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Potential Plant Species for Live Pole Application in Tropical Environment

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Abstract: Problem statement: Slope instability causing landslides, a major geologic hazard, is a risk common to most regions. Among all categories of landslides, shallow slope failures which affect many hill slopes and earthwork projects are the most wide spread and pose the most costly maintenance problem. One of the soil improvement methods that seem suitable for preventing shallow slope failures is the Live Pole technique. **Approach:** Due to the geographical variability in the application of this technique in different regions this study was carried out in a tropical environment. **Results:** This study initially describes the requirement for suitable live poles in tropical regions utilizing indigenous woody species and potential candidates. It then describes screening tests trials that these species were put through to observe their propagation from large live cuttings obtained from branches of small trees and shrubs, viz., tests for root and stem growth in a controlled medium under shade-house conditions with irrigation and then discusses the results of these for their suitability for field trials by replanting in selected natural soils. **Conclusion/Recommendations:** The results of these screening tests found two species, namely, *Hibiscus tiliaceus* (*Ht*) and *Dillenia suffructicosa* (*Ds*) which met the requirements for field test trials.

Key words: Live pole, potential plants, shallow failure, slope stabilization, tropical region

INTRODUCTION

Globally, landslides annually cause billions of dollars in property damage and thousands of casualties. These landslides caused by slope instability constitute a serious geologic hazard in the tropics. These slope failures are typically associated with periods of heavy rainfall normally experienced in tropical regions. It is, therefore, imperative to find effective and economical methods to reduce these soil mass movements.

The reinforcement of soil by the bioengineering method (vegetation) is a highly promising solution with regard to reducing superficial landslide risk and erosion on natural and man-made slopes[1,2]. An increased adoption of the vegetation approach in the design of slope covers by the resulting increase in the benefits from grass and woody slope covers with respect to erosion and stabilization, optimization of slope drainage (together with land-forming[3]) and improved slope maintenance would appear to be the best way forward.

This aforementioned bioengineering (a.k.a. vegetative engineering or eco-engineering) approach for slope cover would be beneficial for the slopes from the following aspects:

- Mechanical: Through reinforcement of soils by plant roots preventing soil surface erosion
- Hydrological: Through reduction in run off by the interception of rain water during rain thus minimizing water entry into the slope which would otherwise weaken it. By keeping the slope relatively dry, the soil suction is maintained for a longer period thus keeping the slope stronger
- Environmental: Through the increase in carbon sequestration to counter the rising carbon dioxide (CO_2) level in the atmosphere which is generally regarded as bringing about global warming

This study first describes the requirement for selecting suitable plants as live poles for slopes in tropical regions and presents the results of screening trials of potential tropical plant species in their ability to propagate from large live cuttings. Then the laboratory tests, further growth under control conditions and,

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finally, the effect of these live pole roots on soil suction are presented. At the end, the effect of some fertilizer on the growth of the selected live poles is also discussed.

Various candidate species were tested for root and stem growth in containers, filled with a control medium under shade-house conditions with irrigation and this yielded three suitable species, namely, *Hibiscus tiliaceus* (*Ht*), *Dillenia indica* (*Di*) and *Dillenia suffruticosa* (*Ds*). These were then planted again in selected natural soils under controlled shade-house conditions for highlighting the influence of soil type on their growth/survivor rate. Only two, namely, *Hibiscus tiliaceus* (*Ht*) and *Dillenia suffruticosa* (*Ds*) were found to be suitable and were used as live poles for the next stages of research.

Requirements for plant species for use as live poles: Of the many conditions that can be considered in selecting a species as a potential live pole for slope stabilization, the specifications which appear more significant are as follows[4]:

- Ability to propagate from large-selection hardwood cuttings
- Ability to grow rapidly
- Ability to root at depth
- Ability to coppice
- Ability to grow in waterlogged conditions
- Ability to withstand desiccations
- Ability to resist impacts imported by driving
- Ability to grow long straight branches needed for ease of installation
- Ability to withstand burial and impact by moving slope debris

However, the selection of plant species for testing as live poles is based on their meeting the following requirements:

- Root growing quality
- Growing rate of the plant and root
- Potential of preparing bigger sized and straighter fresh cutting with enough length (up to 2.00 m)
- Mechanical properties

Literature review showed that based on above conditions some of tropical indigenous species which stood as potential live poles are: *Acacia mangium*, *Andria surinamensis*, *Casia siamea*, *Cerbera manghas*, *Dillenia suffruticosa*, *Erythrina orientalis*, *Erythrina variegate*, *Gliricidia sepium*, *Hibiscus tiliaceus*, *Leucaena leucocephala*, *Perrocarpus indica*, *Macaranga gigantean*[4].

