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Yield Response of Kenaf (*Hibiscus cannabinus* L.) to Different Rates of Charcoal and Nitrogen Fertilizer on Bris Soils in Malaysia

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Abstract: Kenaf (*Hibiscus cannabinus* L.) was recently introduced in Malaysia as a crop to substitute tobacco under the East Coast Economic Region (ECER) program. As tobacco is widely planted on BRIS soil, there are challenges in establishing kenaf cultivation in those areas due to BRIS soil poor chemical, physical and microbiological characteristics. Over the years, charcoal has been proved to significantly enhances soil properties and increase plant growth. Its' recalcitrant characteristics is appropriate for tropical soil organic matter management. A study was conducted in Kg. Saujana, Setiu, Terengganu (05° 61393' N, 102° 73928' E) to assess kenaf response to charcoal and different rate of N fertilizer cultivated on BRIS soil. Five rates of N fertilizer (F1: 0, F2: 200, F3: 400, F4: 600, F5: 800 kg/ha) and four rates of charcoal (C1:0, C2: 5000, C3: 10000, C4: 15000 kg/ha) with five replications were established with Factorial Randomized Complete Blocked Design (RCBD) on Rudua series soil. The results showed that the application of charcoal have significant effects on soil CEC and exchangeable cations, kenaf yield and weekly plant heights and leaves length. The treatment of 10 t/ha charcoal + 400 kg/ha N fertilizer is recommended for increasing kenaf yield production on BRIS soils.

Key words: Charcoal · BRIS soil · Kenaf · Fertilizer · Yield

INTRODUCTION

Kenaf *(Hibiscus cannabinus* L.) originated from east-central Africa and has the potential to become an industrial crop in Malaysia. This crop has been cultivated for food and fiber, fiber strands, protein, oil and allelophatic chemical products [1]. Currently, there are about 200 farmers in Kelantan and Terengganu involved in the planting of kenaf for core, fiber and seed productions. Yield of kenaf ranges from 18 to 35 ton/ha/year [2] Under the Malaysian East Coast Economic Regions program, kenaf has been acknowledged as a substitute crop for tobacco.

BRIS (Beach Ridges Interspersed with Swales) soil covers an area of about 155, 400 ha in Peninsular Malaysia and 40, 400 ha in Sabah [3]. It is distributed along the east coast of Peninsular Malaysia, mainly along Kelantan, Terengganu and Pahang [4]. BRIS soils are marine deposits formed from continuous action of the sea waves. This soil composed largely of mineral quartz and is classified into several soil series such as Baging, Rudua, Rhu Tapai and Rusila [5]. BRIS soil composed of more than 95% sand with less than 3% silt and clay [3]. The soils pose a critical challenge for water and nutrient management due to the relatively low water holding and nutrient retention capacities [6]. They also experience excessive nutrient leaching, low organic matter content and high surface soil temperature [7].

The application of various organic matter amendments has proven to improve the fertility of BRIS soils [8]. Under humid tropical climate, these organic materials decomposed rapidly and must be added continuously. Charcoal is one of the potential organic amendments to this soil. Charcoal amendment to the infertile BRIS will stimulate the "Terra Preta" phenomenon which may induce sustainable management of fertilizer, reduce leaching of nutrient and improve crop yield [9]. The poor nature of BRIS soils and coupled with the yearly increase in fertilizer market price must be addressed. The ability of charcoal to retain nutrient and moisture [10] will hopefully improve the soil physical and chemical properties and consequently improve kenaf yield. This study intended to assess the effect of charcoal amendment and different rates of N fertilization on kenafs' growth and yield cultivated on sandy BRIS soil.

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MATERIALS AND METHODS

Study Location and Soil Amendment: A field experimental study was conducted in Kampung Saujana, Setiu, Terengganu, (05° 61393' N, 102° 73928' E) Malaysia. The area has a mean rainfall of 109 mm (from May until July 2010), mean temperature of 32°C and humidity of 68% [11]. Mean number of rainy day during planting period which was from May until July was 7 days per month. The BRIS soil was classified as Rudua series soil, with texture consist of 96.3% sand, 0.9% silt and 2.8% clay. The wood charcoal used in this study was crushed into particles of different sizes ranging between 2 mm to 2.5 mm. Charcoal was amended a week before planting (24 April 2010) by manually mixing them into the soil within the 20 cm depth.

