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Physico-chemical Characteristics of Rhizospheric Soils of Some Important Medicinal Plants Found in North East India

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Abstract The present study was conducted to investigate the soil physical and chemical properties in the rhizosphere regions of four medicinal plants *Asparagus racemosus, Tinospora sinensis*, *Vitex negundo* and *Clerodendrum colebrookianum* naturally occurring in the upper flood plains of Lakhimpur district in Assam and one medicinal plant, *Coptis teeta* from the high altitude regions of the Lower Dibang Valley district in Arunachal Pradesh. Representative soil samples, a total of 27 (9x3) random soil samples were collected from different sampling sites and laboratory experiments were conducted with standard methodologies. Sand content was highest (86%) in the rhizosphere soil of *C. teeta* followed by *V. negundo* (76%) and *T. sinensis* (75%). Organic carbon (SOC) in the rhizosphere of selected medicinal plants ranges from 1.0% to 6.3%. Total nitrogen (TN) in the rhizospheric soil of selected medicinal plants ranges from 0.01 to 0.34%. Comparatively, P was higher in summer seasons in all the rhizospheric soils as compared to the winter seasons in the present study. Compared to the other selected plants, the soil of *C. teeta* possesses lower Ca and Mg. Overall, the study reveals that the soil of the rhizosphere of selected medicinal plants is rich in nutrients and differs between the study sites.

Keywords Microbial Activity, Microclimate, N_2-fixation, Soil Nutrients

1. Introduction

Soil is the uppermost surface layer of the earth's crust. It serves a vital function in nature by providing nutrients for plant growth as well as habitats for millions of micro and macro organisms [1]. The properties and functions of soil are influenced by various factors such as temperature, rainfall, altitude, aspect, vegetation cover, land use type, etc. [2]. Extensive and unabated deforestation also has a very negative impact on soils [3]. Similarly, microorganisms are also reported to influence the physical, chemical and biological properties of soil either directly or indirectly [4]. Nutrients in soil are naturally derived from various sources like input of nutrients from the atmosphere, weathering of minerals, litter decomposition and the fixing of some nutrients by microorganisms [5]. However, plant communities in various habitats serve as the primary source of nutrients in the soil, though the quality and quantity of nutrients varies with vegetation types and species composition. The deposition of organic materials by plant communities stimulates the growth and activity of microorganisms in the rhizosphere and controls the turnover of key nutrients [6-8]. The seasonal variations of soil physico-chemical properties are considered to be the key factors in controlling the qualitative and quantitative variations of soil microbial community composition [9].

Keeping above in consideration, the present study was undertaken to understand the physical and chemical properties of soil in the rhizosphere regions of four medicinal plants *Asparagus racemosus, Tinospora sinensis*, *Vitex negundo* and *Clerodendrum colebrookianum* naturally occurring in the upper flood plains of Lakhimpur district in Assam and one medicinal plant, *Coptis teeta* from the high altitude regions of the Lower Dibang Valley district in Arunachal Pradesh.

2. Materials and Methods

Study Site

The present study was conducted by collecting soil samples from the rhizosphere of five selected medicinal plants found at two study sites located in Assam and Arunachal Pradesh, North East India. Site I: Dhakuakhana, Lakhimpur District, Assam: located in the upper flood plains of Dhakuakhana sub-division (27˚14'16.68''N, 94˚06'21.59''E, 316 ft, Altitude 102 m asl) in Lakhimpur district of Assam. Site II: located in Mayodia within Mishmi Hills range of Lower Dibang Valley district in Arunachal Pradesh (28˚14'37"N, 95˚55'35"E, Altitude 2500 m asl). soil moisture content and temperature were varied in different sampling sites (Figure 1).

Soil Sampling from Rhizosphere of Medicinal Plants Laboratory Analysis

Representative soil samples, a total of 27 (9x3) random soil samples were collected from a depth of 10-30 cm below the surface layers in the rhizosphere region of each medicinal plants using soil corer. Soils were sampled for a period of two years, twice a year during warm summer and wet season [summer 1 (S1) in the first year and summer 2 (S2) in the second year] and during the winter dry and cold seasons [winter 1 (W1) in the first year and winter 2 (W2) in the second year] respectively. The soil samples were carefully transferred into sterile plastic bags and transported immediately to the laboratory for analysis. The soils were passed through a 2 mm test sieve to remove large organic particles and debris. Each of the fresh rhizospheric soil samples were used for isolation of fungi.

