

Antagonistic Effects of Fertilizer on Photochemical Efficiency of *Hibiscus cannabinus* L. (Kenaf) Planted on Beach Ridges Interspersed with Swales Soil

¹Mohd-Hazimy Yusoff, ^{1,2}Hazandy Abdul-Hamid, ^{1,2}Arifin Abdu,

¹Abdul-Latib Senin and ³W.A.R. Wan-Mohd-Nazri

¹Department of Forest Production, Faculty of Forestry,

²Laboratory of Sustainable Bioresource Management,

Institute of Tropical Forestry and Forest Products,

University Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia

³Faculty of Applied Science, University Technology MARA, 26400 Jengka, Pahang, Malaysia

Abstract: Problem statement: *Hibiscus cannabinus* L. or Kenaf is a highly productive, warm-seasonal C₃ annual crop and is one of the potential candidates to substitute kenaf fiber as raw product for pulp and paper production. It survives well on less fertile soils including those of Beach Ridges Interspersed with Swales (BRIS) soil. **Approach:** The objective of this study was to determine the effect of fertilizer on photochemical efficiency of *H. cannabinus* L. planted on BRIS soil using chlorophyll fluorescence technique. NPK with the ratio of 12:12:36 + 2MgO + TE (Trace-elements are mineral substances that act as an essential nutrients at a very low concentration) and the micronutrient of the trace elements compositions are Boron, Copper, Iron, Manganese, Molybdenum and Zinc were used for fertilizer treatment. Three levels of fertilizer treatments were applied in three plots; high (1960 kg plot⁻¹), medium (1260 kg plot⁻¹) and low (700 kg plot⁻¹) respectively each plot comprising 106, 000 plants and were planted in 20 lines. Photochemical efficiency in terms of F_v/F_m ratio was determined under water deficit condition, fertilizer toxicity and interaction of both factors.

Results: Contrasting trends for photochemical parameters were observed between different fertilizer levels where antagonistic effects were found between the three fertilizer treatments. The mean values ranged for minimal fluorescence (F_o) were from 256.27-273.06, maximal fluorescence (F_m) were from 970-1110.5, variable fluorescence (F_v) were from 705-854.23 and the ratio of F_v/F_m (photochemical efficiency) were from 0.72-0.77, respectively. Hitherto, for stress level, percentage for the low fertilizer level was 23.5% as compared to medium with 26.8 and 27.6% for high fertilizer level.

Conclusion: The present study revealed that an appropriate amount of fertilizer is required to maximize the yield production cost effectively.

Key words: Antagonistic effects, photochemical efficiency, *Hibiscus cannabinus* L., chlorophyll fluorescence, BRIS soil, fertilizer treatments, significantly different, maximal fluorescence, raw product, plant stress, fertilizer level

INTRODUCTION

Hibiscus cannabinus L. is belong to the family of hibiscus (Malvaceae) is one of the most potential crops in terms of environmental performance related to carbon storage capacity as a sustainable 'sink' for atmospheric carbon dioxide and as substitute of non-renewable resources. As an annual warm-seasonal fiber crop; it is C₃ photosynthetic pathway, achieving high biomass yield in Greece (Danalatos and Archontoulis, 2004). The plant has been utilized in the cordage and

sacking manufacture as substitute to jute and, more recently, as raw product for the production paper pulp. The species is grown in the Asia-Pacific region, with India, China, Bangladesh, producing the largest portion of the world's supplies. It was first introduced in the early 70's in Malaysia and become popular in the late 90's as an alternative and cheaper source of material for producing panel products such as fiberboard and particleboard. Stems of kenaf plants consist of an inner thick core of short woody fibers 0.5-1.0 mm long and of an external bark with fibers of 3.0-4.0 mm long. The

Corresponding Author: Hazandy Abdul-Hamid, Laboratory of Sustainable Bioresource Management, Institute of Tropical Forestry and Forest Products, University Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia Tel: +603-89467585 Fax: +603-89432514

bast fibres are of better quality than the core fibres and both, can be utilized in various blends for the production of pulp (Petrini *et al.*, 1994).

