Agriculture and Natural Resources 50 (2016) 54–59

Contents lists available at ScienceDirect

Agriculture and Natural Resources

journal homepage: http://www.journals.elsevier.com/agriculture-and-natural-resources/

Original article

Effects of sulfur and phosphorus application on the growth, biomass yield and fuel properties of leucaena (*Leucaena leucocephala* (Lam.) de Wit.) as bioenergy crop on sandy infertile soil

Songyos Chotchutima,[a] Sayan Tudsri,[a,*] Kunn Kangvansaichol,[b] Prapa Sripichitt[a]

[a] *Department of Agronomy, Faculty of Agriculture, Kasetsart University, Bangkok 10900, Thailand*
[b] *PTT Research and Technology Institute, PTT Public Company Limited, Ayutthaya, Thailand*

A R T I C L E I N F O

Article history:
Received 5 November 2014
Accepted 10 September 2015
Available online 10 February 2016

Keywords:
Bioenergy crop
Leucaena
Phosphorus
Sandy soil
Sulfur

A B S T R A C T

A field experiment was conducted to determine the effect of Sulfur (S) and Phosphorus (P) fertilizer on the growth, biomass production and wood quality of leucaena for use as a bioenergy crop at the Buriram Livestock Research and Testing Station, Pakham, Buriram province, Thailand during 2011–2013. The experiment was arranged in a split plot design with two rates of S fertilizer (0 and 187.5 kg/ha) as a main plot and five rates of P (0, 93.75, 187.5, 375 and 750 kg/ha) as a sub-plot, with four replications. The results showed that the plant height, stem diameter, total woody stem and biomass yield of leucaena were significantly increased by the application of S, while the leaf yield was not influenced by S addition. The total woody stem and biomass yield were also proportionately greatest with the maximum rate of P (750 kg/ha) application. The addition of S did not result in any significant differences in fuel properties, while the maximum rate of P application also showed the best fuel properties among the several rates of P, especially with low Mg and ash contents compared with the control (0 kg/ha).

Introduction

The use of biomass as a source of renewable energy is a potential way to mitigate climate change by reducing greenhouse gas emissions from fossil fuel combustion and to secure energy supplies (Gasol et al., 2009). Biomass can be burnt or gasified in gasification plants to generate electricity (Hughes et al., 2007). Biomass for electricity generation sourced from natural forest is undesirable, due to the possible associated risks of deforestation and the increased pressure on this resource (Abe et al., 2007). Fast-growing tree farming is likely to be the most sustainable method of fuel supply for biomass production. Leucaena (*Leucaena leucocephala*) is expected to become one of the major bioenergy crops because it is a fast-growing tropical tree (Tewari et al., 2004), its stems and branches can serve as biofuel for heat and electricity production (El Bassam, 2010) and it is a nitrogen-fixing tree, which can generally improve soil nutrient conditions (Abe et al., 2007).

The use of fast-growing trees as a source of biomass for bioenergy crop production has markedly increased in recent decades and this trend is likely to continue (El Bassam, 2010). To abate any conflict between food and bioenergy crops, many researchers have proposed the use of marginal and poor abandoned lands for biomass feedstock plantations (Schroder et al., 2008). Northeastern Thailand has large areas of sandy soil that is generally acidic making such soils infertile (Imsamut and Boonsompoppan, 1999). Radrizzani et al. (2010) reported that the major factors contributing to P and S deficiencies and affecting leucaena response were inherently low soil fertility, soil shallowness and soil acidity. Acid soil is one of the causes of reduced efficiency in the use of P (Fageria, 2004). Barker and Collins (2003) found that P is one of the most important fertilizers influencing biomass production and N_2 fixation in forage tree legumes. Phosphorus and S nutrient deficiencies limit plant growth directly and suppress the symbiotic N_2 fixation of leucaena (Shelton and Brewbaker, 1998; Radrizzani et al., 2010). Acid soil requires P and S to improve the soil conditions in order to increase legume growth, survival of root growth and N_2 fixation (Kisinyo et al., 2005). Gypsum reduces the acidity and also supplies both calcium (Ca) and S; S deficiencies normally occur in acid soils because the sulfate leaches through these soils relatively rapidly

* Corresponding author.
E-mail address: agrsat@ku.ac.th (S. Tudsri).

http://dx.doi.org/10.1016/j.anres.2015.09.002

(Barker and Collins, 2003). Legume trees have responded strongly to added S, and N_2 fixation is affected by S (Ezenwa, 1994). Shelton and Brewbaker (1998) reported that it is essential to add S and P fertilizer at planting (early growth) and after each harvest in sandy textured and acidic soil.

Nevertheless, too much P fertilizer increases the risk of environmental damage caused by P runoff, which can be a problem in utilizing biomass for bioenergy (El Bassam, 2010) and leads to a high cost. The wood quality of leucaena is related to the proper application of fertilizer as specifically, Lewandowski and Kicherer (1997) stated that biomass combustion quality depends on ash, nitrogen (N), S and chlorine (Cl), with high amounts of S causing problems regarding emissions of SO_x (Obernberger et al., 2006). Hence, an understanding of the optimum rate of fertilizer applications is desirable to help determine their impact on the environment as fertilizer application plays an important role in sustaining the energy production system.