Part of the fresh soil samples were used for soil pH and moisture determination, and the remaining soil samples were dried in air for further physico-chemical analysis.Soil characteristics such as soil texture, moisture contents, soil organic carbon, total N and P etc. were as determined by different standard methods given by Okalebo *et al.* [10]. Soil pH was measured by using a digital pH meter in a soil to water ratio of 1:2.5 [10]. Available phosphorus and Potassium contents of soil were determined through a flame photometer method [11].

3. Results

Physical Properties of Soil in the Rhizosphere of Medicinal Plants

Soil textures of the rhizosphere of the selected plants were sandy loam to loamy fine sand. Sand content was highest (86%) in the rhizosphere soil of *C. teeta* followed by *V. negundo* (76%) and *T. sinensis* (75%). The highest silt content was recorded from *A. racemosus*, while the lowest was recorded from *C. teeta*. Clay content was highest in the rhizosphere soil of *A. racemosus* and lowest in *C. teeta* (Table 1). Soil temperature in the rhizosphere of 4 medicinal plants in Lakhimpur district ranges from 14.4 to 24.6˚C whereas it varied from a lowest of 5.9 to 10.9˚C in the rhizospheric soil of *Coptis teeta* (Table 2). In all the rhizospheric soils of medicinal plants soil temperature is higher in the summer season and lower in the winter season. The highest soil temperature recorded 24.6˚C in the rhizospheric soil of *Vite*x negundo in the summer season and the lowest (5.9˚C) has been recorded in the winter season in the rhizospheric soil of Coptis teeta.

Moisture content in the soil ranges from a minimum of 14.8 to a maximum of 64.8%. The highest moisture content was recorded in the rhizospheric soil of *Coptis teeta* and the lowest recorded in *Vitex nigundo* in the entire study. The moisture contents were lower during the winter season in all the rhizospheric soils as compared to summer seasons.

Table 1. Soil texture of the rhizospheric soil of five selected medicinal plants

Plant species	% of Sand	% of Silt	% of Clay	Textural class
A. racemosus	58.7	31.3	10.0	Sandy loam
C. colebrookianum	64.7	28.3	7.0	Sandy loam
T. sinensis	75.0	20.3	4.7	Loamy fine sand
V. negundo	76.0	17.0	7.0	Sandy loam
C. teeta	83.0	11.6	2.9	Loamy fine sand

Chemical Properties of Soil in the Rhizosphere of Medicinal Plants

Soil pH in the rhizosphere of medicinal plants in Lakhimpur district was 5.2 to 6.5˚C and in the rhizospheric soil of *Coptis teeta* from Mayodia recorded 3.2 to 4.3˚C. Organic carbon (SOC) in the rhizosphere of selected medicinal plants ranges from 1.0% to 6.3%. The percentage of C in the rhizosphere of *Asparagus*, *Clerodendrum*, *Vitex* and *Tinospora* sp. showed higher in the summer season as compared to the winter season (Figure 2). The rhizosphere soil of *Coptis* sp. was low in organic carbon in summer compared to winter, but it's not significantly different. Organic carbon in the rhizosphere of *C. teeta* ranges from 5.8 to 6.3%, and in the other four plants ranges from 1.0 to 4.0%. Total nitrogen (TN) in the rhizospheric soil of selected medicinal plants ranges from 0.01 to 0.34% (Table 2) The highest was recorded in the soil of *T. sinensis* and *C. teeta* in the entire study as compared to the other selected plants. In all the plants, the rhizosphere N was higher in summer as compared to winter. Total phosphorus (TP) ranges from 0.07 to 0.18 % in the rhizosphere soil of selected medicinal plants. Soil of *C. teeta* contains low P (0.07-0.08%) as compared to the other selected plants. Comparatively, P was higher in summer seasons in all the rhizospheric soils as compared to the winter season in the present study. Available phosphorous (AP) ranges from 9.2 to 24.9 µg g^{-1}. It was higher in summer in the rhizosphere of all selected medicinal plants as compared to in winter. AP in the soil of *C. teeta* (9.2- 9.8 µg g-1) was comparatively lower than the other four selected plants (12.4-24.9 µg g-1). Available potassium (K) in the rhizospheric soil of the selected medicinal plants ranges 83.7 to 216.7 ppm. K of *C. teeta* was less as compared to the other selected plants (103-216.7 ppm). In the rhizospheric soil of the selected medicinal plants, Ca ranges from 0.55 to 2.2 Cmol kg $^{-1}$ and Mg from 0.18 to 1.42 Cmol kg $^{-1}$. Compared to the other selected plants, the soil of *C. teeta* possesses lower Ca and Mg.