According to Sellers *et al.* (1993), Kenaf also has a high potential as a raw material with low density panels suitable for sound absorption and thermal resistance. Being fast growing and multipurpose, Kenaf is also a good carbon sequester and can improve soil fertility. Being a valuable agronomic crop for a number of commodities, thus the effects of plant population, soil fertility, location and cultivar on Kenaf yields have to be studied (Bhangoo *et al.*, 1986; Ching *et al.*, 1992; Webber, 1993a; 1993b). Crop species in arid areas adapt to their environment through different ecophysiological responses such as regulating productivity through gas exchange and carbon assimilation, reducing leaf water potential and having sensitive stomatal control and regulating the net photosynthetic rate and photosystem II efficiency under high light and temperature stress (Flexas and Medrano, 2002; Liu *et al.*, 2003). Kenaf can reach 4 m tall after one rotation (approximately 4 months) on normal soil, rich in nutrient-water content (Le Mahieu *et al.*, 2003). Kenaf variety needed suitable environmental conditions to predict accurately what and how much of a Kenaf commodity can be produced at a given site and geographic location (Ching *et al.*, 1992; Webber, 1993b). It is highly adaptable in broad ranges of soil types from fertilizer to non fertile including the Beach Ridges Interspersed with Swales (BRIS) soil which is poor in water holding capacity and nutrient availability.

In Malaysia, the total area of BRIS soils spread along the east coast of the Peninsular and the coastal area of Sabah cover a total area of 200,000 ha with 155,400 ha in Peninsular Malaysia and 40,400 ha in Sabah respectively. BRIS soils contain 82-99% sand particles, mainly quartz, with low Cation Exchange Capacity (CEC) of 9.53 cmolc kg⁻¹ with pH 4.3-4.4. The soil structure contains mostly of sand particles which has low water-holding capacity (Hamzah *et al.*, 2009; Ahmadpour *et al.*, 2010; Heryati *et al.*, 2011a; 2011b; Abdu *et al.*, 2011) and poor in nutrient. It is well known that water deficit affects every aspect of plant growth, modifying anatomy, morphology, physiology and biochemistry (Hsaio, 1973; Enu-Kwesi *et al.*, 1986).

Recently, it was found to show promising growth with physiological potential on this type of soils treated with different levels of fertilizer (Abdul-Hamid *et al.*, 2009). The increased concentrations of fertilizer application concomitantly accelerate and improve soil nutrients availability for plant growth. With this assumption, plant will receives nutrient

sufficiently and could adapt well after improvement poor soil and also, with higher application rate of fertilizer cause reaction of photochemical efficiency to increase. Thus, this research was carried out to determine the effect of fertilizer on photochemical efficiency of Kenaf planted on BRIS soil.

MATERIALS AND METHODS

Study site: Study was conducted on BRIS soil nearby (how far from the seashore) beach area in Setiu, Terengganu. The location at latitude of 5°36'59.42"N, longitude of 102°44'18.04"E and is 200 m above sea level. The mean relative humidity of the study site is about 7-90%. Mean minimum and maximum temperature ranged from 22-37°C respectively. The annual rainfalls in Setiu fluctuated from the lowest at 2990 mm to the highest of 4003 mm per year. This study was conducted during the dry season.

Plant materials: One variety of *Hibiscus cannabinus* L. i.e. V 36 was used in this experiment and planted on BRIS soils in Setiu, Terengganu. The V36 variety is currently the production variety and chosen by the National Kenaf and Tobacco Board and was planted on 14th February 2008. It was planted in three different plots with different levels of fertilizers. Each plot comprised of 106,000 plants per plot where these plants were planted in 20 lines using seeder machine.