Treatments and Experimental Design: There were four different rates of charcoal (C1:0, C2: 5000, C3: 10000, C4: 15000 kg/ha) and five different rates of N fertilizer (F1: 0, F2: 200, F3: 400, F4: 600, F5: 800 kg/ha) giving a total of 20 treatments (Table 2). Urea was used as source of nitrogen. Phosphorus and Potassium were applied by adding P_2O_5 and K_2O at the rate of 150 kg/ha and 60 kg/ha, respectively. The experimental design used was Factorial Randomized Complete Blocked Design (RCBD). Twenty different treatments were established in five replications on the newly cleared experimental site of Kampung Saujana. Each treatment was applied on the $2m^2$ plots (1m x 2m) forming an entire field area of $406m^2$.

Planting: The variety of kenaf used was V36, as recommended by Tobacco and Kenaf National Board Malaysia. Sowing was done manually on 1^{st} May 2010 with planting distance of 15cm between plants and 28cm between rows. The density of plant was approximately 180,000 plants/ha. Fertilizer was applied twice, at the 15^{th} and 30^{th} day after planting, respectively. Irrigation was carried out twice a day using sprinkler system with the water sourced from the nearby pond.

Soil Sampling, Growth and Yield Parameters: Soil samples were collected from the experimental site at the depth of 0-15 cm once before charcoal amendment and another on the harvesting day. The growth parameters measured were plant height, leaves number, leaves width and leaves length. Measuring was done at weekly interval. Yield parameter was obtained by conducting destructive sampling of kenaf. Fresh and dry biomasses of stems were recorded.

Samples Analysis: The collected samples were air-dried and sieved through a 2mm sieve. The sieved samples were analyzed for active (pH_w) and total pH (pH_{KCl}) with 1:2.5 soil to solution ratio using Coleman's pH meter. Total N content was determined using Kjehdahl method. Available P was determined using Bray and Kurtz no. 2 method. CEC and exchangeable bases (K, Ca and Mg) were determined using leaching method. Charcoal characterization was established to determine pH, total C, N, P, K, Ca, Mg and Cation Exchange Capacity (CEC). Total N was determined using Kjehdahl method, while available P was determined using Bray and Kurtz no.2 method. CEC and K, Ca, Mg were determined by using leaching method with NH_4AO_c at pH 7. All methods of analysis were based on procedures authorized in book of Soil Sampling and Methods of Analysis by Martin R. Carter, 1993 [12].

Data Analysis: All data were analyzed for difference in treatment means using Analyses of Variance (ANOVA). Significant treatments effects were detected using Duncan test.

RESULTS AND DISCUSSION

Charcoal Chemical Properties: The results of wood charcoal characteristics are presented in Table 1. Referring to the table, the pH_w value of wood charcoal is almost neutral, while the C content is very high, as expected from charred material. Exchangeable cations (K, Ca and Mg) values are very low, while values of CEC, total N and available P are low. These values proved that charcoal does not have the ability to function as fertilizer itself. It has to be applied together with additional nutrients in order to maximize its' functions. As reported in previous study, it needs to be combined together with organic matter (O.M) or fertilizer to work better [13]. However, chemical properties of charcoal varied base on several circumstances such as type of organic matter used for charring, the charring environment (e.g. temperature, air) and additions during charring process [10]. The source of charcoal material strongly affects content and availability of nutrients in the soil after amendment. The soil chemical properties after amendment will strongly be affected by source of charcoal amended. Base on the results, mangrove hardwood charcoal can be considered as one of the suitable types of amendment to BRIS soil of this area.

Table 1: Chemical properties of wood charcoal used

Charcoal	characterization							
					CEC	K	Ca	Mg
pH_w	pH_{KCl}	Total C (%)	Total N (g/kg)	Avail. P (mg/kg)	-------------------------------	(cmol$_c$/ kg)	-------------------------------	
6.63 - 6.85	4.50 - 4.84	90.5	5.64	6.88	6.44	0.09	0.03	0.04

