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Soil Health and Insects Harmonizing Soil and Plant Health in Agroecosystems of Sirumalai Hills, Dindigul District, Tamil Nadu

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Abstract

Soil analysis is usually carried out to check soil quality, nutrient content, and changes in various soil parameters and thus provide all the information necessary to understand the nutrient inputs needed to improve the soil. To achieve the expected yields, it is essential to understand the quality of the soil in advance. Soil may be tested for nutrient content, moisture content, texture, and pH amongst other factors to procure more information. It changes its properties with respect to the environment. Soil reflects both natural and human activities. It turns its properties into ecological problems. Two desirable functions of healthy soil are nutrient cycling and insect suppression. Insects can affect soil and plant health directly by feeding on pests or serving as alternative prey for larger predatory arthropods. In this study, soil quality such as pH, electrical conductivity (EC), nitrogen, phosphorus, potassium, iron, zinc, manganese and chromium were measured in sediment samples from Sirumalai hill. The results show that the soil contains enough organic carbon and nutrients for the growth of microbes and plants.

***Key words*:** Soil nutrient, Sirumalai, Insect and soil relation, Detrital shunt

Soil is a multicomponent, multifunctional system that influences the structure and functioning of arable ecosystems through the activities of diverse soil organisms interacting with the abiotic environment [1]. The interactions between the biotic and abiotic components of soil create a multifunctional system that is essential for sustaining arable ecosystems and supporting agricultural productivity. Understanding these interactions is crucial for sustainable soil management practices that maintain soil health and ecosystem resilience. These activities are critical for ecological processes that decompose soil organic matter (SOM) to release or immobilize nutrients, stabilize soil through aggregate formation, and promote plant growth [2-3]. Plants benefit from interactions with soil microfauna in the form of protection against pathogens and pests, attraction of beneficial insects, and increased tolerance to abiotic and biotic stress [4]. The Agricultural Natural Resources Conservation Service defines soil health as "the continued ability of the soil to function as a vital living ecosystem that sustains plants, animals, and people" [5]. Soil health integrates physical, chemical and biological characteristics characterized by an emphasis on biological properties such as biodiversity, food web structure and ecosystem function [6]. A large diversity of organisms inhabits healthy soils in both managed and unmanaged ecosystems, where they support ecosystem multifunctionality, suggesting that soil biodiversity is a key factor in regulating ecosystem functioning [7]. Soil quality depends on climate change. The type of soil depends on the type of humus and the grain size of the rock that creates clay soil, silt soil, sand, etc. The benefits that soil offers support the ecosystem by encouraging plant growth, regulating the rate, purity of water, recycling nutrients using dead animals and plants as substrates, it helps to change the atmosphere and place for the life of animals, insects and microbes.

The main purpose of soil testing and analysis of soil samples from a specific area is to offer an in-depth understanding of soil composition, soil productivity and its biological activity and to provide recommendations for overall improvement of soil health. soil [8]. It is very important that the relationship between soil nutrient and its impact keep in mind other parameters in the region in order to effectively use the information obtained from the results and analysis of soil testing procedures [9]. The process of soil testing and analysis further assists in promoting long-term soil nutrition and overall soil health by promoting organic farming and other natural practices that keep the soil fertile and keep the side effects of man-made chemicals at bay [10]. Most soil testing processes involve analyzing a soil sample for the presence of nitrogen (N), phosphorus (P) and potassium (K) and other nutrients [11]. An optimal level of nitrogen in the soil ensures the correct growth of plants, since this element forms a key part of the plant structure, which is particularly important for the formation of fruits of plant organs and the specific cellular differentiation of buds, among other things, it increases the capacity of leaves for photosynthesis. function [12]. After nitrogen, phosphorus (P) ranks second in supporting overall soil fertility. its nutrients are usually required by plants in sufficient quantities because it plays a vital role in various plant development processes, including fruit formation, aids in plant reproduction by aiding

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the flowering and seed formation process, and promotes overall plant growth by promoting photosynthesis (phosphorus is a key element of the plant's energy currency ATP), supports cell reproduction, especially meristematic tissues and root growth. Phosphorus (P) also plays an important role in the process of nitrogen fixation in the root nodules of gymnosperms. However, this nutrient is naturally low in most soils [13]. The key function of potassium (K) as a soil nutrient is to support nitrogen metabolism while aiding overall plant growth, especially root system care [14]. The overall growth and productivity of a plant is governed by a number of factors, particularly the content of nutrients taken up by different parts of the plant such as roots, leaves and stem. Different crops have different specific requirements for different essential elements, especially crops may show deficiency symptoms [15]. After a careful study of the literature, it became clear that there is a need to find out the soil quality of Sirumalai Hill, Dindigul District, Tamil Nadu. Therefore, this study was attempted.