Species screening (1): Growth investigations for possible live pole species: Eleven of the potential species, listed in Table 1, were identified for screening trials for their ability to propagate from large live cuttings obtained from branches of trees. These were tested for root and stem growth in irrigated containers under shade-house conditions. Sand was considered to be the best growing medium to use initially, at least, in the screening tests as, otherwise, if a rich soil is used it will encourage growth of many kinds of fungi and bacteria and some of these could attack the cutting in its vulnerable unrooted condition and kill it before it can produce roots[5]. Hence, these species were planted in four replicates in a medium consisting of crushed well-graded sand and 10% peat soil (as organic matter) for about 8 weeks in the shade-house.

After opening the containers, the roots were scanned and the results are summarized in Table 2 and Fig. 1. Seven species did not show any significant growth while four species, namely, *Hibiscus tiliaceus* (*Ht*), *Dillenia indica* (*Di*), *Pterocarpus indicus* (*Pi*) and *Dillenia suffruticosa* (*Ds*) seemed to indicate a potential for use as live poles. The survivor rates of these four species were 50, 50, 50 and 75% respectively.

From the observations of the distribution/location and shape of the root growth (Fig. 2) as *Pterocarpus indicus* had shown only end roots the other three species, namely, *Hibiscus tiliaceus* (*Ht*), *Dillenia indica* (*Di*) and *Dillenia suffruticosa* (*Ds*) were selected as the primary candidates to be used as live poles. These were replanted in selected natural soils to determine their ability to withstand more natural field conditions as described later.

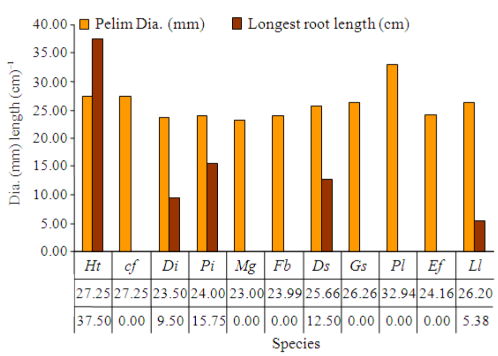
Table 1: Potential tropical plant species as live pole

No.	Species	Symbol	Description
1	*Hibiscus tiliaceus*	*Ht*	An evergreen tree with 3-10 m height, adaptable in wide range of soils and coastal environment.
2	*Cassia fistula*	*Cs*	A semi-evergreen tree growing to 10-20 m tall and fast. Best growth on well-drained soil in tropics and sub-tropics
3	*Dillenia indica*	*Di*	An evergreen large shrub growing to 15 m tall. It is distributed within high rainfall areas on sandy or clayey soil.
4	*Pterocarpus indicus*	*Pi*	A large deciduous tree growing to 30-40 m height, prefer rainforest and very easily propagate from large cuttings.
5	*Macaranga*	*M*	A large genus of Old World tropical trees. It has hollow stem which is used as nesting space by ants.
6	*Ficus benjamina*	*Fb*	A topiary tree reaching 30 m tall, with elegant growth even in poor conditions, large and stately tree in tropics.
7	*Dillenia suffructicosa*	*Ds*	An evergreen shrub perennial 5-12 m tall in tropical, grows on eroded soil, well drained soils and even on white sands.
8	*Gliricidia sepium*	*Gs*	A mid-sized tree grows 10-12 m high in acidic, sandy and clay soils with low fertility, fast propagated and growth.
9	*Pajanella longifolia*	*Pl*	An old world tropics and Southeast Asian tree with dense, wood which is used for canoes, boats and house planking.
10	*Erythrina fusca*	*Ef*	A deciduous flowering tree highly adapted to coastal conditions along rivers in tropical Asia, Oceania and Africa.
11	*Leucaena leucocephala*	*Ll*	A small mimosoid tropical tree, grows quickly and forms dense thickets which crowd out any native vegetation.

