Exploring the Use of Inorganic Nitrogen Fertilizer at Different Levels to Improve the Yield, Nutrient Content and *In-vitro* Gas Production of Immature Kenaf (*Hibiscus cannabinus*)

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Received: 23 March 2023
Accepted: 24 June 2023

Abstract

Kenaf (*Hibiscus cannabinus* L.) is a herbaceous plant in the family of Malvaceae, native to Africa and India and primarily produced for its fibre. It has been suggested that the immature kenaf is suitable to be used as fodder for ruminants. The crude protein content of the kenaf depends on the soil nutrient levels and other environmental and management factors. The study aims to evaluate the use of inorganic nitrogen fertilizer at different levels on the plant height, yield, nutrient content and *in vitro* gas production of immature kenaf. There were five different levels of additional inorganic nitrogen fertilizer (urea: 0, 20, 40, 60, 80 kg/ha) and were given to Kenaf V36 which was initially fertilized with NPK (15:15:15). Kenaf V36 seeds were obtained from National Kenaf and Tobacco Board and used as planting materials. The kenaf plants were watered twice daily and fertilized with inorganic fertilizer on day 10 and 20 after planting. On day 35 after planting, the dry matter yield (DM yield), plant height, proximate analysis, Neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent lignin (ADL) and *in vitro* gas production were determined. The result shows that the DM yield ranged from 0.55 to 0.62 tonnes per hectare. There was a significant difference ($P<0.05$) in CP, NDF and ash of kenaf fertilized with different levels of inorganic nitrogen fertilizer. There are highly significant differences ($P<0.01$) in plant height, DM content and gas production of kenaf fertilized with different levels of inorganic fertilizer application of immature kenaf fertilised with 40 kg/ha and harvested on day 35 post-planting was observed to reach the optimum performance and suitable as ruminant feed.

Keywords: *Hibiscus cannabinus,* inorganic fertilizer, Ruminant feed, *in vitro* gas production

Introduction

Kenaf (*Hibiscus cannabinus* L.) is a herbaceous plant in the family of Malvaceae, native to Africa and India. Kenaf is primarily produced for its fibre which consists of a non-wood lignocellulose fibre crop and is used to produce various commercial fibre-based products (Saba *et al.,* 2015). The nutrient composition of kenaf can be influenced by many factors and one of the important factors is plant maturity. The crude protein content in leaves could reach up to 20% during their immature stage has been reported (Chantiratikul *et al.,* 2009), however, as the plant ageing, the crude protein content in the stems and leaves decreases. It has been suggested that the immature kenaf is suitable to be used as fodder for ruminants

(Chantiratikul *et al.*, 2009; Najid & Ismawaty, 2001). The immature kenaf with crude protein content can be used as a forage source for ruminants and its response to the soil nutrient levels, environmental and management factors (Alexopoulou *et al.*, 2013; Olanipekun *et al.*, 2020). With better nutrient content and good results of *in vitro* gas production, it can be used as an indicator of the suitability of forages for ruminants. The study aims to evaluate the use of inorganic nitrogen fertilizer at different levels on the plant height, yield, nutrient content and *in-vitro* gas production of immature kenaf.

Materials and methods

A total of 50 kenaf plants were selected based on condition and height after 7 days post propagation at field 2, Faculty of Agriculture, Universiti Putra Malaysia (UPM), Serdang Selangor. Each plant was planted in a medium size polyethene bag of 14 cm (height) x 14 cm (width) filled with mixtures of soil, compost and sand (3:2:1 ratio) and placed under a white netting box. The density of the plant that was used is 100,000 plants/ha. On days 10 and 20 after planting the plants were divided into five different treatments at random to receive additional inorganic nitrogen fertilizer (urea) either at 0, 20, 40, 60 or 80 kg/ha which initially received NPK at (15:15:15). All kenaf plants were watered twice daily.

The height of the plant was measured using measuring tape from the plant base to the tip of the highest leaf on days 7, 21 and 35 after planting.

The kenaf was harvested manually at 30 cm above the ground on day 35 after planting. The samples were determined for dry matter, crude protein (AOAC, 2000), neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent lignin (ADL) (Van Soest *et al.*, 1991) and i*n vitro* gas production (Menke & Steingass, 1988).

Statistical analysis

Data collected were analysed by analysis of variance (ANOVA) using the SAS package. Tukey's range test was used to indicate the differences between the treatment means.

Results and discussion

Height and the dry matter yield of kenaf

The kenaf height on day 35 after planting shows an increasing trend with an increasing level of inorganic nitrogen fertilizer (Figure 1). There were significant differences ($P<0.01$) in the height of kenaf fertilized with different levels of inorganic nitrogen fertilizer. Kenaf with T80 on day 35 after planting resulted in being 15.7 cm taller than T0.

