Effects of irrigation treatments and nitrogen applications on Napier grass planted in dry season as energy crop at Chiang Mai province

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ABSTRACT: The productive potential of Napier grass a recently introduced energy crop was evaluated during the dry season in Chiang Mai province, Thailand. A field experiment was conducted to investigate the effects of various irrigation treatments, namely rainfed conditions, 0.5 x ET_0 (Reference Evapotranspiration) 1.0 x ET_0, and nitrogen application rates of 0, 120, 240 and 300 kg N.ha^{-1}, on biomass production of Napier grass. Nitrogen was applied two weeks after planting. Simultaneously, after the 1st harvest, ET_0 was calculated and applied to the field by drip irrigation system every five days. Napier grass was harvested three times, firstly two months after planting, then at one and two months after the first harvest. The experimental results showed that applying 0.5 x ET_0 could increase total dry matter yield of Napier grass from 4,344 kg.ha^{-1} under rainfed conditions to 6,260 kg.ha^{-1}. Simultaneously, 240 kg N.ha^{-1} application was sufficient for reaching the statistically highest total dry matter yield from 2,340 to 7,911 kg.ha^{-1} compared with no nitrogen application. However, the interaction of 1.0 x ET_0 and 300 kg N.ha^{-1} application could potentially reach above ground dry matter yield up to 12,000 kg DM.ha^{-1}.

Keywords: Napier grasses, Irrigation, Reference Evapotranspiration, Nitrogen

Introduction

The Alternative Energy Development Plan 2012-2021 by the Ministry of Energy of Thailand aims to increase biogas production for power generations from 138 to 600 MW and for Compressed Biogas from 37 x 10^4 to 1 x 10^6 tons of oil equivalent (Cheokul, 2012). In order to increase biomass supply for green energy, Napier Grass is expected to be a main contributor according to the Thai National Energy Policy Committee Resolution's aims; this requires promoting collaboration of farmers in the Napier production plans (DEDE, 2013) because Napier grass can grow in and tolerate broad climate and soil conditions throughout the humid tropical and sub tropical regions. Suitable conditions for Napier grass include well-drained medium-textured soils, soil pH from 4.5 to 8.2, precipitation from 850 to 2,500 mm.yr^{-1} with optimum temperature from 25 to 40°C (Moore et al., 2006). Under these conditions, Napier grass can be very productive, especially, under intensive management of invariable nitrogen fertilizer and irrigation level. For instance, in a Napier experiment in Khon Kaen, Thailand, at planting space 50 x 40 cm, 70,800 kg DM.ha^{-1}.yr^{-1} were harvested over 11 harvest times dates (Wijitphan et al., 2009). In Puerto Rico, under natural conditions of 2,000 mm.yr^{-1} rainfall and 897 kg N.ha^{-1}.yr^{-1}, Napier grass produced up to 84,800 kg DM.ha^{-1}.yr^{-1} when cut in 90-day intervals (Vicente-Chandler et al., 1959). Nevertheless, biomass yields depend on cultivar (Nyambati et al., 2007; Tudsri et al., 2002). However, in general crop

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growth, water and nitrogen and other minor nutrients are the main factors to determine potential yield and attainable yield respectively which are depended on vary cultural sites and climates (Bowen and Baethgen, 1997). In case of water, Napier morphology and biomass yield are clearly affected by water stress. For instance, Napier grass blades started rolling at 50% of field capacity under controlled greenhouse conditions (Purbajanti et al., 2012). Moreover, field study in Kenya showed that daily dry matter production varied from 25 kg DM.ha^{-1} in the dry season to 178 kg DM.ha^{-1} in the rainy season under low nitrogen application (Anindo and Potter, 1994). On the other hand, nitrogen application rates and times directly affect Napier grass growth (Snijders et al., 2011). For example, experimental field in Islamabad, Pakistan, showed that biomass yield of Napier grass in one cutting at 60 days after planting responded positively to increased nitrogen application rates from 0 to 80 kg N.ha^{-1} and the biomass yield could not increase anymore when up to 120 kg N.ha^{-1} were applied (Ullah et al., 2010). However, combined effects of irrigation and nitrogen applications to Napier grass growth in Chiang Mai are not well understood. Therefore, this experiment was conducted to quantify effects of alteration levels of irrigation treatments and nitrogen application rates.