4. Discussion

Spatial Variation in Physico-chemical Properties of Rhizosphere Soil

Soil texture governs the other soil properties, including biological characteristics. Increasing sand percentage followed by silt percentage in the present study might be due to frequent floods in the study area of Dhakuakhana. Soil texture of *C. teeta* could be the altitudinal effect [12]. *A. racemosus* rhizospheric soil was collected from the riverside area. Therefore, comparatively silt percentage was higher in the soil texture of this sample. The rhizosphere communities in the sandy soil and sandy loam were primarily affected by the root zone [13]. Soil temperature (ST) varied between 5.9˚C in the rhizosphere soil of *C. teeta* during winter to 24.6˚C in the rhizosphere soils of *V. negundo* during summer seasons. The rhizosphere soil of four medicinal plants except *C. teeta* is exposed to high solar radiation along the low altitude flood plains, leading to increased soil temperature. Soil moisture (SM) was higher in the rhizospheric soil of *C. teeta* (56.1-64.4) as compared to other plants of Lakhimpur district might be due to the area where *Coptis teeta* occurs is covered by thick layer of litter and forest cover with minimum exposure of sunlight reaching the ground surface and less evaporation leading to lower soil temperature and high moisture storage. Soil moisture of the *A. racemosus, T. sinensis*, *V. nigundo*, C. *colebrookianum* (range 14.8- 30.6) supports the result of Das *et al.* [14].

Soil pH was acidic in the rhizosphere soils of all plants under this study. Soil acidification is a natural process mainly conditioned by naturally acid parent rocks and leaching and run off losses of nitrate nitrogen, cations such as Ca, Mg and K attributed to high precipitation [15]. The pH values were slightly acidic (5.2 to 6.4 pH) and did not vary significantly among the rhizosphere of *A. racemosus*, *C. colebrookianum, T. sinensis* and *V. negundo.* However, pH in the rhizosphere of *C. teeta* (Myodia) was strongly acidic ($pH < 5.0$) compared to other plants in both seasons. Similar findings also reported by Strong *et al.* [16], from the rainforest of Lamington National Park, southeast Queensland. The main reasons for the strongly acidic pH in the rhizosphere of *C. teeta* could be due to the presence of high amounts of organic acids derived from the decomposition of organic matter, and the presence of cations such as Al^{3+}, Ca^{2+} derived from the parent soil materials under strong leaching activities.

Soil organic carbon (SOC) in the rhizospheric soil of *A. racemosus, T. sinensis, V. nigundo, C. colebrookianum* (1.4-4%) in present study supports the result of Bhattacharyya and Jha [28]. *C. teeta* rhizospheric soil contains a higher amount of organic carbon (5.8-6.3%), might be the combined effect of high altitude, cool temperature, reducing organic matter turnover rates due to lower microbial processing [17,18,12]. The low organic carbon content in the rhizosphere soil of medicinal plants in the Dhakuakhana as compared to *C. teeta* could be related to rapid decomposition at warmer temperatures, as well as erosion and translocation of surface soil containing organic matter during frequent flooding occurring in the area.

The range of the total nitrogen (TN) in the present study is similar to the Das *et al.* [14], studied on Dibru- Saikhowa Biosphere Reserve Forest of Assam; *Bhuyan and Momin, in Meghalaya* [19]. Gairola *et al.* [20], studied on valley slopes of Garhwal Himalaya, and Devi and Yadava [21], studied on mixed-oak forest ecosystem of Manipur. Total N did not show significant variation among the rhizosphere soils of medicinal plants, though there was high N contents during summer seasons as recorded in *T. sinensis* and *C. teeta* soils. N was high in the rhizosphere of *C. teeta* due to the accumulation of higher organic matter, as evidenced by the high organic carbon contents during both seasons.