The dry matter yield of kenaf harvested on day 35 after planting shows an increasing trend with an increasing level of inorganic nitrogen fertilizer (Figure 2). The mean dry matter yield ranged from 0.55 to 0.62 t/ha with the highest yield of kenaf fertilized at 80kg/ha (T80). The trendline for the dry yield is polynomial with an equation $y= -0.0029x^2 + 0.0348x + 0.5222$ with the production of 522.9 kg/ha, 523.6 kg/ha, 524.3 kg/ha and 525.0 kg/ha of DM kenaf when the plants received 20, 40, 60 and 80 kg/ha inorganic fertilizer, respectively.

Additional inorganic fertilizers of more than 40 kg/ha only are able to increase the DM yield of kenaf by 100 kg/ha. Kenaf exhibits lower dry matter yield than typical forages like Napier grass. For instance, four cultivars of Naper grass harvested at 4 weeks displayed yields of 0.79 – 1.08 tonnes/ha/cut (Zailan *et al.*, 2016). However, employing 150 kg N, 60 kg P, and 100 kg K/ha/year led to 2 -3 times higher dry matter yield at 2.90 – 3.73 tonnes/ha when harvested at 35 days (Haryani *et al.*, 2018

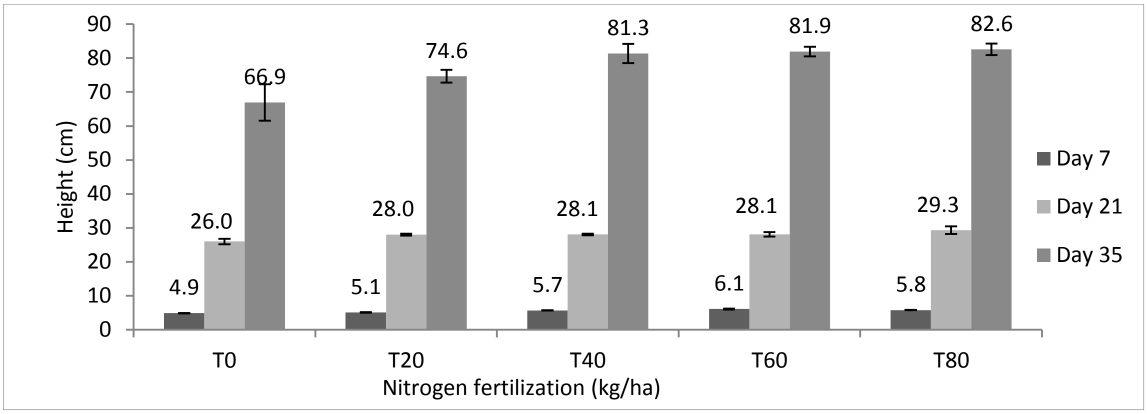

Figure 1. Height of plants (cm ± SE) of kenaf fertilized with an inorganic nitrogen fertilizer at different levels on 7, 14 and 35 days after planting.

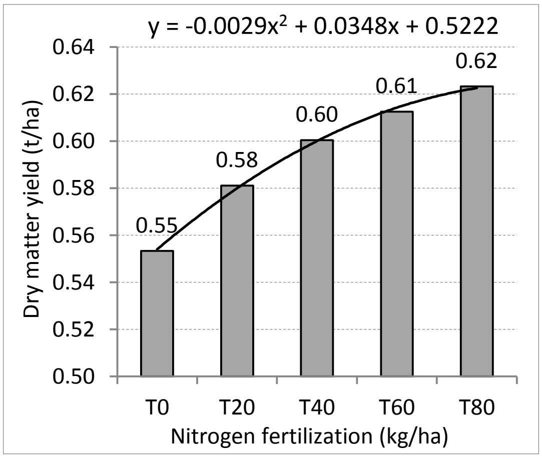

Figure 2. The dry matter yield (t/ha) of kenaf fertilized with an inorganic nitrogen fertilizer at different levels harvested on day 35 after planting.

Dry matter yield rose higher with higher nitrogen levels, consistent with Oliveira et al. (2014) who found increased Marundu grass yield due to N application. However, N application could exhibit a threshold effect on crop growth and yield, potentially hindering improvement. In this study, the maximum nitrogen rate (80 kg/ha) likely remained below this threshold. The dry matter yield of less than 1 tonne/ha at the age of 35 days (five weeks) was consistent with the reports by Wong *et al.* (2008). However, the plant population used in this study was 100,000 plants/ha differs from Wong *et al.* (2008) which involves 800, 000 plants/ha.

It has been recommended to farmers in Indonesia to increase fibre yield and improve its quality (Salih, 2022). However the information on immature kenaf yields as forages is limited since most of the work emphasized maximizing stalk yields as the source of the bark (bast) and core fibres (Phillips *et al.*, 1999; Dayang Safinah & Abdul Razak, 2014).

