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Soil quality assessment in *Aquilaria malaccensis* Lamk. (Agar) growing localities of three districts in upper Assam, India with respect to natural infection

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Abstract

A total of six pedons were studied from the Aquilaria malaccensis Lamk. (Agar) growing areas of upper Assam and in these areas natural infection of agar trees occur. The objective of research work was to study the relationship of soil quality with natural infection of agar trees. Pedon 1 and 2 are in Nahorani, Golaghat district of Assam. Pedon 3 and 4 are in Sotai and in Jorhat district, Pedon 5 and 6 are from Namti, Sibsagar district. Available soil nitrogen was recorded within low (102.42 kg ha^{-1}) to medium (326.41 kg ha^{-1}) range in all the six pedons and variations are found to be statistically insignificant. Available phosphorous was ranged low (15.12 kg ha^{-1}) to high (75.71 kg ha^{-1}) in Nahorani soils, low (21.40 kg ha^{-1}) to medium (48.10 kg ha^{-1}) for Sotai soils and also low (15. 23 kg ha^{-1}) to medium (46. 37 kg ha^{-1}) for Namti soils. Available K was within the range of low (56.11 kg ha^{-1}) to medium (336.00 kg ha^{-1}). Secondary soil nutrients such as Ca and Mg are found low for all the studied sites. Wide variation was observed in soil textural class, soil pH and soil organic carbon content among the three sites. Presence of clay fractions differ significantly between the pedons in all the depths. Soil pH was strongly acidic in Namti (4.4-5.2) and Nahorani ((4.3-4.9) soils. Soil pH was found moderately acidic in Sotai soils (5.0-5.6). Soil organic carbon was recorded low in Sotai soils whereas it was in medium range in both Nahorani and Namti soils and it showed a significant difference among the pedons. This study reveals that there is a strong relationship between the natural infections of agar trees with soil parameters. Maximum natural infection was found in soils with pH between 4.3-5.2, finer soil texture class particularly clay loam to loam and medium to high soil organic carbon.

Keywords: Agar, infection, natural organic carbon, pH, soil texture *etc*.

Introduction

Aquilaria malaccensis Lamk. syn. *A. agallocha* Roxb. is one of the seventeen tree species of genus *Aquilaria* under family *Thymelaeaceae.* This tree species is popularly known as Sanchi or Agaru in India, Agarwood, Aloewood and Eaglewood in Europe, Gaharu and Kalamabak in Malasia. The genus was first described by Lamark in Encyclopedia in 1783; later William Roxburgh (1814) named the tree as *Aquilaria agallocha*. Under genus *Aquilaria* only eight species are found to produce agarwood (black resin). Agarwood producing species like *A. malaccensis* and *A. khasiana* are found in India particularly in north east. Agarwood is actually the diseased wood produced as a result of host-pathogen and insect interaction. *Neurozerra conferta* Walker[1] (*Zeuzera conferta* Walker) a stem borer makes ziz- zag vertical tunnels and facilitates the entry of fungus and bacteria. Oleoresinous compound[2] found to accumulate in the infected wood particularly in the phloem tissues. Agarwood resin makes it highly demanded material in aromatic, incense, perfume, soap and in pharmaceutical industry. The bark of agar is used in paper and pulp industry. Presently tea prepared from agar tree leaf is popular due to health benefits. High demand of agarwood both in national and international market resulted in indiscriminate felling of agar trees from forest. Finding old tree in forest is almost rare. There may be few trees in protected reserve forest and also deep inside in natural forest. *A. malaccensis* is listed in Appendix II of the Convention on International Trade in Endangered Species[3] of Wild Fauna and Flora, the species is globally 'vulnerable' according to the IUCN red list, and has been included in The World List of Threatened Trees. This species is considered 'critically endangered' in India[4] and almost extinct in the wild in Assam. The formation of resin with in tree is very rare and naturally occurs in few trees out of hundreds. Commercial cultivation of agar is common in Nagaon, Hojai, Golaghat, Jorhat, Sibsagar and Dibrugarh district of Assam.