Total phosphorus (TP) is a limited resource in the soil in spite of its wide distribution [22]. Total P in the rhizosphere soils ranges from 0.07 % in *T. sinensis* and *C. teeta* during winter seasons to 0.18% in *A. racemosus* during summer seasons. The range of total P in the present study was similar to the report of soils of southwestern Siberia [23] but higher than the soils of Mediterranean oak forests [24]. In plants rhizosphere total phosphorus depends upon the root morphology, physiological and biochemical responses on various environmental conditions [25]. Soil Available phosphorus (AP) mainly comes from the cleavage of soil organic P through biochemical P mineralization or decomposition of soil organic matter by biological mineralization [26]. Plant roots and soil micro-organism produce phosphatase which is constructively N rich enzyme, for biochemical P mineralization [27]. Available phosphorus ranges from 9.2 $\mu g\ g^{-1}$ in *C. teeta* to 24.9 $\mu g\ g^{-1}$ in *A. racemosus.* AP recorded in rhizospheric soil of *A. racemosus, T. sinensis*, *V. nigundo*, C. *colebrookianum* in the present study similar with Bhattacharya and Jha [28] and AP of *C. teeta* soil similar with Gairola *et al.* [20].

Potassium (K) exists in different forms in soils viz. water soluble, exchangeable, non-exchangeable and lattice potassium [29]. Available P in the rhizosphere soil of higher altitude plant *C. teeta* similar to the range of Gairola *et al*. [20], Wani and Kumar [29]. Less amount of Ca and Mg in the rhizospheric soil of *C. teeta* might be due to of leached out of precipitation or lower pH [30].

Seasonal Variation in Physico-chemical Properties of Rhizosphere Soils

Soil moisture is higher in all the rhizospheric soil in summer as compared to winter. This could be the fact of Tropical wet climate due to heavy rainfall in summer because of the monsoon. Soil pH is higher in summer seasons as compared to winter. Root exudates neutralizing the soil pH and alters the microclimate of the rhizosphere through discharge of water and carbon dioxide [31]. Higher rainfall during summer could be the cause of the low pH during summer due to leaching of anions. Both the study sites belong to North East India, among the highest rainfall receiving regions in the globe [32]. Soil organic carbon, total nitrogen, total phosphorus and available phosphorus are comparatively high in summer as compared to winter. In summer the favorable temperature, moisture and root activity favored the rhizospheric microbes to mineralization [33], decomposition of soil organic matter, which makes more available of nutrients in the rhizosphere than winter season. In the case of *C. teeta*, the rhizospheric soil contains higher amounts of SOC and TN because of higher accumulation of organic matter year after year, but due to the low temperature, high pH, and slow microbial activity remaining more or less constant, it does not show much seasonal fluctuation. AP and K are high in *A. racemosus* could be because of rhizodeposition which harbored groups of microbes that mineralize and solubilize phosphorus and K.

Available K, Mg and Ca have not shown significant seasonal fluctuations. Mg, Ca and available K have relation with soil pH, and in the present study pH also not showing much of seasonal effects.

Table 2. Physico-chemical properties of rhizospheric soil of selected medicinal plants in 4 consecutive seasons

