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Full Length Research Paper

Effects of four depths of spodic horizon on root morphology and nutrient partitioning of kenaf grown on sandy beach ridge soil

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Kenaf has a potential to be an industrial crop in Malaysia. Hence, this study was conducted to investigate the root morphology, nutrient partitioning and yield of kenaf at various depths of spodic horizons in beach ridges interspersed with swales (BRIS) soil. Study was conducted at RhuTapai Research Station, Terengganu, Peninsular Malaysia. Kenaf was grown at L1 20 cm, L2 48 cm, L3 77 cm and L4 118 cm depth of spodic horizons. Texture was sandy with more than 90% sand. Soil pH ranged from 5.17 to 5.27, TC content ranged from 0.10 to 0.39% and TN content ranged from 0.01 to 0.03% at surface of the sandy soils at four locations with different depths of spodic horizons. Stem of kenaf was found higher in carbon and nitrogen content while bark was found in higher content of phosphorus grown at 20 cm depth of spodic horizon as compared to other depths of spodic horizons. No visual deformation was observed in roots of kenaf; generally kenaf root growth was stunted with the increase in depth of spodic horizons. Yield of kenaf decreased from 12, 19 and 21% at 48, 77 and 118 cm depths of spodic horizons as compared to 20 cm depth of spodic horizon, respectively. It is concluded that spodic horizon at 20 cm depth was not a problem for kenaf cultivation on sandy beach ridges soils.

Key words: Kenaf root morphology, nutrient content, yield, depth of spodic horizon, sandy beach ridges soils.

INTRODUCTION

Kenaf is a potential industrial crop in Malaysia (NEAC, 2001). The multiple use of kenaf offers a way to make a variety of products for paper industry and provide high quality composite materials for the interior portions of automotives (Alexopoulou et al., 2000; Ardente et al., 2008). Kenaf is grown in more than 20 countries of tropical and sub-tropical climate; capable of adapting to large varieties of climatic and soil conditions (Stricker et al., 2006; Liu, 2009) but knowledge about the dissemination of kenaf worldwide is still poorly documented.

Sandy beach ridges soils are the common landforms running parallel to most of the world's shorelines and widespread in all climatic zones on the globe. About 195,800 ha of sandy soils are running parallel to shoreline of Peninsular Malaysia (Esnan et al., 2004) which is locally known as beach ridges interspersed with swales (BRIS) soils (Shamshuddin, 1978). BRIS soil contains more than 90% sand, low in water holding capacity, low in nutrients and organic matter content (Zaki and Mustafa, 2005). BRIS soils in Malaysia are classified based on the occurrence of the spodic horizon at various depths known as spodosols while without spodic horizon known as entisols (soil survey staff, 2010). Some Spodosols are cemented to form an ortstein; some

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are loose with many roots, when the texture is slightly clayey the structure may be crumb and consistency fluffy (De Coninck, 1980).

Tobacco is the main crop of BRIS soil area but efforts have been taken by government anti-smoking campaign, to replace tobacco by other crops like kenaf. The farmers of BRIS soil area are with insufficient income and kenaf has a potential to increase the income of the farmers. Land scarcity is the main cause which diverts the research efforts to focus on the marginal productivity areas for large scale plantation of Kenaf in Peninsular Malaysia (Najib et al., 2004).

During heavy rain and irrigation, leaching of plant nutrients is common problem in top infertile A and bleached E horizons of BRIS soil (Wahab and Zain, 1991) while spodic horizon Bhs which is fertile (Roslan et al., 2010) and accumulated with active amorphous materials have tendency to curtail the movement of plant nutrients and water in soil profile.

The scrapping of top infertile horizons by farming community without knowing the affect of underlying spodic horizon on root morphology and yield of kenaf is impractical. Therefore, this study was conducted to investigate the root morphology, nutrient partitioning and yield of kenaf at various depths of spodic horizons in BRIS soil.