Table 2: Details of treatment used and yield of kenaf obtained in this study

NUMBER	CODE	TREATMENT	YIELD (T/HA)
T1	C1F1	CONTROL	0.76
T2	C1F2	0 CHARCOAL + 200 KG/HA FERT	0.97
T3	C1F3	0 CHARCOAL + 400 KG/HA FERT	0.89
T4	C1F4	0 CHARCOAL + 600 KG/HA FERT	1.06
T5	C1F5	0 CHARCOAL + 800 KG/HA FERT	1.04
T6	C2F1	5000 KG/HA CHARCOAL + 0 FERT	1.14
T7	C2F2	5000 KG/HA CHARCOAL + 200 KG/HA FERT	1.17
T8	C2F3	5000 KG/HA CHARCOAL + 400 KG/HA FERT	1.20
T9	C2F4	5000 KG/HA CHARCOAL + 600 KG/HA FERT	1.27
T10	C2F5	5000 KG/HA CHARCOAL + 800 KG/HA FERT	1.31
T11	C3F1	10000 KG/HA CHARCOAL + 0 FERT	1.40
T12	C3F2	10000 KG/HA CHARCOAL + 200 KG/HA FERT	1.42
T13	C3F3	10000 KG/HA CHARCOAL + 400 KG/HA FERT	1.63
T14	C3F4	10000 KG/HA CHARCOAL + 600 KG/HA FERT	1.68
T15	C3F5	10000 KG/HA CHARCOAL + 800 KG/HA FERT	1.71
T16	C4F1	15000 KG/HA CHARCOAL + 0 FERT	1.79
T17	C4F2	15000 KG/HA CHARCOAL + 200 KG/HA FERT	1.87
T18	C4F3	15000 KG/HA CHARCOAL + 400 KG/HA FERT	2.46
T19	C4F4	15000 KG/HA CHARCOAL + 600 KG/HA FERT	2.08
T20	C4F5	15000 KG/HA CHARCOAL + 800 KG/HA FERT	3.58

Table 3: Mean square values of kenaf dry matter yield

Source of variation	d.f.	dry weight (tha^{-1})
Charcoal	3	36.29
Fertilizer	4	5.88
Block	4	0.19
CharcoalxFertilizer	12	2.18**
Error	76	0.17
Total	99	

* * p = 0.05 (Duncan test)

Kenaf dry matter yield: Data presented in Table 2 shows details of all treatments and yield of dry matter weight of plant. T20 produce highest yield with 3.58 t/ha kenaf, while control plot produced only 0.76 t/ha of dry matter yield.

Stem Dry Biomass: Base on ANOVA (Table 3), there were highly significant effect (p=0.05) of interaction found on dry matter weight of kenaf. Referring to Figure 1, correlation between kenaf dry matter weight and combination of charcoal and fertilizer resulted in r^2 value of 0.76. Dry matter yield increases as the rate of charcoal and fertilizer increased (Table 2). Application of 15 t ha^{-1} charcoal and 800 kg ha^{-1} yielded in highest value of kenaf dry matter weight which is 3.58t ha^{-1}. Yield obtained from control plot was the lowest. There was 50% increment in dry matter yield of 5 t ha^{-1} charcoal plus no fertilizer compared to control. The increment of 22.81% dry matter yield was observed from T11 compared to T6 and 27.85% increment obtained from comparison of T16 to T11. These results indicate that amendment of different charcoal rates alone did affect the productivity of kenaf. Base on correlation and mean square values of kenaf dry matter yield, application of charcoal plus fertilizer did have significant effects on kenaf yield. Plots that were treated with fertilizer impregnated charcoal produced higher yield

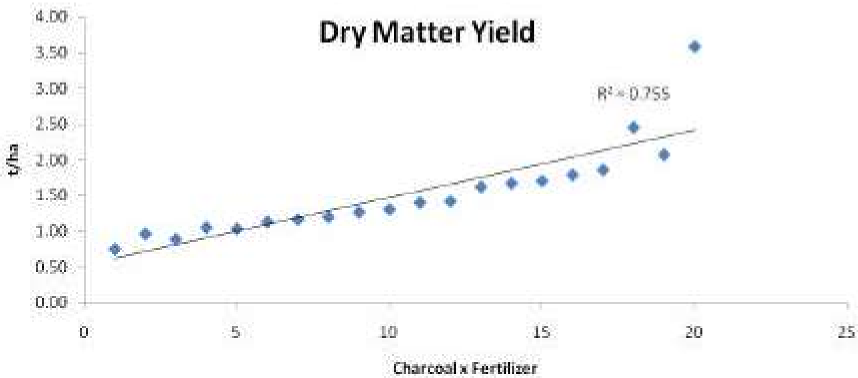

Fig. 1: Dry matter yield of kenaf

Table 4: Chemical properties of soil samples before and after amendment

Soil properties	Before amendment	After amendment
pH_w	6.27	6.39
pH_{total}	5.49	6.77
Total N (%)	0.14	2.99
Avail. P (mg/L)	0.56	7.91
CEC (cmol$_c$/kg)	0.02	0.18
K (cmol$_c$/kg)	0.06	0.30
Ca (cmol$_c$/kg)	0.08	0.23
Mg (cmol$_c$/kg)	0.05	0.80