Materials and Methods

The experimental field was established during November 2013 to March 2014 at Mae Hia Agricultural Research, Demonstrative and Training Center (18º46'N, 98°55'E, 350 m a.s.l.). The soil is a loamy-skeletal, mixed, isohyperthermic Typic (Kandic) Paleustults, Mae Rim series. The soil pH was 5.7 and soil moisture at planting was 14.6%. Before planting, the soil contained 1.5 % organic matter, 38.8 ppm of NH_4^+, 20.1 ppm of NO_3^-, 21.45 ppm of P and 138.8 ppm of K at 0-30 cm depth by 5 sample points. A randomized complete block split-plot design with three replications was used to evaluate the effects of three irrigation treatments and four nitrogen applications. The irrigation treatments, rainfed conditions, 0.5 x ET_0 (Reference Evapotranspiration) and 1.0 x ET_0, were set in three main-plots randomly. Simultaneously, the nitrogen applications rates, 0, 120, 240 and 300 kg N.ha^{-1}, were set randomly as four split-plots within a main-plot. Therefore, the experimental field was composed of 36 units of 4 x 5 m each. The field was plowed on the day before planting at 30 cm depth by a diesel-engine tractor with plough-plates. Pak Chong 1 (*Pennisetum purpureum* × *Pennisetum americanum*) variety was used to investigate the effects of irrigation and nitrogen application. Two-node Napier stem cutting, 12.88 ± 2.53 cm internode length (n=30), were planted at 50 x 40 cm planting space by burying the bottom node underground and setting the top node above ground. The stems cutting were planted by one stem cutting per hole on Nov 16. The viability rate of the stems cutting was 95% at two week after planting. Average air temperature, average relative humidity and average wind speed obtained from daily statistic reports of the Thai Meteorological Department, measured at Chiang Mai airport, were used to calculate daily ET_o with the Penman-Monteith equation on daily time step (Allen et al., 1998). Subsequently, water lost by ET_0 was drained to the experimental field by drip irrigation in five-day intervals after the 1st harvest. Urea fertilizer was applied into excavated holes and buried following the calculated rates at the 2nd week after planting. The 1st harvest was conducted two months after planting, 2nd harvest one month after the 1st and the 3rd harvest one month after the 2nd harvest. Grass was cut closely to the ground surface at harvest time. Eight plants were sampled at each harvest time to calculate above ground dry matter ($kg.ha^{-1}$). The fresh plants were dried in open air conditions for three days; then, cut and dried at once in a hot-air oven for 24 hours before weighing. Soil samples were collected weekly at two points in each main plot at 0-30 cm and air-dried in order to determine gravimetric soil moisture (%). STATISTIX v8.0, statistical analytical software, was used to analyze variance and compare the treatments' means.

Results and Discussion

Weekly top soil moisture contents: The experimental field received 90.2 mm rainfall in the 1st and 2nd week after planting and 28.0 mm in the 4th and 5th week. In total, 118.2 mm of rainfall added to soil moisture before starting irrigation of 0.5 x ET_0 and 1.0 x ET_0 started in the 8th week after planting. Soil moisture in all plots slightly decreased after the last rainfall of the experimental period (**Figure 1**). After the 8th week after planting, soil moisture in the plots was clearly affected by irrigation treatments. Consequently, rainfed condition plots had the lowest soil moisture in the 9th week and highest soil moisture was found in the 1.0 x ET_0 plot. Similarly, the differences were continuously the same until the final 15th week. Gravimetric soil water content after the 8th week of 1.0 x ET_0 plots was around 10 to 12%, 0.5 x ET_0 plots were around 8 to 11% and rainfed condition plots slightly decreased from 8% in the 9th week to 4% in the 15th week.