Plant species	Seasons	SM (%)	ST (°C)	pH	SOC (%)	TN (%)	TP (%)	AP (µg g-1)	K (ppm)	Mg (Cmol kg^{-1})	Ca (Cmol kg^{-1})
A. racemosus	W1	26.3±0.1	17.9±0.1	6.0±0.02	1.7±0.05	0.10±0.009	0.11±0.002	14.1±0.2	146.7±4.3	0.96±0.29	1.36±0.13
	S1	29.1±0.4	21.3±0.7	5.9±0.05	1.7±0.09	0.14±0.003	0.16±0.003	24.9±0.9	180.0±1.7	1.01±0.22	1.66±0.18
	W2	28.0±0.1	16.1±0.2	6.2±0.06	1.4±0.03	0.16±0.006	0.11±0.002	15.2±0.7	113.3±1.5	1.05±0.42	1.47±0.23
	S2	30.6±0.4	20.6±3.1	5.5±0.02	2.1±0.09	0.14±0.004	0.18±0.005	23.2±0.7	216.7±5.3	0.91±0.27	1.66±0.22
C. colebrookianum	W1	14.8±0.2	15.3±2.1	6.1±0.04	1.0±0.01	0.13±0.006	0.09±0.004	14.2±0.2	136.7±2.0	1.32±0.57	1.75±0.18
	S1	22.3±0.2	22.9±3.0	5.7±0.01	2.3±0.06	0.18±0.004	0.11±0.004	15.8±0.8	113.3±2.4	1.35±0.43	1.80±0.17
	W2	16.6±0.2	15.4±0.5	5.7±0.02	1.9±0.04	0.13±0.003	0.09±0.004	13.6±0.2	120.0±2.9	1.42±0.43	1.64±0.18
	S2	20.9±0.3	24.0±0.1	5.5±0.02	2.4±0.04	0.17±0.005	0.09±0.003	17.8±1.1	136.7±2.9	1.28±0.56	1.55±0.21
V. negundo	W1	17.0±0.3	21.9±1.7	6.4±0.02	2.3±0.04	0.17±0.005	0.10±0.003	13.0±0.4	103.3±3.4	0.91±0.27	1.75±0.25
	S1	19.1±0.2	24.6±1.6	5.6±0.02	2.6±0.03	0.24±0.003	0.13±0.001	18.1±0.5	118.9±4.1	0.98±0.29	1.98±0.44
	W2	14.8±0.3	20.0±0.1	5.9±0.01	2.4±0.08	0.17±0.004	0.11±0.003	12.4±0.4	153.3±3.4	0.69±0.29	1.86±0.22
	S2	22.4±0.2	23.6±2.9	5.3±0.03	2.6±0.09	0.22±0.002	0.13±0.002	18.8±0.6	153.3±6.3	0.75±0.29	1.75±0.18
T. sinensis	W1	21.6±0.1	14.4±0.4	6.5±0.03	2.4±0.10	0.23±0.006	0.08±0.002	19.3±0.5	149.1±5.6	0.4±0.17	1.9±0.31
	S1	27.6±0.6	22.6±2.3	5.2±0.04	4.0±0.03	0.34±0.005	0.10±0.003	18.8±0.8	133.3±3.1	0.5±0.20	2.2±0.28
	W2	20.8±0.2	17.3±0.2	5.7±0.05	1.7±0.08	0.22±0.004	0.07±0.004	20.3±0.9	150.0±2.9	0.5±0.20	2.0±0.37
	S2	24.5±0.4	24.2±2.8	5.3±0.03	3.1±0.05	0.33±0.007	0.08±0.002	19.3±1.0	140.0±4.2	0.5±0.18	2.0±0.38
C. teeta	W1	57.5±0.4	5.9± 0.5	3.9±0.07	6.3±0.01	0.28±0.005	0.07±0.002	9.2 ±0.2	83.7 ±2.4	0.19±0.09	0.58±0.12
	S1	63.3±0.2	10.0±1.0	3.2±0.01	6.0±0.02	0.31±0.009	0.08±0.002	9.7±0.2	90.7 ±1.0	0.24±0.10	0.56±0.10
	W2	56.1±0.3	6.8±1.8	4.3±0.01	6.1±0.02	0.28±0.006	0.07±0.001	8.8±0.2	91.7 ±1.0	0.23±0.11	0.58±0.12
	S2	64.4±0.3	10.9±1.0	3.8±0.05	5.8±0.04	0.30±0.004	0.08±0.003	9.8±0.1	103.3±1.5	0.18±0.08	0.55±0.10

Note: W1 & W2 = Winter seasons; S1 & S2 = Summer Seasons; (Values are means of 9 replicates ± standard error), ST- Soil temperature; SM- Soil moisture; SOC- Soil organic Carbon; TN- Total Nitrogen; TP- Total phosphorus; AP- Available phosphorus; Mg- Magnesium; Ca- Calcium; K- Available potassium

Compared with the soil organic carbon, total nitrogen is high, but total phosphorus, available P, available K, Ca and Mg are low in the rhizospheric soil of *C. teeta* as compared to other rhizospheres of the selected plants. The higher percentage of Ca in the rhizosphere of medicinal plants collected from Dhakuakhana may be due to having parent material rich in limy material, i.e. limestone. Heavy rainfall and acidic soil are the main causes of less Mg, Ca and K in the rhizospheric soil of *C. teeta*. Rainfall contributes to a soil's acidity. Water (H_2O) combines with carbon dioxide (CO_2) to form a weak acid - carbonic acid (H_2CO_3). The weak acid ionizes, releasing hydrogen (H+) and bicarbonate (HCO_3). The free hydrogen ions replace the cations such as calcium, magnesium, sodium and potassium held by soil colloids, and the dislocated cations combine with the bicarbonate ions which is soluble, is leached from the soil. The net effect is increased soil acidity.