Table 2: Lab trial screening of potential tropical plant species as live pole

Name*	Prelim Dia. (mm)	Week 2 Bud/ shoot	Week 2 1st leaf size (mm)	Week 4 Bud/ shoot	Week 4 1st leaf size (mm)	Week 6 Bud/ shoot	Week 6 1st leaf size (mm)	Week 8 Bud/ shoot	Week 8 1st leaf size (mm)	Dry weight (kg)	Green weight (kg) With leaf	Green weight (kg) Without leaf	Average no. of roots**	Average root size (mm)	Longest root length (mm)
Ht 1	29.00	0		2		3	65.0	5	116.0	0.30	0.45	0.35	27	2.5-5.0	195
Ht 2	26.00	0		2		0	0.0	0	0.0	0.30	0.30	0.30	50	2.5-4.5	420
Ht 3	24.00	0		3		6	30.0	6	95.0	0.30	0.35	0.30	43	4.0-5.0	485
Ht 4	30.00	0		4		0	0.0	0	0.0	0.45	0.60	0.45	52	5.0-8.5	400
Cf 1	30.00	0		2		3	85.0	5	115.0	0.40	0.45	0.40			
Cf 2	30.00	0		4		10	142.0	12	161.0	0.65	0.65	0.65			
Cf 3	20.00	0		2		2	45.0	2	67.0	0.40	0.45	0.40			
Cf 4	29.00	6		3		4	50.0	6	129.0	0.55	0.60	0.55			
Di 1	25.00	0		4		6	105.0	6	155.0	0.50	0.60	0.55	24	3.0-5.5	80
Di 2	22.00	0		2		7	92.0	7	150.0	0.45	0.60	0.50	35	2.0-5.5	110
Di 3	25.00	0		3		0	0.0	0	0.0	0.33	0.35	0.35	-	-	-
Di 4	22.00	0		4		5	45.0	0	0.0	0.35	0.40	0.40	22	3.0-5.0	150
Pi 1	26.00	0		3		7	75.0	10	105.0	0.50	0.45	0.35			
Pi 2	24.00	0		2		4	45.0	5	75.0	0.40	0.45	0.35	28	0.3-6.0	115
Pi 3	23.00	0		2		4	76.0	5	132.0	0.35	0.60	0.50			
Pi 4	23.00	0		1		5	45.0	4	95.0	0.50	0.55	0.50	36	0.3-6.0	200
M 1	22.00	0		0		0	0.0	0	0.0	0.20	0.20	0.20			
M 2	25.00	0		0		0		0	0.0	0.20	0.20	0.20			
M 3	20.00	0		0		2	30.0	0	0.0	0.15	0.15	0.15			
M 4	25.00	0		1		3	35.0	0	0.0	0.25	0.25	0.25			
Fb 1	27.12	0		0		0		0		0.25		0.25			
Fb 2	18.45	0		0		0		0		0.20		0.20			
Fb 3	23.30	0		0		0		0		0.23		0.23			
Fb 4	27.10	0		0		0		0		0.35		0.35			
Ds 1	26.21	0		1		3	45.0	4	85.0	0.35	0.45	0.40		4.0-6.5	200
Ds 2	29.64	0		2		3	55.0	5	70.0	0.50	0.60	0.55		3.5-5.5	350
Ds 3	21.13	0		2		0	0.0	0	0.0	0.25	0.25	0.25		2.5-3.5	120
Ds 4	28.70	6		4		6	35.0	8	55.0	0.30	0.25	0.25		4.0-5.5	280
Gs 1	22.99	0		0		0		0		0.35		0.30			
Gs 2	32.64	0		0		0		0		0.55		0.55			
Gs 3	22.92	0		0		0		0		0.30		0.30			
Gs 4	26.47	0		0		0		0		0.60		0.30			
Pl 1	31.15	0		0		0		0		0.55		0.55			
Pl 2	29.40	0		0		0		0		0.45		0.50			
Pl 3	31.86	0		0		0		0		0.55		0.55			
Pl 4	39.34	0		0		0		0		0.95		1.00			
Ef 1	26.07	0		0		0		0		0.25		0.30			
Ef 2	22.50	0		0		0		0		0.20		0.20			
Ef 3	21.02	0		0		0		0		0.25		0.25			
Ef 4	27.05	0		0		0		0		0.25		0.25			
Ll 1	27.00	0		3		6	65.0	10	85.0	0.29	0.40	0.35	35	1.0-4.5	120
Ll 2	25.00	0		2		4	35.0	0	0.0	0.22	0.25	0.25			
Ll 3	24.50	0		0		0	0.0	0	0.0	0.20	0.25	0.25			
Ll 4	28.30	0		2		5	45.0	4	75.0	0.33	0.45	0.40	33	0.5-4.0	95