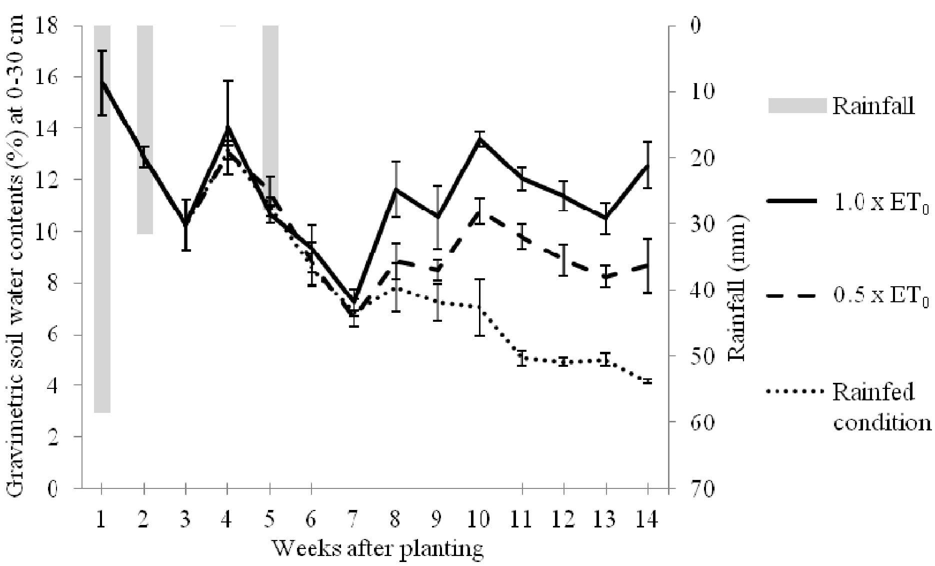

Figure 1 Weekly gravimetric soil water contents in the ploughed horizon (0-30 cm) and rainfall during the experiment (started drip irrigation in 8th week)

Dry matter yield: Effects of the different irrigation treatments by average from all nitrogen application (**Table 1**) were found that after the 1st harvest in 8th week, applying 0.5 x ET_0 and 1.0 x ET_0 could positively affect dry matter yield of Napier grass at the 2nd and 3rd harvest date and the total dry matter yield. However, dry matter yield at 2nd harvest did not differ between 1.0 x ET_0 and 0.5 x ET_0 treatments, while the plots under rainfed conditions significantly showed the lowest biomass production at all harvest times. Highest total dry matter yield including all harvest dates was 7,341.9 kg $DM.ha^{-1}$ in 1.0 x ET_0 plot and the lowest was 4,344.3 kg $DM.ha^{-1}$ in the rainfed condition plots but the total dry matter yield between 0.5 x ET_0 and 1.0 x ET_0 did not differ significantly.

Table 1 Dry matter yield of Napier grass at 1st, 2nd, 3rd harvest and total dry matter yield under effects of the three irrigation treatments after 1st harvest by average from all nitrogen applications

Irrigation treatments[1]	Dry matter yield (kg $DM.ha^{-1}$)			
	1st Harvest[2] Jan 10	2nd Harvest Feb 8	3rd Harvest Mar 8	Total
Rianfed conditions	2,609.2	1,131.5 b	603.7 c	4,344.3 b
0.5 x ET_0	2,968.5	1,744.1 a	1,667.0 b	6,260.2 a
1.0 x ET_0	2,834.2	1,846.2 a	2,788.7 a	7,341.9 a
F-test	ns[3]	*[4]	**[5]	*
CV%	24.5	29.6	35.4	21.9

[1/] received 118.2 mm rainfall before 1st harvest, [2/] irrigation treatments had not been applied yet until after 1st harvest, [3/] not significantly different ($p>0.05$), [4/] significantly different ($p<0.05$),
[5/] significantly different ($p<0.01$)