Table 5: Mean square values of soil chemical properties after charcoal amendment

					CEC	K	Ca	Mg
Source of variation	d.f.	pHw	Total N (%)	Avail. P (g/kg)	-------------------------- cmol$_c$/ kg --------------------------------			
Charcoal	3	0.17	0.48	3.99	0.03	0.01	0.02	0.01
Fertilizer	4	0.09	0.54	2.02	0.28	0.01	0.08	0.01
Block	4	0.23	0.31	56.02**	0.01	0.01	0.01	0.01
CharcoalxFertilizer	12	0.11	0.58	1.85	0.26**	0.01	0.05**	0.01**
Error	76	0.11	0.6	4.34	0.01	0.01	0.01	0.01
Total	99							

* * p = 0.05 (Duncan test)

compared to control plots. This further confirms report by [14] that impregnation of fertilizer into charcoal enables major nutrients to be taken up by plant due in time. As BRIS soil suffers from extensive leaching problem, application of charcoal enable nutrients to be stored and used slowly by kenaf. The increment of kenaf dry matter yield is proportional to rates of charcoal applied. This result is similar to study conducted by [11], stating that charcoal amendment increases production of shoots and pod of yard-long bean cultivated on sandy soil. Steiner *et al*. [13] also reported that charcoal plus fertilizer improved plant growth and doubled grain production in comparison to the fertilizer without charcoal. Highest kenaf production was produced by plots treated with 15t ha^{-1} charcoal with 800 kg/ha fertilizer. On economic basis, the best rate that should be recommended to farmers is the combination of 10t ha^{-1} charcoal with 400 kg ha^{-1} fertilizer.

Soil Properties: Soil chemical properties before and after charcoal amendment: The data presented in Table 4 showed that pH_w of the initial soil samples was nearly neutral. The value of N, P, CEC and exchangeable cations were low, while there was more than 96% sand particles. The clay content is 2.8%, which denoted for the low CEC value of this soil. Data of soil properties after amendment were taken from data of soil treated with 15t ha^{-1} charcoal with no fertilizer. Referring to results in Table 3, there was an increased on pH_{total} value on soil sampled 64 days after planting. Similar trends were observed on values of total N, available P, CEC and exchangeable bases as well. The value of available P showed most obvious increment, which is 7.35 mg/kg. The increased in available P value is due to charcoal amendment. Table 5 shows mean square values of soil properties sampled on harvesting day. Highly significant effects (p = 0.05) were detected for CEC, exchangeable Ca and exchangeable Mg between treatments. It was also found that there is highly significant effect (p = 0.05) of block on available P values. There were no significant effects (p =0.05) observed between means of treatments on pH, total N and exchangeable K. Generally, BRIS soil has pH value that is more than 5 [14]. The result indicates that charcoal amendment to soil did increase the pH value and inadvertently confirms previous report stated that application of charcoal can increase the pH of humid tropics soils [10]. [11] reported that amendment of charcoal and manioc peel increased P availability and decreased soil acidity. There was also report that pH increase was larger in sandy soils than in clayey soils [16]. The improvement in CEC and exchangeable cations values after amendment was due to oxidation of charcoal as results of being exposed in the open air. Oxidation of charcoal leads to increasing formation of functional groups such as carboxyl and carbonyl [10]. The increasing numbers of these functional groups inadvertently promoted the cation exchange sites of charcoal. The amended charcoal has recalcitrant characteristic which allows it to last longer in the soil compared to other organic matters. Therefore, this amendment is reusable and allows farmers to reduce the cost of kenaf production due in time. As the formation of functional groups increase by time, the fertility of soil will also increase and this will optimize the production of kenaf.

CONCLUSION

BRIS soils are known for their poor physical and chemical properties. These soils are generally classified as unsuitable soils for agriculture. In Malaysia, there are about 2 million people depends on these poor soils for economic survival and the need for their improvement is important to address. Amending charcoal to these soils can be just one of the approaches to improve the soils. In this study, application of charcoal and different rates of N fertilizer did have significant effects (p = 0.05) on kenaf yield and chemical properties of BRIS soil (Rudua series). Considering the economic aspect of kenaf planting, the best treatment recommended would be the combination of 10t ha^{-1} charcoal with 400 kg ha^{-1} fertilizer in order to achieve optimum production. Amending hardwood charcoal into BRIS soil can be considered as one of the solutions towards sustainable agriculture practices in humid tropics regions. In country where the agricultural and forestry wastes are abundantly available, biochar is highly recommended and can be the best form of charcoal to amend poor sandy or acid soils. Works are currently ongoing on the use of biochar made from oil palm, rice husk and cocoa wastes as well as wood sawdust to amend poor acid soils in Malaysia.

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