MATERIALS AND METHODS

Geographically study area is located at 5.304221°N 102.580316°E RhuTapai Research Station, Terengganu, Peninsular Malaysia. Before the cultivation of kenaf four locations were selected according to the depth of spodic horizon; L1 20, L2 48, L3 77 and L4 118 cm; locations L1 and L2 are classified as RhuTapai: sandy, siliceous, isohyperthermic arenic alorthods while L3 belongs to Rudua: sandy, siliceous, isohyperthermic arenic alorthods and site L4 belongs to Jambu: sandy, siliceous, isohyperthermic arenic alorthods (Soil Survey Staff, 2010).

Before the planting of kenaf soil, samples were collected at 0 to 15 cm depth air-dried, sieved through 2 mm sieve. Soil samples were analyzed for pH in 1:2.5 (w/v) ratio of soil to water with digital pH meter (Model 827 pH Lab Metrohm) P using Bray II method (Bray and Kurtz, 1945) Quickchem, FIA 8000 auto-analyzer (Lachat Instruments, Milwaukee, WI, USA).

Exchangeable Ca, Mg and K using NH_4OAC followed by Perkin Elemer 5010 atomic absorption spectrophotometer and cation exchange capacity using leaching method (Thomas, 1982). Soil texture was determined by pipette method (Gee and Bauder, 1986). Land was ploughed in May-2009 and chicken manure was applied at 10 ton ha^{-1} (Vimala et al., 1990). Certified seed of kenaf variety V-36 was planted at 1 to 2 cm deep with 25 to 30 cm inter-row and 10 to 20 cm within row space (Aminah et al., 2006).

Recommended doses of fertilizers 100 kg N ha^{-1}, 200 kg P ha^{-1} and 60 kg K ha^{-1} were applied in three splits (Othman et al., 2006). Management practices pre and post establishment of kenaf at all the operational areas were the same as recommended by Mat Daham et al. (2005). In middle of each plot area of 1 m^2 was harvested manually at ground level after 150 days of kenaf growth (Mambelli and Grandi, 1995; Liu and Labuschagne, 2009). The leaf and bark were separated from the stem of kenaf and each proportion was transferred to paper bags and dried in oven at 70°C for 72 h (Charles and Venita, 2002).

The dried plant samples were ground to pass through a 1 mm sieve and concentration of P, K, Ca and Mg were determined with dry-ashing method (Benton, 2001). In soil and plant samples TN was determined by Kjeldahl method (Bremner and Mulvaney, 1982) and TC was determined by dry combustion method (Nelson and Sommers, 1982) with LECO CR-412 carbon analyzer.

Root samples were taken with pin board method (Smith et al., 2000) and washed over a mesh sized 0.053 mm with tap water. Roots were transported to laboratory and cut into pieces according to the A4 size of transparent tray for scanning. Root length, volume and surface area were analyzed using root scanner with Winrhizo analysis software (Hamdy et al., 2007).

Before conducting the ANOVA, it was necessary to achieve the homogeneity of variance among the four locations with four depths of spodic horizons with the same experimental design and replications. Therefore, Bartlett's test (Glass et al., 1972) was applied to get the homogeneity of variance among four locations then ANOVA and mean separation were computed by Tukey (HSD) test with SAS statistical software.

RESULTS

Texture was sandy at surface of the soil with more than 90% sand; <2% silt and minimum content of clay were observed at four depths of spodic horizons (Table 1). It is evident that the soil chemical properties vary at four locations with different depths of spodic horizons. Soil pH ranged from 5.17 to 5.27, TC content ranged from 0.10 to 0.39% and TN content ranged from 0.01 to 0.03% at surface of the sandy soils at four depths of spodic horizons.

The highest value for phosphorus (4.53 ppm), potassium, magnesium and Cation exchange capacity were (0.14, 0.13, 2.91 cmol (+) kg^{-1} soil) observed at 20 cm depth of spodic horizon. The concentration of C, N, P, K, Ca and Mg in three kenaf proportion of leaf, bark and stem shown in (Table 2).