5. Conclusions

Overall, the study reveals that the soil of the rhizosphere of selected medicinal plants rich in nutrients and differ between the study sites. As for the plants which were collected from Dhakuakhana, the range of nutrients is more or less similar, but the rhizosphere soil of higher- altitude plant *C. teeta* differs from it due to geographical condition. Though not significant, season also showed influence in soil pH, SOC, TN, TP, AP. The physical property of soil, temperature and moisture also reveals the influence of season.

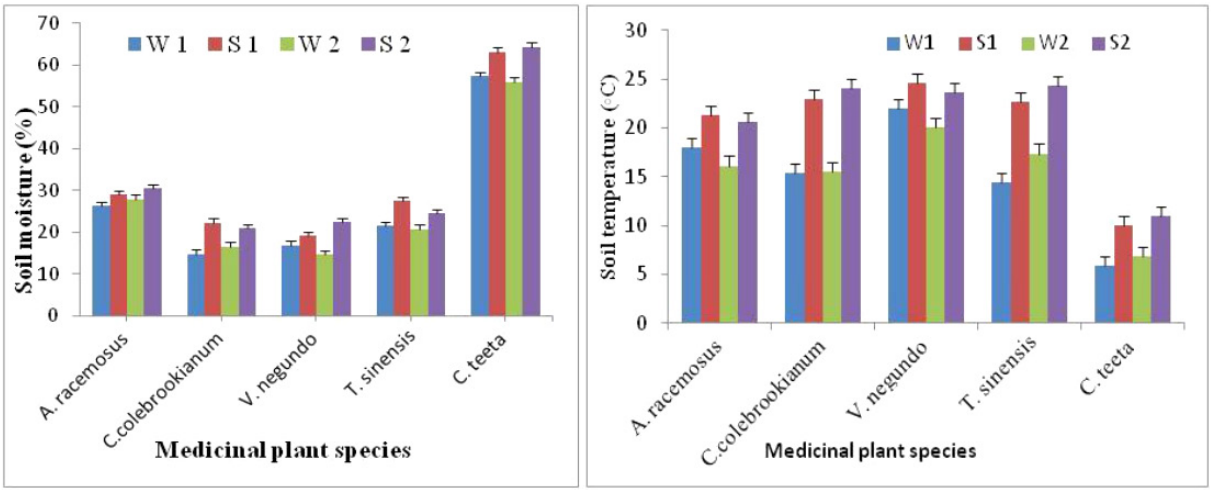

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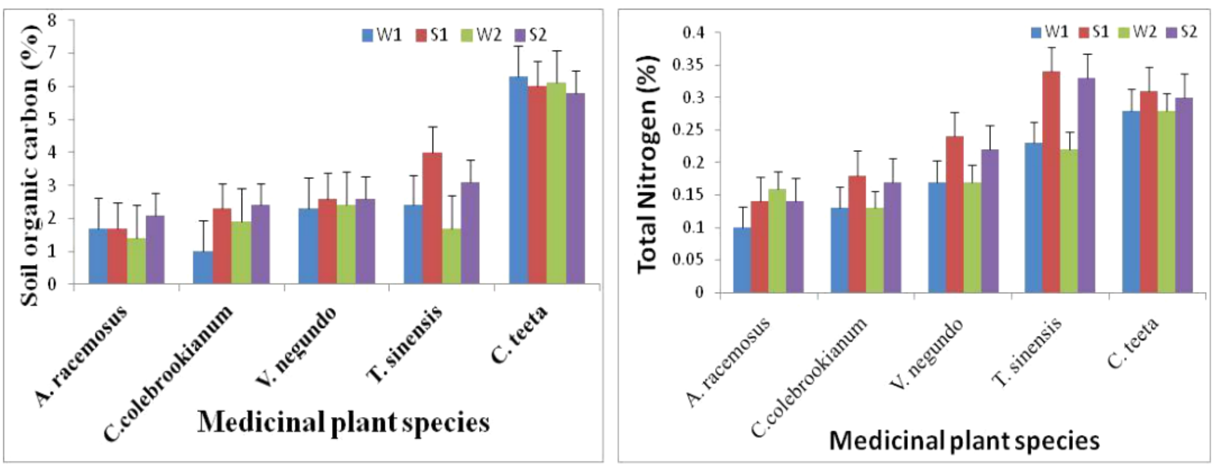
Figure 1. Temporal and spatial variations in soil moisture content (A) and temperature (B) in the rhizosphere soils of five medicinal plants (Vertical bars indicate standard error)



