* (L.) Walp.; 4700 kg ha$^{-1}$), and 'Rio Verde' and 'Tecomate' lablab (*Lablab purpureus* (L.) Sweet; 4000 kg ha$^{-1}$), generally yielded less biomass than crotalaria. Because of their consistent biomass yields Iron & Clay cowpea, Red Ripper cowpea cut repeatedly through the growing season as well as Rio Verde and Tecomate lablab, or pigeonpea cut at the end of season are suitable biomass options for these and similar environments. Further experiments are needed to determine the potential role of these legumes as crop rotation, cover crop, or integrated livestock-bioenergy uses for biomass production.



## 1. Introduction

Some of the characteristics of an ideal bioenergy crop as defined by Zegada-Lizarazu et al. [1] are that the feedstock has a high yield and water use efficiency, a broad pest resistance and environmental range, desirable feedstock qualities for a given biofuel processing method, require low inputs, and provide ecosystem services such as wildlife habitat. Warm-season grasses, such as miscanthus (*Miscanthus × giganteus*), switchgrass (*Panicum virgatum* L.), and sorghum (*Sorghum biocolor* (L.) Moench), are potential biorefinery feedstocks which can be grown on marginal lands and are less competitive to food and feed production than corn (*Zea mays* L.) [1]. Warm-season grasses, especially the perennials, meet the criteria of an ideal feedstock; however, N fertilizer is a requirement to maximize biomass and ensure stand persistence of even the most N-use efficient grasses [2].

Legumes improve soil fertility and organic matter due to their chemical composition and quality of residue to the soil [3]. Legumes add N to the soil due to biological nitrogen fixation, thereby, reducing the nitrogenous fertilizers needed for non-legume crops grown in rotation. Reducing the amount of ammonium fertilizers applied means a reduction in fuel required for application and the natural gas required for fertilizer production [4]. There are negatives to the greater N concentration of legumes for biomass to bioenergy conversion, for example greater $N_2O$ emissions than grasses during thermochemical conversion [5]. However, there are still potential uses of legumes in biomass for bioenergy systems include rotating annual legume monocrops, integrating legumes into grass systems or using them as cover crops which would enhance biodiversity and ecosystem services [1,6–10]. Additionally, N removal as protein removal prior to bioenergy conversion has economic market potential, either as extract or separation of leaf

*Abbreviations:* DM, dry matter; OM, organic matter.

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http://dx.doi.org/10.1016/j.biombioe.2017.08.016
0961-9534/

for protein use from stem material for bioenergy [11]. Legumes provide a relatively low input feedstock for conversion of biomass into biofuel especially when grown on marginal lands. Despite the benefits of integrating legumes into grass biomass systems, research evaluating the potential for production of tropical legumes in the southern USA and comparing the biomass yields of many potential warm-season and tropical legumes is lacking [9]. The objective of this experiment carried out in Beeville and Stephenville, TX, was to evaluate and compare the suitability of annual, warm-season legumes in semi-arid climates under season-long or end-of-season harvest regimens. The goal of this experiment was to identify those entries that produce a large amount of biomass, persist through abiotic pressures, and yield the most N. The rational of this goal is that further experiments focus on incorporation of adapted, high-yielding legumes into grass biomass production systems.

## 2. Methods and materials

A factorial randomized complete block design field experiment with four replications was conducted at sites near Beeville and Stephenville, TX, USA, during the 2010 and 2011 growing seasons. The Beeville location (28°27′N, 97°42′W, elevation 70 m) was on a Parrita sandy clay loam (loamy, mixed, supereactive, hyperthermic shallow Petrocalcic Paleustolls; pH 7.2; $NO_3$-N was 21.2 mg $kg^{-1}$, P was 3.7 mg $kg^{-1}$, K was 111 mg $kg^{-1}$, organic matter was 17 g $kg^{-1}$). The Stephenville location (34°17′N, 96°12′W, elevation 370 m) was on a Windthorst fine sandy loam (fine, mixed thermic Udic paleustalfs; pH 6.8; $NO_3$-N was 0 mg $kg^{-1}$, P was 14 mg $kg^{-1}$, K was 170 mg $kg^{-1}$; organic matter was 6.8 g $kg^{-1}$). Fifteen annual, warm-season legumes (Table 1) were planted in tilled seedbeds on 25 cm row spacing with a cone planter in May of each year at both locations. Whole plot (1.5 m × 6 m) treatment was legume species and subplot was half (1.5 m × 3 m) of each plot. Subplot treatments included harvest every 30 d (repeated harvest; initiated at first flower or canopy closure, whichever occurred first) or harvest once at the end of the season (October) or plant death, whichever occurred first. The actual number of repeated harvest for each legume varied by year and location and is summarized in Table 1.