Carbon and nitrogen elements were found higher in bark and stem fractions of kenaf grown at the spodic depth of 20 cm as compared to other depths of spodic horizons. Spodic horizon depth of 20 cm was observed significantly higher in carbon (46%) (P=0.0004) and nitrogen (0.06%) (P=0.0008) in the stem as compared to other types of spodic horizons (Table 2).

Phosphorus was also found significantly higher (P=0.0053) in the bark of kenaf grown at the spodic depth of 20 cm as compared to other depths of spodic horizon (Table 2). Potassium content was not observed to be significantly different at all depths of spodic horizons in stem and bark fractions of kenaf.

Calcium percentage (0.14%) in bark of kenaf was significantly lower (P=0.004) at 118 cm depth of spodic horizon as compared to other depths of spodic horizons (Table 2). Calcium content was not significantly different in leaf of kenaf grown at 20, 48 and 77 cm depth of spodic horizon (Table 2). Magnesium percentage was not significantly different (P=0.19) in the bark of kenaf grown at all the depths of spodic horizon while at 118 cm depth of spodic horizon had lower (P=0.0024) content of magnesium in stem of kenaf as compared to other depths

Table 1. Physical and Chemical properties of soil at different depths of spodic horizons.

Depth of spodic	Sand	Silt	Clay	Texture	pH	T.C	T.N	P	K	Ca	Mg	CEC
cm	------------ % ------------			USDA	H_2O	------ % ------		ppm	------- Cmol(+)kg^{-1}Soil ------			
20	98.50	1.28	0.22	Sandy	5.17	0.33	0.03	4.53	0.14	0.27	0.13	2.91
48	98.46	1.48	0.06	Sandy	5.27	0.39	0.02	3.33	0.10	0.28	0.10	2.72
77	98.60	0.70	0.70	Sandy	5.24	0.11	0.01	1.77	0.09	0.12	0.09	1.63
118	98.16	0.94	0.90	Sandy	5.24	0.10	0.01	1.36	0.09	0.16	0.07	1.78

T.C=Total carbon; T.N= Total nitrogen; CEC=Cation exchange capacity.

Table 2. Nutrient content in Leaf, Bark and Stem fraction of kenaf at different depths of spodic horizon.

Kenaf proportions	Depth of spodic horizon (cm)			
	20	48	77	118
Carbon (%)				
Leaf	43.59^{a}	43.76^{a}	43.47^{ab}	43.24^{b}
Bark	42.67^{a}	42.41^{ab}	42.07^{b}	42.28^{ab}
Stem	46.09^{a}	45.13^{b}	44.89^{b}	44.67^{b}
Nitrogen (%)				
Leaf	0.49^{a}	0.46^{a}	0.44^{a}	0.42^{a}
Bark	0.08^{a}	0.06^{b}	0.06^{b}	0.07^{ab}
Stem	0.06^{a}	0.05^{b}	0.04^{b}	0.05^{b}
Phosphorus (%)				
Leaf	0.19^{a}	0.19^{a}	0.18^{a}	0.18^{a}
Bark	0.26^{a}	0.20^{b}	0.21^{b}	0.21^{b}
Stem	0.25^{a}	0.23a	0.21^{a}	0.19^{a}
Potassium (%)				
Leaf	2.25^{a}	2.04^{a}	1.80^{b}	1.35^{dc}
Bark	2.48^{a}	2.42^{a}	2.39^{a}	2.49^{a}
Stem	1.80^{a}	1.14^{a}	1.34^{a}	1.73^{a}
Calcium (%)				
Leaf	0.90^{a}	0.87^{ab}	0.76^{ab}	0.71^{b}
Bark	0.22^{a}	0.20^{ab}	0.18^{b}	0.14^{c}
Stem	0.05^{ab}	0.03^{b}	0.06^{a}	0.05^{ab}
Magnesium (%)				
Leaf	0.11^{a}	0.10^{a}	0.07^{b}	0.09^{ab}
Bark	0.16^{a}	0.15^{a}	0.12^{a}	0.11^{a}
Stem	0.03^{a}	0.03^{a}	0.03^{a}	0.02^{b}

In each row, means followed by the same letters(s) are not significantly different at the 5% level using Tukey (HSD).

of spodic horizon (Table 2).