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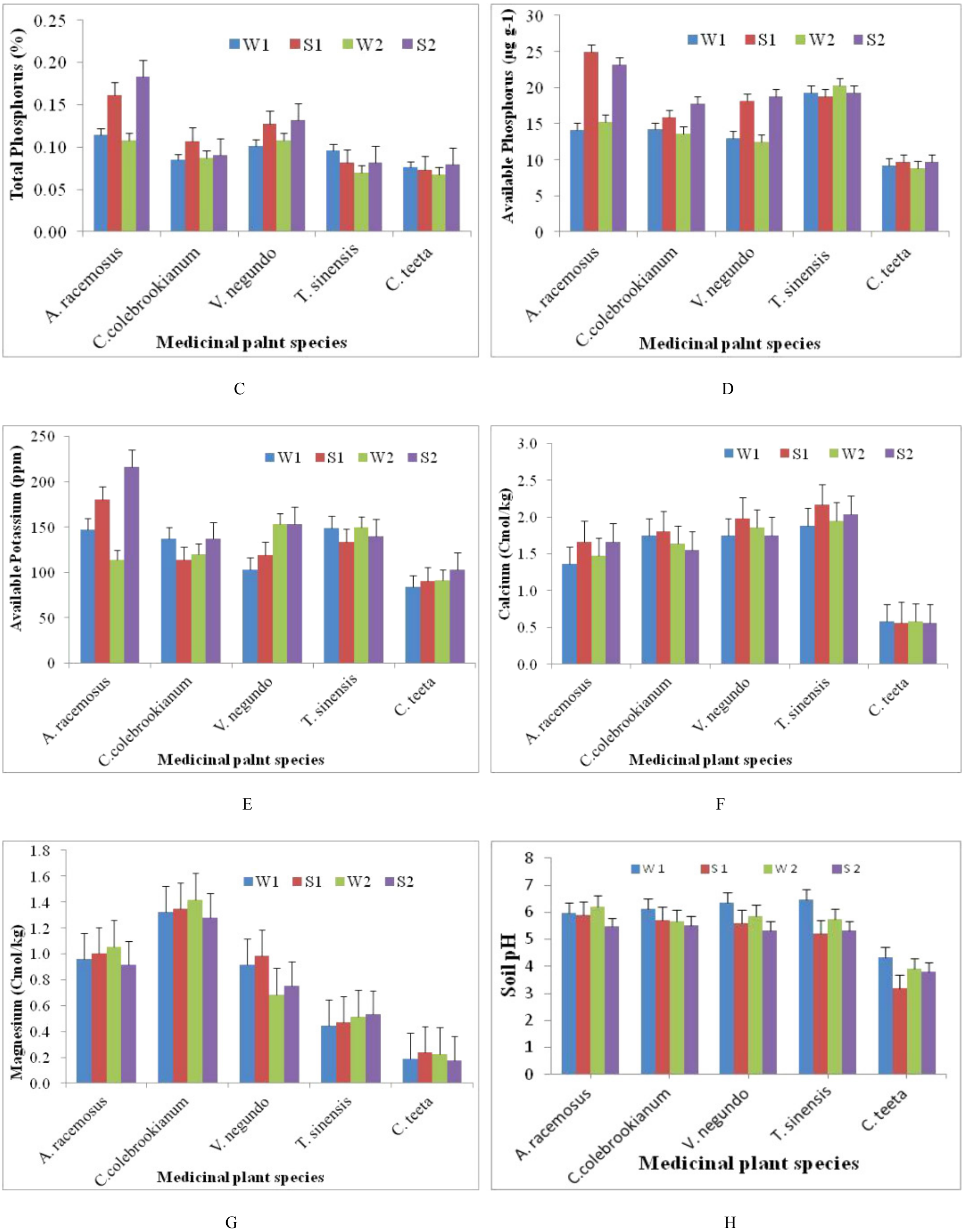

Figure 2. Soil Organic carbon (A), total nitrogen (B), total phosphorus (C), available phosphorus (D), available potassium (E), calcium (F), magnesium and pH (H) of rhizospheric soils of the five medicinal plants. (Vertical bars indicate standard error)

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