However hundred percent natural infections occur only in few localities. Natural infection is not continuous and even but in patches and pockets. Sometimes infection occurs in one field and no infection is found in adjacent field which may be away in one or two kilometer or even in few meters. For this along with the microbes and borer insect the role of edaphic (abiotic) factors cannot be ruled out. Agar tree is also planted in some

parts of Kerala, Tamilnadu, Western Ghats of Karnataka and Goa but trees are either chemically treated or mechanically wounded, or fungus is artificially inoculated for resin formation[5]. Lack of natural infection might be due to absence of insect and/or fungus along with other edaphic factors. Soil physico-chemical properties and also local microclimate around the trees might play an important role in the entire mechanism. Study of soil characteristics with relation to natural infection of agar is scanty so the present research work was undertaken to find out whether abiotic factor has any role in agarwood formation.

Methodology

Site characteristics: Three districts in Assam, India were selected for study based on occurrence of natural infection. Geographically the sampling site Nahorani is situated at $26^0 45^/$N latitude and $96^0 16^/$E longitude in Golaghat districts. Topography is gently sloping plain and is at 92 m above MSL. Sotai is situated between $26^0 20^/$ and $28^0\ 15^/$ N latitude and $93^0\ 52^/$ and $95^0 22^/$E longitude in Jorhat district. Topography is flat and is situated at 91m above mean sea level. Namti is situated between $26^0 51^/$ N latitude and $94^0\ 38^/$ E longitude and in Sibsagar district. The soils of all the three sites have developed from alluvial sediments of river Brahmaputra. Region receives about 2000 mm rainfall annually. Relative humidity remains very high throughout the year. Average summer temperature ranges from 28^0C to 32^0C and winter temperature ranges between 14^0C to 16^0C. Geologically study site comes under recent alluvium. It belongs to hyperthermic soil temperature and Udic soil moisture regime. Mineralogy is mixed type and particle class of fine loamy.

Soil sampling: Soil samples were collected from six pedons which were in homestead garden. Location of pedons represents the different intensities of agar trees natural infection and formation of agarwood. Pedon P1 and P2 are in Nahorani, Pedon P3 and P4 are in Sotai and Pedon P5 and P6 are from Namti respectively. Soil samples were collected from genetic horizons for the laboratory analysis. Weighted average of most varied soil physicochemical properties were calculated for 0-25 cm, 25-50 cm and 50-100 cm and statistically analyzed following two way ANOVA without replication in excel 2010 software.

Analytical procedure: Collected soil samples were air dried, grinded and passed through a 2mm mesh size sieve. Soil pH was determined with pH meter in 1:2.5 soils: water suspension, Soil organic carbon by titrimetric method[6], available N by alkaline permanganate method[7] whereas available P was extracted by Bray I reagent and determined by blue colour method[8]. Available K was extracted by neutral normal ammonium acetate and estimated with the help of flame photometer[9]. Complexometric titration method was followed for Ca and Mg. And for mechanical analysis international pipette method was followed.

Results and discussion

In the location of pedon P1 and P2 age of the agar trees are from 10-15 years. Hundred percent natural infection and formation of agar wood was observed. Trees are 7-8 years of age in the location of pedon P3 but no natural infection was found, some mechanical injuries were done to facilitate the microbes and insect entry and initiate the infection however infection in the trees were absent (Figure-1). Pedon P4 was about 800 meter away from P3, where heavy natural infection found and hundred percent agar wood formations were recorded. Pedon P5 and pedon P6 sites have agar trees of varying age from 1-15 years old. Natural infection and formation of agarwood was observed in all the trees, infection was heavy and some seedlings of 1 year old were also got natural infection in such case seedlings dies before attaining the harvesting age and a lose to the farmer (Figure-2). Insect frass materials were observed on bark of seedlings (Figure-3) and oozing out of some black materials from insect holes of matured trees trunk was found and it is the sign of oleoresinous agarwood formation (Figure-4). It was observed that occurrence of natural infection and formation of agarwood was not related to age of plantation but on the locality.

