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The effects of cultivation methods and planting season on biomass yield of Napier grass (*Pennisetum purpureum* Schumach.) under rainfed conditions in the northeast region of Thailand

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ABSTRACT

The worldwide search for carbon dioxide neutral biomass for the conversion into bio-energy as alternative to fossil fuels has promoted Napier grass for cropping in warm climates due to high yields even under less-than-ideal management. Our objectives were to evaluate the effects of cutting types (setts, 60-cm and 120-cm stem sections and terminal cuttings), planting methods of setts (vertical insertion or horizontal burial), and planting date (rainy or dry season) of Napier grass for dry matter yield (DMY) in a field experiment under low-fertile conditions carried out and repeated in two consecutive years in northeast region of Thailand.

Terminal cuttings produced up to 16.14 Mg DM ha^{-1} and also showed the best planted-to-produced biomass ratio, followed by long stems but the setts produced the smallest yields. It was observed that the organogenesis of stem-section cuttings was slower than terminal cuttings which, consequently, produced more DMY. In fact, terminal cuttings appeared most suitable for the direct propagation in the field for the highest biomass production. Non-significant differences between DMY were observed between planting methods of vertical insertion or horizontal burial of setts as what prefers their handling in the field. Furthermore, an unclear pattern was found for the planting date of setts when more biomass was produced in the dry season from 2012 to 2013, and vice versa during second year of the experiment. Nevertheless, the non-significant differences of planting date showed that Napier grass could improve land-use efficiency and bear additional income, if cropped during the dry season.

1. Introduction

Napier grass (*Pennisetum purpureum* Schumach.) is a stem-forming tall grass which attracted recent interest as a bio-energy crop due to its vigorous biomass production (Waramit and Chaugool, 2014). Its tropical origin makes this thermophilic species a high-productive crop for warm climates as found in Thailand. Under fertile conditions, Napier grass can produce more dry matter (DM) per unit area than many other crop, if cut once a year (El Bassam, 2010). Besides its numerous positive characteristics for handling as a crop, e. g. diazotrophic life, drought resistance or compatibility for many soil types (de Morais et al., 2012). Napier grass is easily propagated by planting cuttings directly in the field (Lounglawan et al., 2014). Three planting methods of Napier grass have emerged from literature: small stem sections which contain two nodes, also referred to as setts, are inserted vertically or with an angle in the ground while longer stem sections, referred to as canes, are completely buried (Knoll and Anderson, 2012).

Napier grass with its vigorous development of biomass was found to be a promising renewable energy source for different bioenergy fuels. A recent investigation found a heating value of 18.11 MJ/kg in Napier grass stems as opposed to 16.21 MJ/kg in leaves, combined, making 16.58 MJ/kg in stem and leaf, which indicates matured stands with tall stems will be a higher quality feedstock for bioenergy (Mohammed et al., 2015; Tsai and Tsai, 2016). The ratio of energy output to energy input is sometimes declared as 25:1, since it was confirmed that the heat of combustion of the biogas compounds was estimated to be 3.7–7.4 times higher than the heat required to pyrolysis of Napier grass (Strezov et al., 2008).

In 2013, the National Energy Policy Council introduced the 10-year Alternative Energy Development Plan (AEDP) to the public, and promoted Napier grass to meet the target of 3000 MW bio-electricity (or an estimated 221,760,000 t of fresh mass), compressed biogas (CBG) and liquid petroleum gas (LPG) onto 480,000 ha (3 million rai) within 10 years (Waramit and Chaugool, 2014). The maximum-yield potential of Napier grass are an estimated 58 Mg DM ha^{-1} on Thailand's soils, reached only when well-irrigated and fertilized (Wijitphan et al., 2009).

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Nakhon Ratchasima province, with a tropical savanna-like climate, belongs to the northeast region, which also comprises the largest producing acreage of all Thailand (Kottek et al., 2006; National Statistical Office, 2013). Cropping in this province goes along with the monsoon rains which supply enough precipitation to the fields during the rainy season (from May to September) while cropping during the dry season needs supplemental irrigation. It is estimated that, in the northeast region, about 30% of cropping capacity is reached during the dry season under irrigation while un-irrigated fields lie completely fallow (Sethaputra et al., 2001). With the current interest in planting large fields with bio-energy crops for conversion, improvements of successful propagation for the establishment of Napier grass stands under less-than-ideal conditions, namely without additional irrigation or fertilizer application, is essential for the Nakhon Ratchasima province due to the fact that many farmers neither can afford additional costs nor have access to additional irrigation.

The purpose of this study was to determine effects of propagation and methods of Napier grass's various cutting types and their suitability for the biomass production under rainfed conditions. Different cuttings types as well as the planting method of setts (vertically or horizontally) were tested in a two-year in-situ field experiment. For the rainy and dry seasons, horizontally buried setts were compared for their response to in-field propagation. A further objective of this study was to address field performance by the planted-to-produced biomass ratio.