To ensure the long-term sustainability of biomass production of leucaena in sandy soil, a small-scale field experiment was conducted in Buriram province in northeastern Thailand, to evaluate the potential of leucaena plantation on sandy soils as an additional source of income for crop-growing farmers. Moreover, only a few researchers in Thailand have focused on increasing the biomass production of leucaena by determining the requirements for the application of S and P under such conditions (Chotchutima et al., 2013). Thus, the objectives of this study were to evaluate the application of P and S fertilizer on the growth, biomass yield and fuel properties of leucaena for biomass production on acidic soils.

Materials and methods

Experimental site and design

The experiment was conducted on the Buriram Livestock Research and Testing Station, Pakham, Buriram province, Thailand under rain-fed conditions. The soil on the site was a sandy loam with pH 5.2. The soil consisted of organic matter (0.55%), 2 ppm of available P and 9 ppm potassium (K). A split plot in a randomized complete block with four replications was used to compare two strategies of S application as gypsum (S at 0 and 187.5 kg/ha) as a main plot and five rates of phosphorus fertilizer as triple superphosphate (P1, 0 kg/ha; P2, 93.75 kg/ha; P3, 187.5 kg/ha; P4, 375 kg/ha; and P5, 750 kg/ha) as a sub-plot and the size of each plot was 6 × 5.5 m.

Establishment and management

After preparing the area for the experiment, leucaena (*L. leucocephala*, cv. Tarramba) seeds were scarified, inoculated with rhizobium strain 3126 and then sown in polythene bags (size 10 × 23 cm). The seedlings were grown in a greenhouse for 1 month until they were transplanted into the field in March 2011 at a spacing of 1 × 0.5 m. The seedlings were irrigated from March to May 2011 and no further field irrigation was applied thereafter. Weeding was done manually in all the plots. The fertilizer treatments were applied by hand broadcasting 2 months after planting, including a broadcast application of KCl (0-0–60) at 250 kg/ha. All fertilizer treatments were applied after each harvest at the same rates of S, P and K.

Plant measurement

Plant data collection was done at 4 and 12 months after planting in the field. The parameters measured consisted of plant height, the stem diameter at breast height (130 cm above ground level) and sprout number, with all measurements undertaken on 10 randomly selected plants per plot. The plant height was measured from the ground level to the highest point of the plant using a graduated meter stick, the stem diameter was measured using a vernier caliper and the sprout number was determined based on the number of green sprouts at the main axis of the stump by direct counting. At 12 months after planting, 18 plants in each treatment were selected and cut at 50 cm above ground level using a handsaw. Each plant was partitioned into leaf (including the green stem), branch and woody stem. The fresh weight of every tree part was recorded immediately after harvesting using an electronic balance. The dry weight (DW) of the leaf, branch and woody stem were each determined after drying in a hot air oven at 70 °C for 2 wk and then the woody stem component was air dried again for about 3 months. The woody density was measured by the water-displacement method as described by Pottinger et al. (1998) and woody stems were also analyzed for carbon (C), hydrogen (H), oxygen (O), nitrogen (N) and S content (ultimate analysis) using an elemental analyzer (LECO, 2003). The chemical composition of P, K, Ca, magnesium (Mg) and sodium (Na) was analyzed using the methods of the Association of Official Analytical Chemists (AOAC) (AOAC, 1980). The ash content was measured by a proximate analysis method and the heating value was determined using a standard bomb calorific combustion method (AOAC, 1980).

Statistical analysis

All data were subjected to analysis of variance appropriate for a randomized complete block design. The least significant difference at the 5% level was used to identify significant statistical differences.

Results

Rainfall distribution

In the establishment year (2011), the rainfall exceeded the long-term average at the start of the experiment, but there was no rainfall during the first two months followed by a little rainfall (5 mm in July 2011) (Fig. 1). Rainfall increased from August to October 2011 and the maximum rainfall occurred in September 2011 (243 mm). The only rainfall during November 2011 to February 2012, was 94 mm in January. After the first-year harvest in March 2012, there was a small amount of rainfall (33 mm) in March 2012 and the rainfall increased from April 2012 to June 2012 (99–181 mm). In both August and September, the amount of

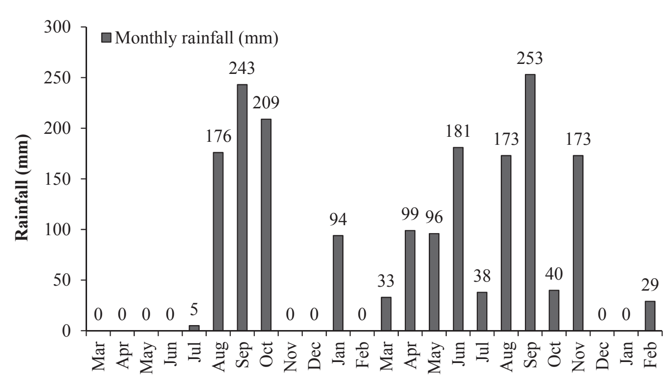

Fig. 1. Mean monthly rainfall from March 2011 to February 2013 at Buriram Livestock Research and Testing Station, Pakham, Buriram province, Thailand.