All the three sites come under same climatic region and are within the range of less than 80 km of road distance. So, emphasis was given to study some selected soil parameters, data is presented in Table-1-2. Available soil nitrogen was recorded within low (102.42 kg ha^{-1}) to medium (326.41 kg ha^{-1}) range in all the six pedons and variations are found to be statistically insignificant. Available phosphorous was ranged low (15.12 kg ha^{-1}) to high (75.71 kg ha^{-1}) in Nahorani soils, low (21.40 kg ha^{-1}) to medium (48.10 kg ha^{-1}) for Sotai soils and also low (15. 23 kg ha^{-1}) to medium (46. 37 kg ha^{-1}) for Namti soils. Available K was within the range of low (56.11 kg ha^{-1}) to medium (336.00 kg ha^{-1}). Secondary soil nutrients such as Ca and Mg are found to be low for all the studied sites.

Other than soil primary and secondary nutrients, wide variation was observed in soil textural class, soil pH and soil organic carbon content among the three sites. In Nahorani and Namti sites finer soil particles such as silt and clay fraction are found more and soil textural class was clay loam to clay whereas in Sotai soils sand size particles were high and soil texture was sandy loam, sandy clay loam and loam respectively (Table-1). Statistical differences in distribution of sand, silt and clay sized particles were presented in Table-3. Calculated value for distribution of sand with depth was highly significant and also the differences in distribution of sand sized particles in six pedons were found to be statistically highly significant. Silt sized particles did not vary significantly with the soil depth in the studied locations, but silt content of soil of different pedons differ significantly with each other. Presence of clay fractions differ significantly between the pedons in all the depths. Soil pH was strongly acidic in Namti (4.4-5.2) and Nahorani ((4.3-4.9) soils. Soil pH was found moderately acidic in Sotai soils (5.0-

5.6). pH varied significantly with soil depth in all the six pedons (Table-3). Soil organic carbon was recorded low in Sotai soils whereas it was in medium range in both Nahorani and Namti soils and it showed a significant difference among the pedons. This study reveals that there is a strong relationship between the natural infection of agar trees with soil pH, soil texture particularly percentage of clay content and also with the soil organic carbon content. Agar trees prefer acidic soil pH. Acidic natures of agar growing soils were reported earlier[10]. Traditionally agar cultivation was mostly in acidic soil, which might be due to formation of agar wood in such conditions. Mycorrhiza, fungi and other beneficial bacteria which were found responsible for agar oil formation are soil borne and require acidic soils to build up their population[11]. Acidic soils helps soil born fungus to grow well since most of the bacteria and actinomycetes prefer neutral pH range and there is less competition for fungus[12]. Rhizosphere soil of agar trees contains many soil born microbes, so far 528 fungi and 279 bacteria belonging to 21 fungal strains and 19 bacterial strains were isolated from surrounding soils of infected agar trees and reported that 13.6 % of soil isolates have the capacity of agarwood formation[13]. Further low soil pH can be related to organic carbon content of the soils of that particular area[14]. Local tree environment effect the succession of fungal communities and the infection of agar trees naturally[15]. In this study agar trees were found to be infected naturally in the places of fine textured and low pH and high organic carbon content soils such as in Namti , Nahorani and also in pedon P4 of Sotai soils. Fine textured soils are able to hold more soil nutrients which help the growth of microbial colonies including arbuscular mycorrhizal (AM) fungi. Preference of soft and sandy clay soils by agar trees were also reported by other researcher[16]. Maximum AM fungal association was reported in the soils surrounding infected agar trees in Golaghat district of Assam[10]. Studies confirmed that agar wood formation is a persistent interaction of fungus with plant[17]. In areas which were not able to meet any of the favourable conditions are lacking natural infection, in such case artificial infection can be useful for farmers[18]. Further another important bio- catalyst, an insect called *Neurozerra conferta* Walker (*Zeuzera conferta*) also reported to be habitually associated with agar trees and natural infection[19] in the environment which meets all the edaphic requirements.

Figure-1: Low natural infection in Jorhat, mechanical wounding to facilitate infection.

Figure-2: Natural infection in seedlings of agar trees in Namt, Sibsagar.