MATERIALS AND METHODS

In the present study, 10 sampling station were fixed in the Sirumalai Hills, Dindigul, Tamil Nadu **(**Fig 1), stations are namely Thenmalai (S_1), Agasthiyar Malai (S_2), Palaiyur (S_3), Puthur (S_4), H.P.B. - 13 (S_5), H.P.B. - 08 (S_6), H.P.B. - 03 (S_7), Check Post (S_8), Natham main Road (S_9), Dindigul Junction (S_{10}). Sirumalai is an area of 60,000 acres (200 km^2) located 25 km (16 mi) from Dindigul, 90 km (56 mi) from Madurai, and 125 km from Trichy, Tamil Nadu, India. There are many high hills in the area Sirumalai range is the last mountain range of the Eastern Ghats. The nearest Eastern Ghats hills to Sirumalai Hills are the Narthamalai Hills. Sirumalai is a dense forest region with a mild climate throughout the year. With an altitude of 1600 meters above sea level, it contains diversified flora and fauna. The hill has 18 hairpin bends.

Collection of samples

The soil samples collected at a depth of 15cm from Sirumalai hills, Dindigul district, Tamil Nadu, and was selected for the present study. The collected soil samples were removed and freed from debris, stones and then sieved. The sieved sample (1 kg) was packed and sealed in an airtight Zip-lock plastic cover and sent for nutrient analysis. Analysis of soil nutrients was determined by ICAR, soil testing laboratory, Tiruchirappalli.

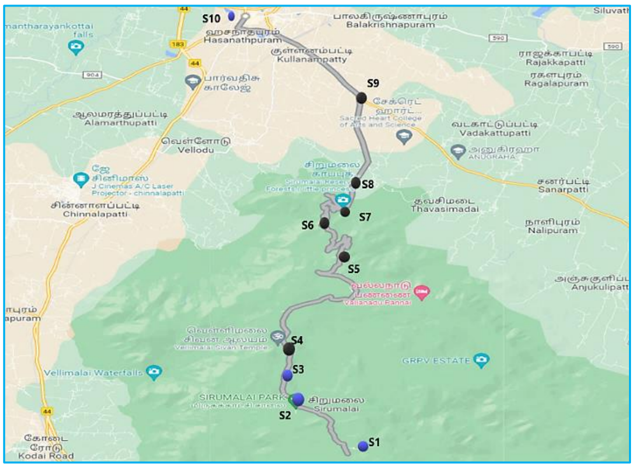

Fig 1 Map showing the sampling station in Sirumalai hills

RESULTS AND DISCUSSION

The physical parameter pH and EC were detected in Sirumalai hills sediments. The observed pH was ranged from 6.46 (S_9) to 8.02 (S_{10}). The electrical conductivity level between 0.18(d/Sm) in S_2 and 0.28 (d/Sm) in S_6. The macronutrients nitrogen, phosphorous, and potassium content was analyzed in Sirumalai hills sediments. The minimum nitrogen content was 69.4 in S_2 and the maximum 96.6 in S_8. The phosphorous content was found 2 in S_9 and 6 in S_3. The potassium content ranged from 100 (S_7) to 298 (S_5). The micronutrients iron, manganese, zinc and chromium levels were analyzed in the sediments samples of the Sirumalai hills. The Iron content was between 3.11 ppm in S_6 and 12.6 ppm in S_4. The minimum manganese content was 1.47 ppm in S_9 and the maximum 6.26 ppm in S_8. The zinc content was found 1.28 ppm in S_9 to 0.33 ppm in S_8. The chromium level ranged between 0.16 ppm in S_9 and 0.97 ppm in S_6 (Table 1-3).

Table 1 Nutrient content in sediment samples of Sirumalai in 2019

Station name	pH	EC (d/Sm)	N (%)	P	K	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cr (ppm)
S_1: Thenmalai	7.92	0.20	72.8	2	177	3.79	5.41	0.72	0.93
S_2: Agasthiyar malai	7.83	0.18	71.4	3	279	5.41	4.0	0.63	0.94
S_3: Palaiyur	7.84	0.20	74.6	4	234	7.26	4.2	0.65	0.92
S_4: Puthur	7.89	0.22	82.0	3	220	12.6	4.65	0.68	0.94
S_5: H.P.B. - 13	7.76	0.23	78.4	4	274	3.68	4.01	0.68	0.71
S_6: H.P.B. - 08	7.37	0.26	95.2	3	263	4.9	4.9	0.42	0.94
S_7: H.P.B. - 03	6.97	0.26	93.8	3	107	3.11	5.0	0.41	0.72
S_8: Check post	7.10	0.21	96.6	4	100	6.88	6.17	0.33	0.59
S_9: Natham main road	6.46	0.24	85.4	3	111	4.16	1.47	1.28	0.16
S_{10}: Dindigul junction	6.58	0.24	87.2	3	126	5.21	2.24	0.98	0.26