Idris et al. (2001) extracted the concentration of some elements in 29 accessions of kenaf leaves and found that the Ca in a range of 0.91 to 1.51%, P in a range of 0.15 to 0.25%, Mg in a range of 0.35 to 0.55% and K in a range of 1.32 to 1.97% grown on mineral soil. Stem of kenaf was found higher in carbon and nitrogen content while bark was found in higher content of phosphorus grown on RhuTapai soil series as compared to other series of soils. No visual deformation was observed in roots of kenaf; generally kenaf root growth was stunted with the increase in depth of spodic horizon (Figure 1).

Figure 1. Roots of kenaf at (a) 20 cm, (b) 48 cm, (c) 77 cm and (d) 118 cm depth of spodic horizons.

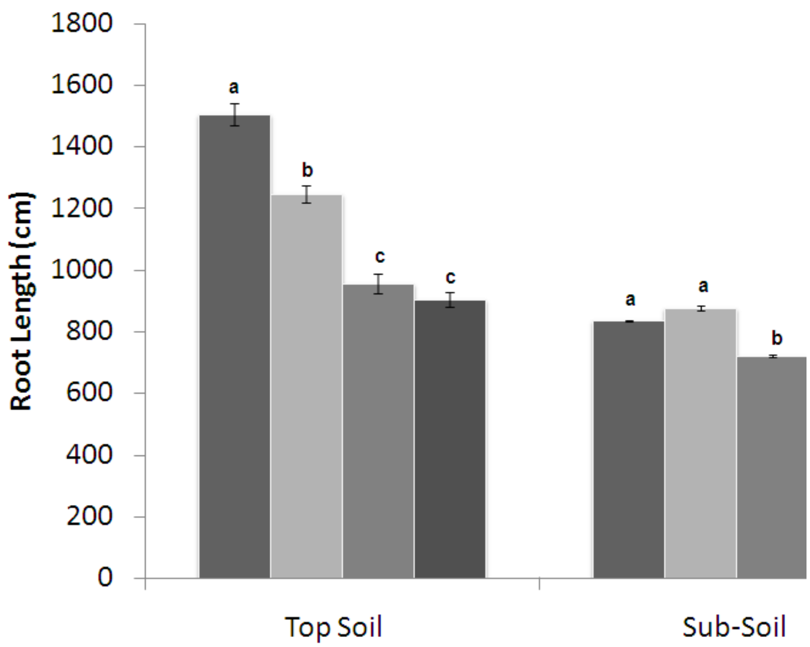

Figure 2. Root length of kenaf at different depths of spodic horizons. Mean with different letters are significantly different at P<0.05.

Most of the roots of kenaf were grown laterally at 20 cm depth of spodic horizon. Kenaf root morphology was studied at top soil and sub-soil at four depths of spodic horizons. At top soil kenaf root length was observed significantly higher (P=0.001) at 20 cm depth of spodic horizon as compared to 48, 77 and 118 cm depths while no significant difference was observed between root length of 77 and 118 cm depths (Figure 2).

At sub soil 20 and 48 cm depths of spodic horizons were significantly higher (P=0.0001) in root length of kenaf as compared to 77 and 118 cm depths. Kenaf root length was decreased 9.7, 26.5 and 31% with the increase in depth of spodic horizon at 48, 77 and 118 cm respectively as compared to upper depth of 20 cm at top soil of four locations (Figure 2).

Surface area of kenaf was significantly higher in 20 and 48 cm depths of spodic horizon as compared to 77 and 118 cm depths at surface (P=0.0001) as well as sub-surface (P=0.002) of BRIS soils (Figure 3). Surface area of kenaf roots was decreased at top soil of BRIS soils 16.9 and 33.7% at 77 and 118 cm depths as compared to 20 cm depths of spodic horizon (Figure 3).

Root volume of kenaf roots was also significantly higher at 20 and 48 cm depths of spodic horizon as compared to 77 and 118 cm depths at surface (P=0.0001) as well as sub-surface (P=0.001) of BRIS soils (Figure 4).