Figure-3: Insect frass materials in the bark of agar tree seedlings in Namti.

Figure-4: Naturally infected agar tree showing oozing out of black materials.

Table-1: Soil texture under different pedons.

Pedon	Horizon	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Texture
P1	A1	0-25	34.00	36.60	29.40	cl
	A2	25-40	39.80	34.60	25.60	l
	AB	40-52	22.80	29.70	47.50	cl
	B1t	52-80	25.70	24.70	49.60	c
	B2t	80-110	27.00	21.90	51.10	,,
	B3	110-189	30.70	19.70	39.60	,,
	A11	0-25	22.80	45.80	31.40	cl
	A12	25-45	15.50	36.50	48.00	c
P2	A21	45-68	13.60	32.00	54.40	,,
	A22	68-97	14.60	28.00	57.40	,,
	B2	97-122	10.20	29.60	60.50	,,
	B3	122-200	9.30	34.30	56.40	,,
	Ap	0-15	66.50	18.50	14.88	sl
	A11	15-27	68.10	11.77	20.13	sl
P3	A12	27-40	65.80	8.53	25.67	scl
	A2	40-55	54.22	21.20	24.58	scl
	B2t	55-120	54.21	13.22	32.56	scl
	B3	120-187	49.28	5.87	44.85	sc
	Ap	0-7	52.90	29.10	18.00	sl
	A2	7-23	49.00	32.10	18.90	l
P4	A3	23-28	48.90	30.60	20.50	l
	B1	28-43	49.50	29.00	21.50	l
	B2t	43-93	42.00	31.40	26.60	cl
	B3	93-183	33.90	40.00	26.10	l
	AP	0-20	30.30	37.50	32.30	cl
	A21	20-38	28.80	38.50	32.70	,,
P5	A22	38-50	28.00	34.60	37.40	,,
	AB	50-80	29.10	30.90	40.00	,,
	B2t	80-150	30.30	32.80	36.90	,,
	B3t	150-200	27.30	30.50	42.20	c
	AP	0-25	29.00	34.00	37.00	cl
	A2	25-40	21.60	30.50	47.90	,,
P6	AB	40-52	49.70	8.80	41.50	sc
	B21t	52-80	29.10	30.70	40.20	c
	B22t	80-110	32.50	21.50	46.00	,,
	B3	110-200	26.70	38.30	35.00	,,

Table-2: Soil chemical properties under different pedons.