2. Materials and methods

2.1. Site description

The experiment was conducted from 2012 to 2014 on a 1,3 ha large site on the farm yard of the campus of Suranaree University of Technology (SUT), Nakhon Ratchasima Province, Thailand (LAT 14.87014° N, LON 102.03209° E, elevation 250 m). For an earlier experiment, Srisa-ard (2007) classified the soil of this site as in the region widespread Korat soil series (Oxic Paleustults). Before the experiment started, soil samples were randomly collected and intermixed from the whole site. Samples from the first 30 cm thick horizon were classified as humic acids sand by the VDLUFA-Method (physical characteristics: 1.05% humus, 3.80% clay, 12.10% silt and 84.10% sand with a pH-value of 5.3 ($CaCl_2$) and a slight deficiency of phosphorus (content 30 mg/kg, CAL) and potassium (content 60 mg/kg, CAL)) (Haegele et al., 2017).

Agro-meteorological field data were recorded with a data logger (T-Warner, Type iMetos 2, Software Version 05.52, Pessl Instruments GmbH, Werksweg 107, 8160 Weiz, Austria) that was installed 200 m away from the experimental site. The logger was equipped with sensors for measuring air temperature (SMT 160–30 with a convection cover) and precipitation (Joss-Tognini principle, Wilh. Lambrecht GmbH, Friedlaender Weg 65–67, 37085 Goettingen, Germany).

2.2. Experimental design and cultivation

Matured canes of Napier grass were harvested from a two-year-old stand on the SUT campus farm yard, pruned from dry leaves and sized a few days before planting. The genotype of tested Napier grass is a tall-growing cultivar which tends to form stems easily (Haegele et al., 2017). Stem-section cuttings were randomly cut from all portions of the canes. Died-off leaves of terminal cuttings were removed from 10 cm of the matured portion of the stem until first green leaf sheaths. A few days before the experiment was planted, the plots were completely cleared and ploughed, same was done for the second year of the experiment. The plots, each sized 6 × 14 m was spaced 1 m apart, were laid out in a randomized block design with three replications for each planting. Four cutting types (terminal, sett, 60 cm stem and 120 cm stem), two planting methods for setts (vertical or horizontal) and two planting dates for setts (regular in May and late in September) of Napier grass were included in the test (Table 1). During the second year of study, heavy rainfall in September 2013 had flooded the experimental fields 10 cm high, so setts were planted in December, not in September, which consequently resulted in a shorter cropping period. The setts contained a minimum of two nodes and were approximately 15 cm long. Stems and setts were horizontally buried, approximately 5 cm deep in the ground, while for vertical planting, setts were inserted with one node in the ground and the other exposed. The terminal cuttings were inserted in the ground as deeply as possible until the fresh leaf sheath reached the soil's surface. Plots, which were laid out with nine cuttings per square meter, were planted in grid patterns, and the stem-containing plots were buried in three equispaced furrows on a square meter. All plots were planted in May, except the treatment planted in late September, and grew uninterrupted for one year. No fertilizer or irrigation was applied during the experiment, plant protection or weeding was also omitted in both years.

Table 1
Experimental set-up and attributes for testing effects of cutting types on biomass, planting method and planting date on biomass production of Napier grass in the years 2012–2014.

Treatment	Explanatory Factor
Sett (horiz)	Nine horizontally buried setts per square meter, planted in May
Sett (late)	Nine horizontally buried setts per square meter, planted in September
Sett (vert)	Nine vertically inserted setts per square meter, planted in May
Terminal	Nine vertically inserted terminal cuttings per square meter, planted in May
60 cm stem	Three horizontally buried 60 cm long stem sections per square meter, planted in May
120 cm stem	Three overlapping horizontally buried 120 cm long stem sections per square meter, planted in May

In May planted (17th of May 2012 and 07th of May 2013), in September planted (10th of September 2012 and 05ft of December 2013).

2.3. Plant sampling and data analysis

After twelve months upon completion of the experiment, plants were cut off 10 cm above ground with a brushcutter to harvest and analyze the treatment-specific aerial biomass. Above-ground harvested biomass was completely cleared of competitive weeds and the yield of the net plot (2 × 6 m) was analyzed. Fresh mass (FM) was weighed and 200 g of the individual samples were oven-dried at 80 °C for 72 h to a constant weight and dry mass (DM) was determined. The sample's DM for the net plot was calculated as followed, DM = FM (1–average moisture content) and then converted from the net plot area by multiplication (x 5/6) into Mg DM ha^{-1} for analysis of variance (ANOVA).

Secondly, cuttings' FM was weighted from random chosen samples (n = 100) before planting and averaged for cutting types (mean FM in 2012: setts 32.17 g; 60 cm stem 133.59 g; 120 cm stem 249.73 g and terminal 87.11 g. Mean FM in 2013: setts 31.96 g; 60 cm stem 99.29 g; 120 cm stem 155.63 g and terminal 68.27 g). To determine the relative distribution of biomass, as referred to as planted-to-produced biomass ratio, for planting used net plots' specific FM (number of cuttings per square meter, shown in Table 1) and net plots' harvested FM were separately totalized for both years and specific treatment, and then calculated as ratio and expressed in percent.

2.4. Statistical analysis

All data were subjected to the ANOVA, performed using the IBM SPSS Statistics for Windows, Version 23.0 (IBM Corp., 2015). The cutting types were treated as a factor with three replications. The LSD-test was used to determine significant differences among treatments. The significant differences among treatments were compared with the critical difference at 0.05 levels of probability for significance.