Significantly highest (P=0.0001) yield of kenaf 8.5 tons ha^{-1} was recorded at 20 cm depth of spodic horizon as compared to 77 and 118 cm depth of spodic horizon which were recorded 6.9 and 6.7 tons ha^{-1}, respectively. Yield of kenaf decreased were decreased 12, 19 and 21% at 48, 77 and 118 cm depths of spodic horizons as

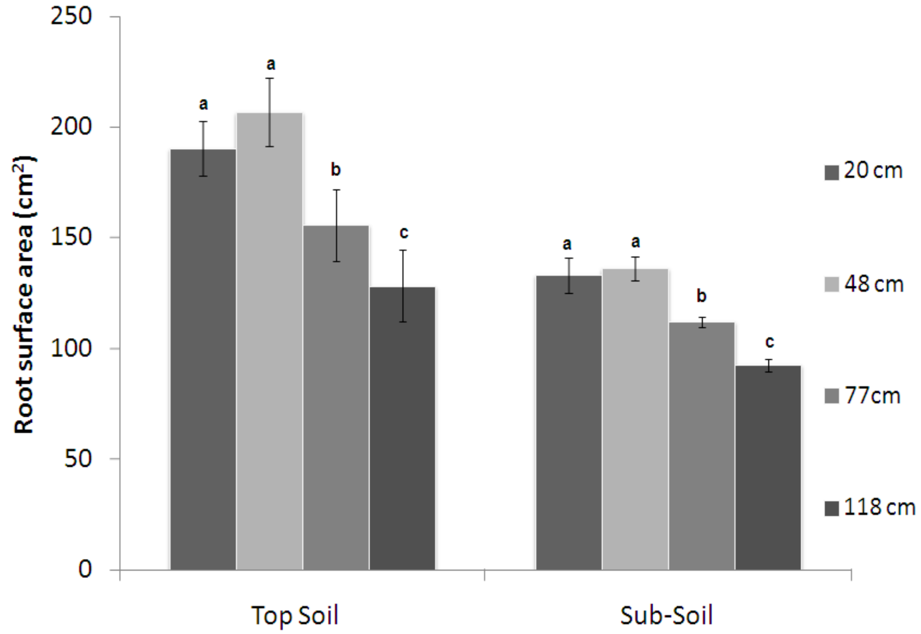

Figure 3. Surface area of kenaf roots at different depths of spodic horizons. Mean with different letters are significantly different at P<0.05.

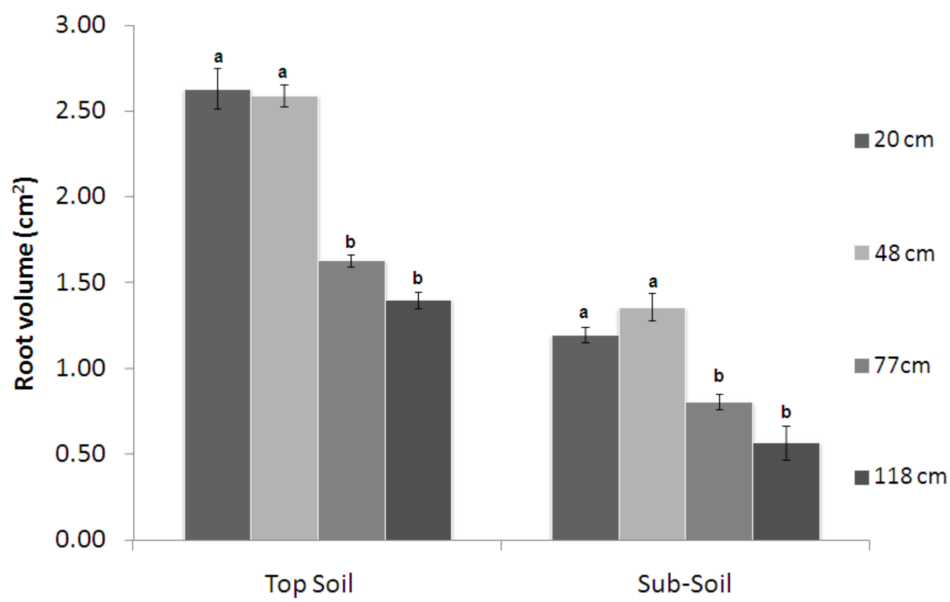

Figure 4. Volume of kenaf roots at different depths of spodic horizons. Mean with different letters are significantly different at P<0.05.