Effects of the different nitrogen application rates by average from all irrigation treatments (**Table 2**) were showed that urea, were applied at 2nd week before 1st harvest (at 8th week). At 1st harvest, applying 120 kg $N.ha^{-1}$ significantly increased dry matter yield from 1,587.7 to 2,921.0 kg $DM.ha^{-1}$ as compared to the treatment without nitrogen application; however, higher nitrogen application rates could not increase biomass production further. At 2nd harvest, higher nitrogen application increased yields from 1,502.5 to 2,063.7 kg $DM.ha^{-1}$ when nitrogen application was doubled from 120 to 240 kg $N.ha^{-1}$. Similarly, at 3rd harvest, increasing nitrogen application rate from 120 to 240 kg $N.ha^{-1}$ increased dry matter yield from 1,140.0 to 2,667.6 kg $DM.ha^{-1}$. On the other hand, dry matter yield in the 240 and 300 kg $N.ha^{-1}$ application plots were not significantly different throughout all harvest dates. Highest total dry matter yield, in 300 kg $N.ha^{-1}$, was 8,209.0 kg $DM.ha^{-1}$, which was not substantially different from 240 kg $N.ha^{-1}$ plot whereas the lowest total dry matter yield was 2,340.8 kg $DM.ha^{-1}$ in the plots without fertilizer application.

Table 2 Dry matter yield of Napier grass at 1st, 2nd, 3rd harvest and total dry matter yield under four nitrogen application rates by average from all irrigation treatments.

Nitrogen applications	Dry matter yield (kg DM.ha^{-1})			
	1st Harvest Jan 10	2st Harvest Feb 8	3rd Harvest Mar 8	Total
0 kg N.ha^{-1}	1,587.7 b	427.2 c	325.8 c	2,340.8 c
120 kg N.ha^{-1}	2,921.0 a	1,502.5 b	1,140.0 b	5,563.8 b
240 kg N.ha^{-1}	3,339.2 a	2,063.7 b	2,667.6 a	7,911.3 a
300 kg N.ha^{-1}	3,440.8 a	2,178.1 a	2,590.1 a	8,209.0 a
F-test	**1	**	**	**
CV%	27.0	25.6	20.7	17.5

1/ significantly different ($p<0.01$)

Combined effects of irrigation treatments and nitrogen application rates with respect to total dry matter yield were significantly different ($p<0.05$, CV%=25.7) at 2nd harvest and highly significantly different ($p<0.01$, CV%= 20.73) at 3rd harvest and total dry matter yield (CV%= 17.49). The relationship of total dry matter yield with irrigation treatments and nitrogen application rates (**Figure 2**) showed that the threshold of total dry matter at no nitrogen application plot was around 2,200 to 2,600; in contrast, at 1.0 x ET_0 treatment was around 2,600 to 12,000 kg DM.ha^{-1} and at 0.5 x ET_0 around 2,100 to 8,200 kg DM.ha^{-1}. The 1.0 x ET_0 treatments yielded 2,600 to 12,000 kg DM.ha^{-1} and responded linearly to increasing nitrogen application rates up to 300 kg N.ha^{-1}. In contrast, total dry matter yield of Napier grass at 0.5 x ET_0 and rainfed condition plot did not respond to applications of > 240 kg N.ha^{-1}. Total dry matter yield in 0.5 x ET_0 plot and rainfed condition plot were around 8,700 and 5,300 kg DM.ha^{-1} respectively under applying 240 kg N.ha^{-1}.

The highest total dry matter of Napier grass in combination effect between 1.0 x ET_0 and 300 kg N.ha^{-1} and between rainfed condition and 0 kg N.ha^{-1} were calculated as 106.1 and 19.1 kg DM.ha^{-1}.d^{-1} respectively within three time harvests. However, those total dry matters were less than calculated 178 and 25 kg DM.ha^{-1}.d^{-1} at rainy and dry season in Kenya, respectively (Anindo and Potter, 1994). As well as the same planting space of the experiment in Khon Kaen, Thailand during 30 Nov to 15 Mar, ratooning Napier grass could produce total dry matter calculated as 128.3 kg DM.ha^{-1}.d^{-1} by three time harvest under three time applications of 75 kg N.ha^{-1} with saturated water 0 to 15 cm of soil (Wijitphan et al., 2009). The different average temperature in the growing period is possibly an important determinant factor of Napier grass growth. In this experiment, the average temperature during the growing period was 23.9°C (average of maximum temperature + minimum temperature/2 of November, December, January and February) while the optimum temperature for Napier grass growth is around 25-

40°C and minimum temperature is about 15°C (Russell and Webb, 1976). In contrast, the experiment in Khon Kaen had average temperature 26.2°C during the entire growing period (Wijitphan et al., 2009).