Weeds were controlled by hand and 25 mm of irrigation was applied at planting and 13 mm weekly when there was no rainfall within the previous 7 d. Irrigation was limited to aid establishment of the experiment and applied to not exceed the 100-year rainfall average for either location. For both locations, 2010 precipitation was near or above 30-year averages during the growing season, except for August (Fig. 1A and B). During 2010, only 25 mm of irrigation were applied to plots at Stephenville in May and 60 mm in August. At Beeville 25 mm of irrigation was applied at planting, and 40 mm each in August and October. In 2011, drought impacted both locations with precipitation in Beeville well below the 30-year average for the entire growing season (Fig. 1A), and Stephenville below the 30-year average precipitation in June, July, and September (Fig. 1B). At Stephenville in 2011, irrigation totaled 25 mm in May and 60 mm in June, July and September. At Beeville irrigation totaled 40 mm in May and June, 50 mm in July and August, 30 in September, and 50 in October. Rainfall and irrigation

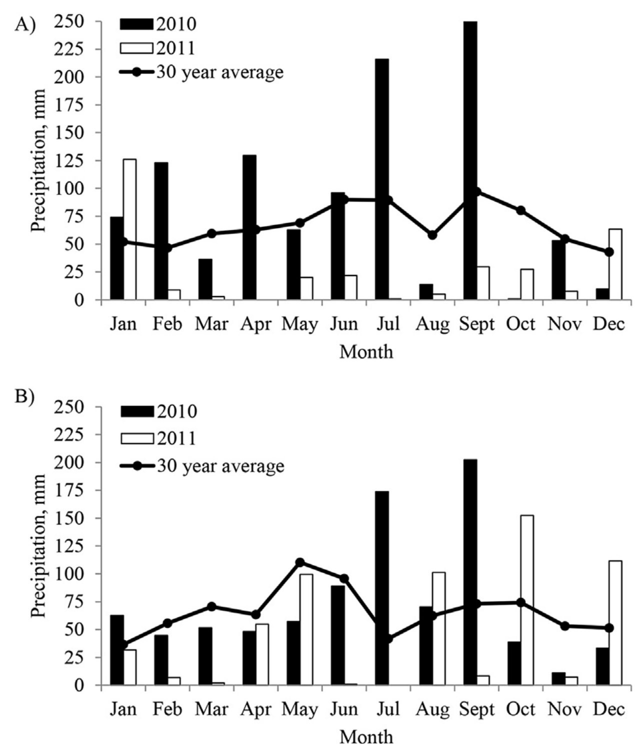


**Fig. 1.** Precipitation (mm) during the experiment and 30-year average at A) Beeville and B) Stephenville, TX USA.

**Table 1**
Annual, warm-season legume cultivar or entry, scientific name, seeding rate and number of harvests in 2010 and 2011 at Beeville and Stephenville, TX USA.

| Common name | Cultivar | Scientific name | Seeding rate, kg $ha^{-1}$ | Number of harvest for repeat harvest treatment (every 30 d) | | | |
|---|---|---|---|---|---|---|---|
| | | | | Beeville | | Stephenville | |
| | | | | 2010 | 2011 | 2010 | 2011 |
| Partridgepea | Comanche | *Chamaechrista fasciculata* (Michx.) Greene | 15 | 1 | 2 | 2 | 3 |
| Forage soybean | Hutchenson | *Glycine* max (L.) Merr | 36 | 0 | 1 | 1 | 3 |
| Forage cowpea | Iron & Clay | *Vigna unguiculata* (L.) Walp. | 50 | 3 | 3 | 3 | 3 |
| Crotalaria | Kauffman | *Crotalaria juncea* L. | 50 | 2 | 2 | 2 | 3 |
| Forage soybean | Laredo | *Glycine* max (L.) Merr | 36 | 1 | 2 | 1 | 2 |
| Velvetbean | Eoana | *Mucuna pruriens* (L.) DC. | 40 | 2 | 2 | 2 | 3 |
| Pigeonpea | Variety not specified | *Cajanus cajan* (L.) Millsp. | 20 | 1 | 2 | 0 | 3 |
| Cowpea | Red Ripper | *Vigna unguiculata* (L.) Walp. | 50 | 3 | 3 | 3 | 3 |
| Smooth-seeded wildbean | Rio Rojo | *Strophostyles leoisperma* (Torrey & A. Gray) Piper | 15 | 2 | 2 | 2 | 3 |
| Lablab | Rio verde | *Lablab prurpureus* (L.) Sweet | 20 | 2 | 2 | 2 | 3 |
| Lablab | Tecomate | *Lablab prupureus* (L.) Sweet | 20 | 2 | 2 | 2 | 3 |
| Trailing wildbean | | *Strophostyles helvula* (L.) Elliott | 40 | 3 | 2 | 2 | 3 |
| Crotalaria | Tropic sunn | *Crotalaria juncea* L. | 50 | 2 | 2 | 2 | 3 |
| Jumbo peanut | Valencia | *Arachis hypogaea* L. | 80 | 2 | 2 | 2 | 3 |
| Forage soybean | Whitetail thicket | *Glycine* max *(L.) Merr* | 36 | 1 | 2 | 1 | 3 |