Nutrient composition of kenaf

The result of dry matter content in whole kenaf plants shows significant differences (P<0.01) with different levels of inorganic nitrogen fertilizer. The percentage of the dry matter content of kenaf decreased with an increasing inorganic fertilizer applied (Figure 3).

The CP content in whole kenaf plants was significantly different (P<0.05) with different levels of inorganic nitrogen fertilizer. The CP content was improved with increasing nitrogen fertilizer (Table 1). The highest crude protein content was 20.6% in T80 kenaf. However, the mean differences started to decline for T40.

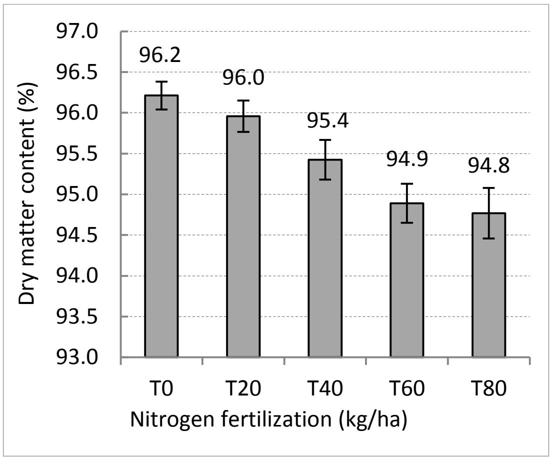

Figure 3. The dry matter content (%) of kenaf plants (mean ± SE) fertilized with an inorganic nitrogen fertilizer at different levels harvested on day 35 after planting

The increase in protein content due to nitrogen fertilization aligns with Mahmud *et al.* (2003). The higher fertilizer levels likely boost amino acid production, leading to increased crude protein (CP). Furthermore, elevated nitrogen application can enhance nitrogen absorption by plants, further elevating crude protein content.

Wong *et al.* (2008) stated that forage from 4 to 5-week-old kenaf had a crude protein (CP) ranging from 27 to 29%, whereas thin this study the data was collected on day 35 and it ranges from 18 to 20%. The discrepancy among the different reports could be due to differences in other contributing factors such as plant variety, light levels and environment. As an example, the colour of the netting box during the establishment stage to avoid pests and insects will reduce the light levels and cause the kenaf variety v36 to develop more stems than leaves (Widmer, 2001). Other studies are more focused on kenaf fibre production by increasing the stalk yield (Phillips *et al.,* 1999). The crude protein obtained was higher compared to most tropical roughages, and comparable to legumes. The range of CP content of seven tropical grasses and five legumes ranged from 6.6 – 16.2% and 18.3 – 29.1%, respectively (Evitayani *et al.*, 2004).

Increased application of inorganic nitrogen fertilizer led to a reduction in NDF fractions, while ADF and ADL fractions remained unaffected (P>0.05). Analysis of kenaf's NDF value at varying levels of inorganic nitrogen fertilizer demonstrated a decreasing trend, with significant differences (P<0.05) observed among fertilizer levels. NDF percentage ranged from 63.34% to 49.33% with the lowest concentration of 49.33% occurring at 8-kg/ha nitrogen fertilization (T80) (Table 4). Nitrogen fertilization can potentially decrease NDF concentration in plants by promoting the growth of new tissue with lower structural carbohydrate levels in dry matter, and this outcome is influenced by climate conditions (Leita *et al.*, 2021).

At 40 days of planting, Phillips *et al.* (1999) reported that stalk NDF content was significantly larger than leaf NDF and ranged from 52 to 63%, and increased (P<0.01) as the harvest date was delayed. McDonald *et al.* (1991) reported that fibre content was decreased by the application of nitrogen fertilizer. Ball *et al.* (2001) reported that Neutral detergent fibre (NDF) consists of the total fibre in the forage and relates to forage intake by the ruminant. The decrease in NDF content may affect the nutritional value of the forage as it reduces the forage intake by the ruminant. The NDF concentration in our study surpassed the suggested minimum fibre range of 25 – 28% for maintaining proper ruminal function (NRC, 1989). Kenaf's NDF levels are relatively lower compared to other common forage plants, like Napier grass (62 – 73% at 4 weeks of age) (Zailan *et al.*, 2016) and guinea grass (90% at 5 weeks of age) (Jusoh *et al.*, 2014).