*: Refer to Table 1 for species name; **: Roots counted only that appears from the main stem; ***: 0 means no any growth is seen



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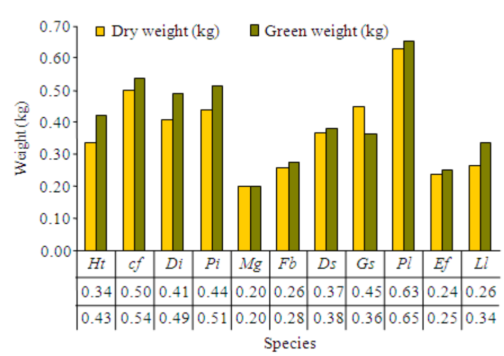


(b)

Fig. 1: Comparison of species growth. (a): Length of roots; (b): Dry/green weight

Species screening (2): Influence of soil types on the growth of selected live pole species: The soil absolutely dictates the success of all plant growth as it is the source of water and minerals and serves as the medium for anchorage. The most effective soil mechanical parameters on root development are: Soil composition and texture, structure, profile and moisture availability. In fact the water and mineral storage capacity is a function of soil composition and texture.

The selected live pole plant species were planted in five types of common soils found in Malaysia, taken from the locations mentioned in Table 3 with an analysis of their nutrients, under shade-house conditions.

In terms of the three elements Carbon, Nitrogen and Potassium, only Serdang soil can be considered as rich agricultural soil. Table 4 shows the result of the shade-house planting after 8 weeks (2 months) and it was again observed that *Ht* and *Ds* had not only the fastest growing rates but were also the most adaptable to the different soil types. The performance of *Dillenia indica* (*Di*) did not match that of the other two species, *Hibiscus tiliaceus* (*Ht*) and *Dillenia suffruticosa* (*Ds*).

Selection of plant species as live poles: From the results of the above mentioned investigations, as *Dillenia indica* (*Di*) could not meet all the conditions, the other two species, namely, *Hibiscus tiliaceus* (*Ht*) and *Dillenia suffruticosa* (*Ds*) were found to be the most suitable candidates and were used in the two further investigations as described below.

Effect of the selected live poles on soil suction: The first test on the selected live poles was the observation of their effect on soil suction. Four specimens were prepared for suction testing in prospect containers which were filled with the reddish yellow well graded sand of Jalan Alumni (UPM campus) which was naturally compacted to an approximate 80% field density. One of the containers was not planted to measure control condition, while the remaining three were used to plant with the selected live pole species, namely, *Ht* and *Ds*. Adequate drainage was also provided to each container in the form of five 10 mm holes on the opposing side and a 20 mm thick bottom layer comprising a mixture of different gravel size grains. These specimens were placed outside the shade-house to simulate natural conditions. However, an irrigation system was erected for controlled watering.

Hibiscus tiliaceus *Dillenia indica* *Dillenia suffruticosa*

Fig. 2: Selected species of first stage

Table 3: Nutrient level of the various soils

No.	Location	N (%)	C (%)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	Cu (ppm)	Zn (ppm)	Mn (ppm)	Fe (ppm)	PH	CEC (cmol/kg)
		Plants nutrition analysis											
1	Jln Alumni UPM	0.07	1.67	0.0	33	60	15	6	58.0	5	58	4	10.3
2	Jln MARDI UPM	0.01	0.05	0.0	12	46	0	TR	11.0	TR	11	4	5.5
3	Balakong	0.04	0.19	121.0	14	46	0	1	3.0	TR	3	5	4.0
4	Bangi	0.01	0.07	0.0	4	58	0	3	2.0	TR	2	5	5.4
5	Jln Saujana UPM	0.19	2.07	52.8	80	697	85	1.5	2.5	7.5	114	6	5.2