Experimental design: Plant samples were assigned randomly adapting the quadrat sampling within the plots. In each experiment, 15 samples per treatments were used. Fertilizer was sprayed for 16 seconds per liter per plot per day. The fertilizer material used is NPK with the ratio of 12:12:36 + 2MgO + TE where the micronutrient compositions included were Boron, Copper, Iron, Manganese, Molybdenum and Zinc. The treatments were divided into three different fertilizer levels namely high (1960 kg plot⁻¹), medium (1260 kg plot⁻¹) and low (700 kg plot⁻¹) respectively. The treatment plots area is one acre.

Photochemical efficiency measurement: Photochemical efficiency (F_v/F_m) has been widely used and accepted over the years as an appropriate indication of the maximum efficiency of Photosystem II. It is an effective and sensitive parameter which may be used as an indicator to sample stress. For each sample, three fully expanded leaves were selected from randomly adapting the quadrat sampling. The leaves selected were maintained in darkness for 5-10 min before taking the data using clips provided. The maximal intensity of

the light source, providing an irradiance saturating pulse of 3000 $\mu\text{mol photons m}^{-2} \text{sec}^{-1}$ were applied using Plant Efficiency Analyzer, Handy PEA (Hansatech Instruments Ltd. Norfolk, UK). The measurements were conducted during the March in dry season. Chlorophyll fluorescence parameters such as minimal Fluorescence (F_o), maximal Fluorescence (F_m), variable Fluorescence ($F_v = F_m - F_o$), maximal quantum yield of Photosystem (PS) II photochemistry (F_v/F_m) and area above the fluorescence curve between F_o and F_m were observed using the software supplied by the Plant Efficiency Analyzer manufacturer.

Data analysis: Data of chlorophyll fluorescence and growth performance of Kenaf were Analyzed using Analysis Of Variance (ANOVA) (SPSS ver 16.0) to estimate the treatment variations while Duncan's Multiple Range Test were used to detect the significant grouping among the treatments.

RESULTS

Photochemical efficiency of different fertilizer application level on *Hibiscus cannabinus* L.: Figure 1 shows the typical Chl a polyphasic fluorescence rise for each fertilizer application level. The amplitude responses were found similar for medium and high fertilizer applications but low fertilizer levels showed otherwise i.e., fluorescence increased through Chl a fluorescence transient (OJIP) when it achieved optimum (P).

There were significant differences for all chlorophyll fluorescence measured between all treatments (Table 1). The value for F_m showed high significant difference at $p \leq 0.001$. In addition, F_o , F_v and F_v/F_m also showed significant differences at $p \leq 0.05$.

In Fig. 2A, mean values of F_o for photochemical efficiency parameter between treatments indicated that the medium fertilizer level was the highest than the ones shown for the other two fertilizer levels. On the other hand, the mean value of F_m of low fertilizer level was found to be significantly different compared to the ones recorded for medium and high fertilizer levels which were not significantly different (Fig. 2B). After calculating the F_v , we found that the mean value of F_v from low fertilizer level was higher than the ones shown for the other two fertilizer levels (Fig. 2C). Meanwhile, there was no significant difference found between the medium and the high fertilizer levels for F_v , F_m and F_v/F_m . The photochemical efficiency of Photosystem II (PSII) was estimated based on the F_v/F_m ratio (Fig 2D). The mean value of F_v/F_m of low fertilizer level was found significantly higher than the medium and the high fertilizer levels.

Table 1: ANOVA of chlorophyll fluorescence parameters between different fertilizer application levels

Parameters	Df	Mean square	F
F_o	2	2151.330	2.629*
F_m	2	146020.700	7.509**
F_v	2	168008.940	8.955*
F_v/F_m	2	0.014	8.992*

Note: * Indicate level of significance; * significant at 0.05, ** highly significant at 0.001