Pedon	Horizon	Depth (cm)	pH (1:2.5)	O C (%)	N kg ha^{-1}	P kg ha^{-1}	K kg ha^{-1}	Ca meq/100	Mg meq/100
P1	A1	0-25	4.30	1.74	272.80	39.20	182.50	0.90	0.70
	A2	25-40	4.40	1.38	285.00	34.72	190.00	0.90	0.60
	AB	40-52	4.40	1.26	269.60	15.68	186.25	0.80	0.30
	B1t	52-80	4.60	1.20	260.00	75.04	124.31	0.70	0.60
	B2t	80-110	4.60	1.29	183.20	12.32	121.30	0.20	0.10
	B3	110-189	4.90	1.20	102.42	17.13	98.76	0.20	0.10
	A11	0-25	4.50	1.80	326.41	38.20	106.25	0.60	0.80
	A12	25-45	4.60	1.52	276.00	69.32	100.00	0.80	0.70
P2	A21	45-68	4.70	1.26	228.90	54.21	110.00	0.60	0.50
	A22	68-97	4.70	1.38	215.36	75.71	105.00	0.60	0.50
	B2	97-122	4.80	1.32	178.31	69.32	106.25	0.80	0.70
	B3	122-200	4.90	0.90	156.34	15.12	87.31	0.40	0.20
	Ap	0-15	5.00	1.52	263.40	48.10	336.00	0.90	0.50
	A11	15-27	5.20	0.78	291.60	35.00	289.00	0.60	0.50
P3	A12	27-40	5.20	0.84	294.30	29.10	194.00	0.30	0.20
	A2	40-55	5.30	0.35	191.20	26.20	188.20	0.30	0.20
	B2t	55-120	5.30	0.24	154.14	26.10	181.40	0.20	0.10
	B3	120-187	5.50	0.19	118.41	23.30	141.10	0.20	0.10
	Ap	0-7	5.30	1.02	291.70	31.10	194.90	0.65	0.30
	A2	7-23	5.40	0.72	288.50	30.00	168.00	0.52	0.90
P4	A3	23-28	5.40	0.56	263.50	28.10	161.30	0.80	0.30
	B1	28-43	5.50	0.48	257.20	27.50	154.60	0.50	0.30
	B2t	43-93	5.60	0.28	228.90	25.50	134.40	0.50	0.20
	B3	93-183	5.60	0.35	222.70	21.40	122.30	0.30	0.10
	AP	0-20	4.40	1.31	227.80	24.64	110.00	0.80	0.30
	A21	20-38	4.50	1.90	285.40	26.88	102.50	0.51	0.26
P5	A22	38-50	4.90	0.98	276.10	46.37	105.00	0.80	0.20
	AB	50-80	4.90	1.10	179.10	28.61	92.50	0.40	0.20
	B2t	80-150	5.10	1.08	169.60	22.84	101.50	0.20	0.10
	B3t	150-200	5.20	0.26	160.30	15.23	98.80	0.20	0.10
	AP	0-25	4.40	1.33	266.60	30.12	215.00	0.80	0.40
	A2	25-40	4.60	1.03	260.30	28.40	188.20	0.50	0.40
P6	AB	40-52	4.80	1.01	269.70	27.40	144.50	0.90	0.30
	B21t	52-80	4.90	0.74	244.60	23.60	102.40	0.40	0.20
	B22t	80-110	4.90	0.69	221.47	25.10	87.21	0.20	0.20
	B3	110-200	5.10	0.33	121.41	23.00	56.11	0.10	0.10

Table-3: ANOVA of weighted average soil properties.

Sand (%)	P1	P2	P3	P4	P5	P6
0-25	35.64	22.80	67.14	50.08	28.79	29.00
25-50	31.41	14.53	56.44	36.35	28.41	31.24
50-100	25.13	13.41	50.27	33.90	28.91	29.70
P value	Depth: 0.014 Pedon:6.56E-06					
Silt (%)	P1	P2	P3	P4	P5	P6
0-25	38.04	45.8	15.78	31.14	36.2	34
25-50	31.26	34.23	14.13	31.69	36.39	21.09
50-100	22.69	28.34	7.34	40	31.04	25.15
P value	Depth:0.078 Pedon: 002					
Clay (%)	P1	P2	P3	P4	P5	P6
0-25	30.46	31.4	17.08	18.78	31.08	37
25-50	33.34	47.06	29.43	31.96	35.16	43.5
50-100	48.17	55.29	42.39	26.1	37.96	40.94
P value	Depth:0.004 Pedon: 0.018					
Org. C (%)	P1	P2	P3	P4	P5	P6
0-25	1.79	1.80	1.21	0.79	1.36	1.33
25-50	1.27	1.47	0.63	0.42	1.45	1.20
50-100	1.18	1.26	0.24	0.35	1.07	0.69
P value	Depth:0.0007 Pedon: 6.92E-05					
pH (1:2.5)	P1	P2	P3	P4	P5	P6
0-25	4.30	4.50	5.08	5.37	4.64	4.50
25-50	4.33	4.62	5.24	5.52	4.85	4.58
50-100	4.41	4.72	5.30	5.60	4.88	4.70
P value	Depth:5.17E-06 Pedon: 1.83E-11					

Soil depths: 0-25 cm, 25-50 cm and 50-100 cm, Pedons: P1, P2, P3, P4, P5 and P6

Conclusion

From this study it can be concluded that soil pH, soil texture and soil organic carbon plays an important role in the natural infection of agar trees since these soil properties showed a significant variation between infected and uninfected localities. Further, it is also included that as information on effect of soil on agarwood formation is scanty more studies are needed in this field to confirm the results. Outcomes of such studies would greatly help the farmers to manage their soils.

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