Table 4: Selected live pole growth-ability in various soils

No.	Location	Agricultural series	Soil description	Date of planting	Species	No. of replicate	Plant screening (after 2 months) (%)
1	Jln Alumni UPM	Melaka (Malacca)	Yellow well-grd Sand with gravel	01-Feb.-08	*Ht*, *Ds*, *Di*	8	*Ht*: 80 survived *Ds*: 50 survived *Di*: 25 survived
2	Jln MARDI UPM	Muchong (Malacca)	White poorly grd Sand with gravel	11-Apr.-08	*Ht*, *Ds*, *Di*	2	*Ht*: 100 survived *Ds*: 100 survived *Di*: 100 survived
3	Balakong	Masai	Yellowish red poorly grd gravely sand with silt	14-May-08	*Ht*, *Ds*,	3	*Ht*: 67 survived *Ds*: 100 survived
4	Bangi	Prang	Red clayey sand with gravel	09-May-08	*Ht*, *Ds*,	4,1	*Ht*: 75 survived *Ds*: 100 survived
5	Jln Saujana UPM	Serdang	Brown clayey sand with gravel	09-May-08	*Ht*	3	*Ht*: 100 survived

The testing was started just after the samples were planted. Four mini-tensiometers 100 kPa capacities connected to a data logger system were install at depths of 200 or 400 mm in each container (Fig. 3 and 4).

Figure 5 shows the result of the suction measurements during an approximately 30 weeks period consists of 2 monsoon seasons. It was observed that the suction of the soil with *Ht* roots is 2-10 times greater than the control (unplanted) soil during dry and wet soil conditions respectively. Also the soil suction at 400 mm depth is obviously 50-60% of the suction at the 200 mm depth (in dry and wet soil conditions respectively). Comparing the effect of *Ht* and *Ds* roots shows that the suction created by the *Ds* roots is 100-70% greater that of the *Ht* roots (in dry and wet soil conditions respectively).

Effect of fertilizers on the selected live poles: In order to investigate the effect of fertilizers on the quality and growth rate of the selected live poles, 16 specimens were prepared in Perspex containers filled with 7 kg gravel as a bottom layer (for providing suitable drainage) and 25 kg crushed well-graded sand as the main planting medium. One fertilizer additive (*NPK Blue* with 12% Nitrogen, 5.2% Phosphorous and 14.1% Potassium) and a rooting hormone (*Seradix with 4-indol-3yl butyric* acid as active ingredient) were utilized according to their manufacturers' instructions.

Fig. 3: Samples for soil suction testing

Fig. 4: A mini-tensiometer for suction testing

Each live pole (of *Ht* and *Ds*) was planted in 4 types of medium (sand plus fertilizer, sand plus hormone, sand plus fertilizer and hormone and pure sand for control conditions) in two replicates and kept under shade-house condition for 10 weeks. The results of the growth by comparing the number and length of leaves of live poles are shown in Fig. 6 and Fig. 7.

It is obviously that the use of a fertilizer is more effective for growth than the root hormone for *Ht* but however, using both additives together has the best effect on quality and growing rate of the *Ds* live poles.

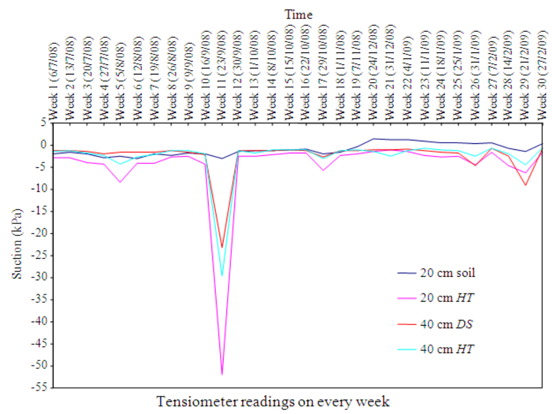
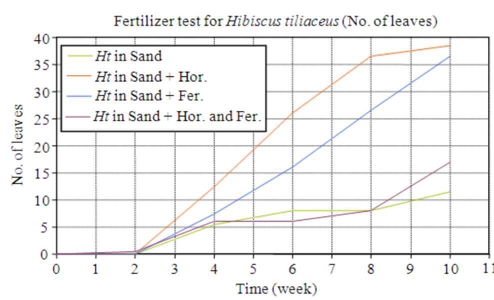