Table 1. The mean percentage of nutrient composition (± SE) of kenaf fertilized with an inorganic nitrogen fertilizer at different levels harvested on day 35 after planting

Parameters	Different levels of inorganic fertilizer				
	T0	T20	T40	T60	T80
CP (%)	18.9±0.30[b]	19.5±0.34[ab]	20.3±0.19[ab]	20.5±0.28[a]	20.6±0.37[a]
NDF (%)	63.3±2.37[a]	51.5±4.48[ab]	50.4±4.21[ab]	49.7±0.86[ab]	49.3±0.37[b]
ADF (%)	29.2±2.80[a]	27.3±2.72[a]	27.0±1.79[a]	26.6±1.16[a]	26.0±1.28[a]
ADL (%)	36.8±7.66[a]	33.3±3.23[a]	28.5±2.34[a]	27.6±7.92[a]	25.9±1.77[a]
Ash (%)	10.3±0.18[a]	9.8±0.10[ab]	8.6±0.35 [b]	8.7±0.49[b]	9.2±0.21[ab]
OM (%)	89.7±0.18[b]	90.2±0.10[ab]	91.4±0.35 [a]	91.3±0.49[a]	90.8±0.21[ab]

[a,b,] Means values with different superscripts within the same row are significantly different (P<0.05);
T0: 0kg/ha; T20: 20kg/ha; T40: 40kg/ha; T60: 60kg/ha; T80: 80kg/ha addition of inorganic fertilizer (urea).

The ADF content of kenaf, fertilized with varying levels of inorganic nitrogen, showed no significant difference (P>0.05). Yet, Phillip *et al.* (1999) found that stalk ADF content (39 – 43%) exceeded leaf ADF content (P<0.01) and increased with delayed harvest (P<0.07). Similarly, ADL content in kenaf did not significantly differ among treatments (P>0.05). Nevertheless, kenaf exhibited relatively high ADL levels (26 – 37%), comparable to other lignocellulosic biomass like empty fruit bunch, 36% ADL (Nur-Nazratul *et al.,* 2021) and oil palm fronds, 25% ADL (Chanjula *et al.*, 2017).

There were significant differences (P<0.05) in the ash content (%) of whole kenaf with different levels of inorganic nitrogen fertilizer (Table 4) and the value fluctuated with an increasing nitrogen fertilizer applied. Ash content of kenaf with 40 kg/ha (T40) decreases by 2% compared with 0 kg/ha (T0), further higher in T80 by 0.5% compared with T60.

In vitro gas production

The gas produced through *in vitro* gas production technique at 24 hours incubation period was used to estimate the digestibility of kenaf (Figure 4). Nitrogen fertilization significantly affected the (P<0.01) *in vitro* digestibility of kenaf. The gas production increases with increasing nitrogen fertilizer levels application. The highest gas produced was 31.66 ml for kenaf fertilized at 80 kg/ha (T80). Kenaf's gas production at 24 hours was slightly greater compared to *B. decumbens* (24.0 ml) and similar to *P. maximum* (31.5 ml), *P purpuphoides* (34.5 ml), and *P. purpureum* (36.1 ml) (Evitayani *et al.*, 2004).

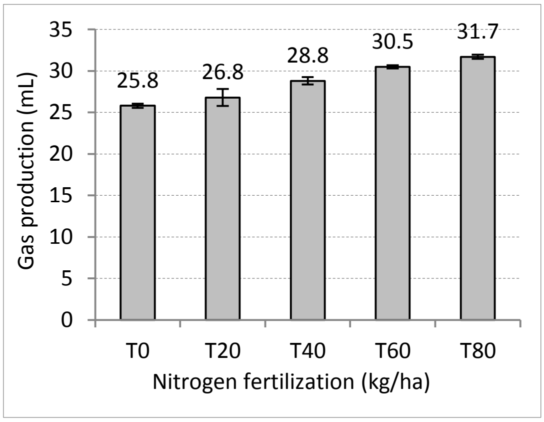

Figure 4. Gas production at 24 hours incubation period (ml ± SE) of kenaf fertilized with an inorganic nitrogen fertilizer at different levels harvested on day 35 after planting

The result observed in this research was in line with Cox and Cherney (2001) who reported that increasing N fertilization linearly increased *in vitro* true digestibility (IVTD) but the effects on NDF concentration were inconsistent. The increase in nitrogen fertilization significantly increases *in vitro* digestibility of kenaf. In addition, there was a relationship observed between crude protein content and *in-vitro gas* production of kenaf fertilized with different levels of nitrogen fertilizer. There was an increase in the digestibility of kenaf with an increase in crude protein content as it can be related to what Fonsca *et al.* (2000) reported that protein content in corn forage has a positive relationship with palatability and digestibility. Oh *et al.* (2018), reported that no negative effects of kenaf on growth performance and could be used as a substitute for rice straw in ruminants.

Conclusion

The application of inorganic nitrogen fertilizer increased the DM yield, and height of the plant, increased the crude protein content and decreased the fibre content subsequently improving *in-vitro* gas production of immature kenaf. It immature kenaf fertilised with 40 kg/ha and harvested on day 35 post-planting was observed to reach the optimum performance and be suitable as ruminant feed.

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