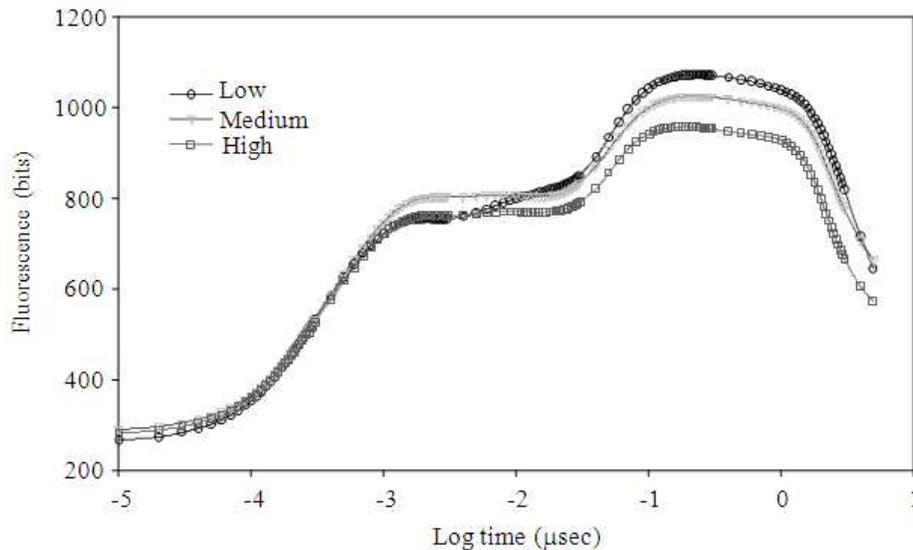


Fig. 1: The typical Chl a polyphasic fluorescence rise for the effects of different fertilizer application level

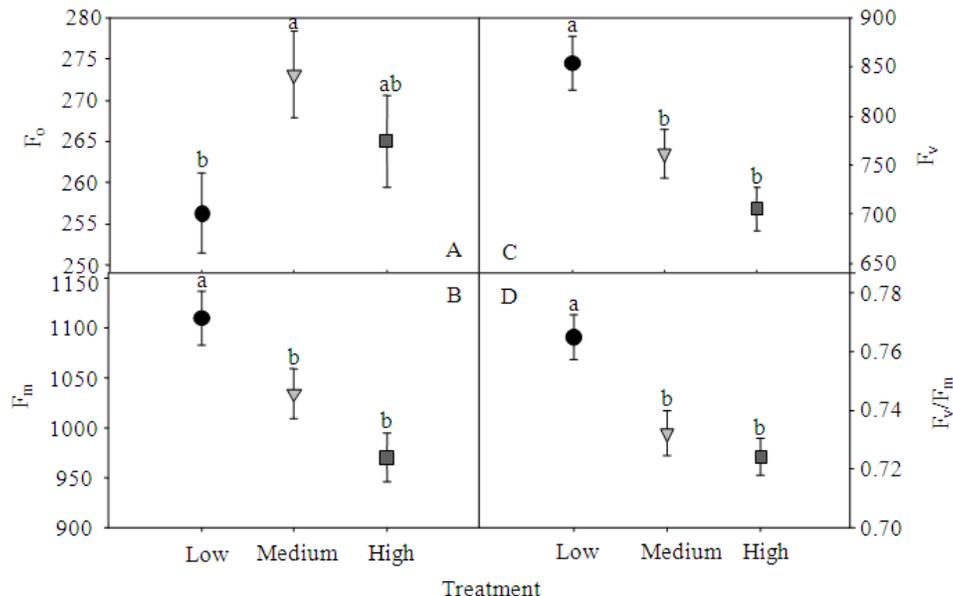


Fig. 2: The mean values for F₀ (A), F_m (B), F_v (C) and F_v/F_m (D) of photochemical efficiency for different fertilizer treatments. *Different alphabet indicates significant differences between treatments at p < 0.05