Fig. 5: Comparing suctions in the Jln Alumni, UPM soil planted with *Ds*/*Ht* and unplanted soils



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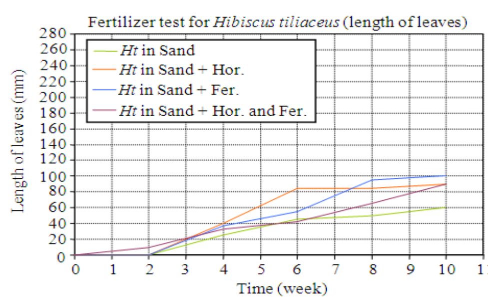
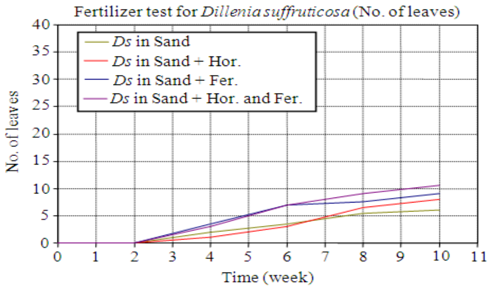


(b)

Fig. 6: Comparison of *Ht* growth (fertilizer additives). (a): No. of leaves; (b): Length of leaves



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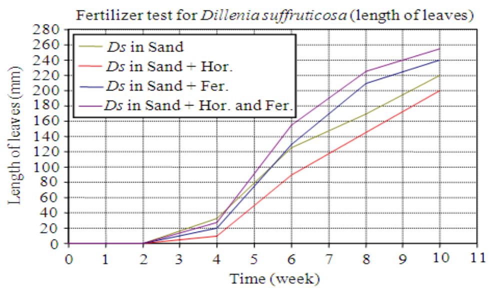

(d)

Fig. 7: Comparison of *Ds* growth (fertilizer additives). (a): No. of leaves; (b): Length of leaves

CONCLUSION

This study was carried out in the tropics to obtain a more practical understanding about the application of the live pole technique and ways of optimizing its effectiveness. Results obtained indicate that the *Hibiscus tiliaceus* (*Ht*) and *Dillenia suffruticosa* (*Ds*) poles could be effective for stabilization of shallow slides in clayey sand to sand soils. It seems remarkable that the live pole technique is even effective for shallow slop failure at depth of approximately less than 1.5 m.

The growth of these live pole species on slope soil provides a form of vegetated soil nailing or dowelling which offers immediate improved slope stability.

The continued growth would be beneficial for the slope as its stability would be progressively increased over time through the development of a root system, increase in soil suction and a reduction in the soil moisture. It is also observed that the growth rate and quality of these potential species can be increase by about 67% and 27% for *Ht* and *Ds* respectively by adding only 0.006% fertilizer to the soil. Hence live poles can be used in close-spaced arrays on suspect or failed slopes providing low-cost and environmentally suitable alternatives to the conventional methods of slope stabilization.

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REFERENCES

1. Gray, D.H. and A.T. Leiser, 1982. Biotechnical Slope Protection and Erosion Control. Van Nostrand Reinhold Co., New York, ISBN: 0442212224, pp: 271.
2. Barker, D.H., A.J. Watson, B. Sombatpanit, B. Northcut and A.R. Magliano, 2004. Ground and Water Bioengineering for Erosion Control and Slope Stabilization. Science Publishers, Enfield, NH., ISBN: 1578082099, pp: 419.
3. Barker, D.H., A.J. Watson, S. Sombatpanit and B. Northcutt, 2004. Live Pole Slope Stabilization in the Tropics. In: Ground and Water Bioengineering for Erosion Control and Slope Stabilization, Barker, D.H. (Ed.). Science Publishers Inc., USA., ISBN: 1578082099, pp: 303-308.
4. Schor, H.J. and D.H. Gray, 2007. Land-Forming: An Environmental Approach to Hillside Development, Mine Reclamation and Watershed Restoration. John Wiley and Sons., USA., ISBN: 0471721794, pp: 354.
5. Holtum, R.E., 1982. Plant Life Malaya. Longman, Malaysia.