compared to 20 cm depth of spodic horizon, respectively (Figure 5).

DISCUSSION

The highest kenaf yield (25.58 tons ha^{-1}) in Malaysia (Othman et al., 2006) was achieved by Malaysia Agricultural Research and Development Institute (MARDI) cultivated on mineral soil which is quite high as compared to the yield of this study due to poor soil properties. The outcomes of study proved successful growth of kenaf and development of its root at BRIS area at lowest depth of spodics. Kenaf bears a wide

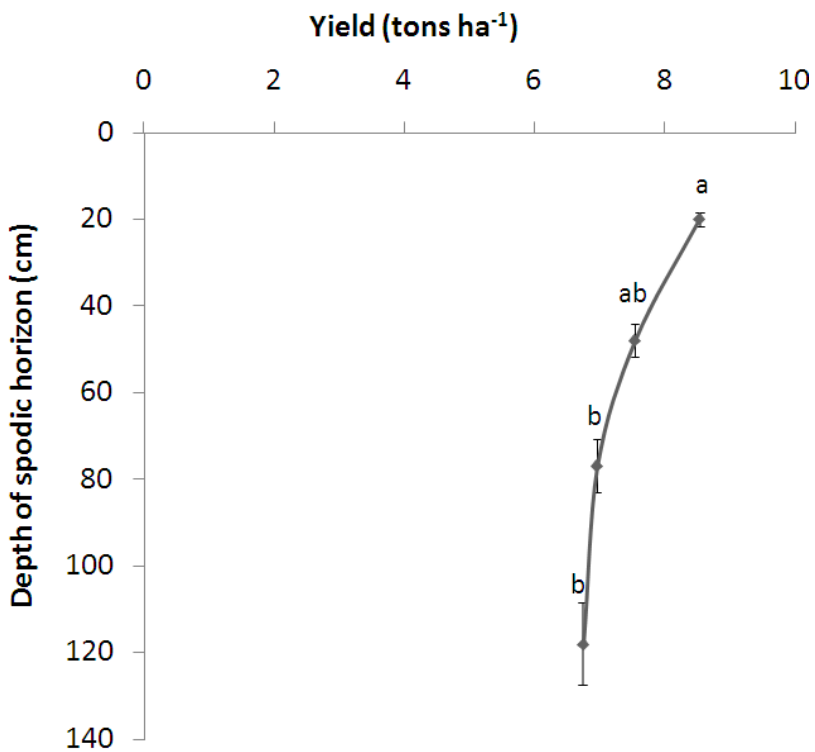

Figure 5. Yield of kenaf at different depths of spodic horizons.

lateral and prolific root system which keeps it relatively drought resistant and highly responsive to changes in soil water content (Stricker et al., 2006).

Banuelos and Bryla (2001) found that the average length of lateral roots may indicate that fiber yield of kenaf was also higher under well drain condition with water table below 50 cm. Root growth of kenaf depends on supply of carbohydrate from the shoot and reduction in leaf area usually reduces root growth (Kramer, 1983). It appears that kenaf has a prolific root system that is highly responsive to changes in soil water content (Muchow and Wood, 1980).

Conclusion

Study revealed that the kenaf can be grown successfully at lower depth (20 cm) of spodic horizon in BRIS soil. It is observed that the kenaf root growth and yield was stunted and decreased with the increase in depth of spodic horizon due to lack of nutrient and organic matter in BRIS soils. Spodic horizon could be a good source of nutrient when crop is cultivated on BRIS areas.

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