DISCUSSION

Chlorophyll fluorescence is an indicator to determine the effects of environmental stresses on plants since photosynthesis is often reduced in plants experiencing adverse conditions, such as water deficit, temperature, nutrient deficiency, polluting agents and attack by pathogens. Chlorophyll fluorescence was used to evaluate the effect of different fertilizer application on photochemical efficiency of Kenaf planted in BRIS soil. BRIS soil being sandy in nature contains mostly sand particles with poor water-holding capacity and poor in nutrient availability and low Cation Exchange Capacity (CEC). In term of plant physiology, the nutrient content utilized by plant will increase along with additional fertilizer. For instance there will be increase in the photosynthetic rates and photochemical efficiency when there is sufficient requirement of nitrogen. According to Cruz et al. 2003, chlorophyll concentration, chlorophyll a/b ratio, stomatal conductance, photorespiration rate and net carbon assimilation rate (on an area and a mass basis, but not on a chlorophyll basis) all decreased in low Nitrogen (N) plants as compared with high Nitrogen (N) ones. The N deficiency decreases the quantum yield of Photosystem II (PS II) electron transport and the maximum PS II photochemical efficiency suggesting that N deficiency may affect the PS II photochemistry. However, for foliar application of inorganic nutrients

comprising N, can be additional to insufficient as well as normal root supply of nutrients and could resulted in enhanced N uptake and assimilation (Peuke *et al.*, 1998).

Percentages of photochemical reaction process on plants found in this study, for low, medium and high fertilizer application were 76.5% (e.g., calculation: 0.765×100), 73.2 and 72.4% respectively. In terms of stress level, percentage for the low fertilizer level is 23.5% as compared to 26.8 and 27.6% for medium and high fertilizer level respectively. The F₀ is at its lowest when given low fertilizer level. This result indicated exhibited that fluorescence emitted from leaves of those given low fertilizer has fast rate in reducing the photochemistry process which simultaneously receive more light intensity reaction.

Initially, we hypothesized that by increasing level of fertilizer induction to the soil will increase nutrient content which than positively affect the photochemical process in plants. Antagonistically, chlorophyll fluorescence parameters were found to decrease with increasing of fertilizer applications. Higher application of fertilizer level resulted in lower F_v/F_m, F_m and F_v values compared to the low application of fertilizer level. It might be due to the effect of higher level of fertilizer concentration in plants that resulted in decreasing photochemical efficiency. Plant stress is also caused by watering irrigation problem and high temperature as data were collected in dry season. The

plants might not get adequate water at that time. Thus, water deficit can increase fertilizer concentration.

Plant response is dependent on species, fertilizer form, concentration and frequency of application, as well as the stage of plant growth (Eddy, 2000). High concentration of fertilizer in plants in relation with water deficit and heat shock can affect the light harvesting systems, the flow through of electron transport chain, Nicotinamide Adenine Dinucleotide Phosphate (NADPH) and Adenosine Triphosphate (ATP) synthesis, photosynthetic carbon reduction cycle in the chloroplast and the utilization of assimilates. On the other hand, the chlorophyll fluorescence of photosystem II increases under both water and temperature stresses, due to imperfect energy dissipation. This, in turn, makes the photosynthetic efficiency decrease to a higher degree when both stress conditions are combined together. Water deficit also causes stomatal closure which eventually, reduces the transpiration rate and affecting heat dissipation. As a consequence of this, causes an increase in the foliar temperature which then leads to stomatal opening. In addition, temperature also affects the stability of photosystem II, as has been previously reported by Delatorre *et al.* (2008).

CONCLUSION

A contrasting result was found for photochemical efficiency with different level of fertilizer application treatments. Significant effects were observed between treatments for photochemical efficiency due to application of fertilizer which concomitantly increased the level of plant stress. Application of low fertilizer level exhibited a higher photosynthesis process than of medium and high levels. The present study revealed that an appropriate amount of fertilizer is required to maximize the yield production cost effectively.

ACKNOWLEDGEMENT

This research couldn't be really without handful funding from Research University Grant Scheme UPM/RUGS/91049. We are also in dept with those who were involved directly and indirectly with this project especially staff of the Faculty of Forestry, Institute of Tropical Forestry and Forest Products (INTROP) and National Kenaf and Tobacco Board (LKTN).

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