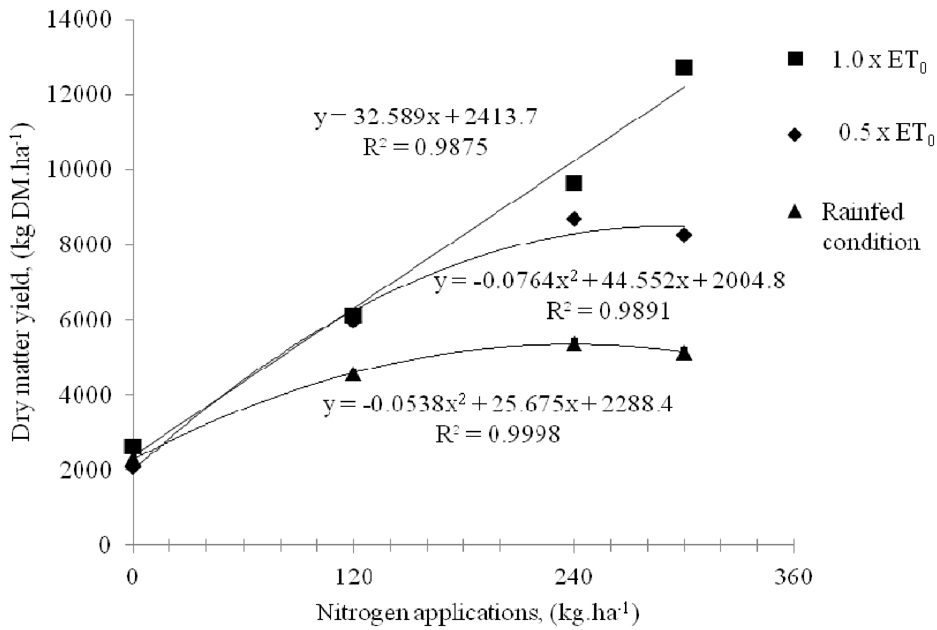

Figure 2 Combined effects of three irrigation treatments and four nitrogen application rates to total dry matter yield of Napier grass by three time harvests (all plot received 118.2 mm rainfall before 1st harvest and begin drip irrigation after 1st harvest)

Conclusion and Suggestions

This experiment demonstrated the effect of nitrogen application rates and irrigation treatment; especially, the combination of those to biomass production of Napier grass during the dry season at Chiang Mai province. For three time harvests, applying 0.5 x ET_0 and 240 kg $N.ha^{-1}$, statistically sufficient for achieving productive total dry matter yield of Napier grass, were around 8,200 kg $DM.ha^{-1}$. Applying 0.1 x ET_0 and 300 kg $N.ha^{-1}$ could potentially reach dry matter yield up to 12,000 kg $DM.ha^{-1}$. Oppositely, 2,200 kg $DM.ha^{-1}$ was a possible base yield in rainfed condition without nitrogen fertilizer application. However, nitrogen fertilizer should be dividedly applied after each harvest time as under common production practice in order to improve efficiency of fertilizer application. The produced biomass from the experimental practice must be qualified to serve required properties for biogas production systems. In addition, cost efficiency for irrigation system, fertilizer application and labor should be evaluated for reasonable investments and energy inputs required should be assessed in order to assess the environmental friendliness of this supposed Green Energy. On the other hand, completed year-round experimental works are repeatedly needed for understanding the seasonal climatic effects on Napier grass growth in Chiang Mai province.

Acknowledgment

The author is grateful to the Energy Research and Development Institute – Nakornping, Chiang Mai University, especially, to the collaboration of Assist. Prof. Pruk Aggarangsi for financial support in conducting field experiment. Simultaneously, the author wishes to express sincere thanks to the Center of Agricultural Resource System Research and to the Department of Animal and Aquatic Sciences, Faculty of Agriculture, Chiang Mai University, for providing instruments and experimental site.

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