Soil health at the intersection of decomposition and pest control

Interactions between soil-dwelling organisms and plants not only influence plant growth and diversity, but these interactions can cascade into higher above- and below-ground trophic groups such as herbivores, parasitoids, hyperparasitoids and pollinators [16]. Both direct and indirect interactions with soil organisms affect the health of plants and aboveground communities [1]. Microarthropods can affect soil and plant health directly by feeding on pests or serving as alternative prey for larger predatory arthropods. Many mechanisms and types of interactions likely contribute to the effects of micro-organisms on pest control and plant protection in agricultural ecosystems. Effects on plant nutrition, nutrient balance, soil and plant health.

Plant nutrition

Plants feed soil food webs through rhizodeposits, such as root exudates, and surface accumulation of dead organic matter [17]. Root exudates are a source of carbon (C), which passes directly through rhizospheric microorganisms. These inputs can modify existing C fluxes in the food web, including CO_2 efflux from soil and litter decomposition [18]. Crop harvest, crop phenology and abiotic stress all affect the quality and quantity of root exudates into the soil [19]. The grazing activity of micro-organisms increases the efficiency of mineralization of nutrients above the efficiency of the microbes themselves. Decomposition is the physical breakdown and biochemical conversion of dead organic material into simpler organic and inorganic molecules. Decomposition is the physical breakdown and biochemical conversion of dead organic material into simpler organic and inorganic molecules [20]. Litter decomposition and stabilization of soil organic matter (SOM) can affect other soil properties such as sorption, nutrient availability, pH, redox potential and water holding capacity. These soil properties directly or indirectly support many essential ecosystem services including crop production, clean water, flood protection and climate regulation [21].

Table 2 Nutrient content in sediment samples of Sirumalai in 2021

Station name	pH	EC (d/Sm)	N (%)	P	K	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cr (ppm)
S_1: Thenmalai	7.98	0.19	70.8	3	169	4.26	5.75	0.69	0.89
S_2: Agasthiyar malai	7.75	0.21	69.4	4	270	5.84	4.12	0.58	0.92
S_3: Palaiyur	7.80	0.19	74.5	6	242	7.65	4.32	0.62	0.90
S_4: Puthur	7.86	0.21	80.1	4	218	11.9	5.45	0.67	0.97
S_5: H.P.B. - 13	7.80	0.20	79.1	5	298	4.86	4.72	0.68	0.70
S_6: H.P.B. - 08	7.25	0.25	95.4	4	272	4.53	5.24	0.39	0.96
S_7: H.P.B. - 03	7.01	0.2	92.9	2	112	3.45	4.94	0.43	0.74
S_8: Check post	7.12	0.20	95.8	3	108	7.23	6.26	0.38	0.61
S_9: Natham main road	6.54	0.25	84.6	2	124	4.84	1.78	1.12	0.24
S_{10}: Dindigul junction	6.62	0.24	88.1	2	136	5.45	2.34	1.08	0.32

Table 3 Nutrient content in sediment samples of Sirumalai in 2022

Station name	pH	EC (d/Sm)	N (%)	P	K	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cr (ppm)
S_1: Thenmalai	8.02	0.24	73.2	3	173	3.97	5.24	0.78	0.96
S_2: Agasthiyar malai	7.92	0.20	72.6	3	280	5.64	4.15	0.67	0.92
S_3: Palaiyur	7.96	0.22	75.4	5	242	7.26	4.24	0.71	0.90
S_4: Puthur	7.86	0.21	83.0	3	228	12.0	4.78	0.72	0.96
S_5: H.P.B. - 13	7.80	0.20	79.4	5	282	3.84	3.98	0.70	0.69
S_6: H.P.B. - 08	7.42	0.28	94.8	3	272	5.02	5.20	0.50	0.97
S_7: H.P.B. - 03	7.16	0.27	94.1	4	110	3.42	4.98.	0.52	0.77
S_8: Check post	7.28	0.22	95.9	4	106	7.10	6.25	0.42	0.62
S_9: Natham main road	6.52	0.25	85.3	3	122	4.22	1.82	1.12	0.22
S_{10}: Dindigul junction	6.74	0.26	87.9	4	131	5.10	2.32	1.06	0.38

Ingestion of living plant materials, detritus and attached organisms by micro-organisms converts energy into biomass of micro-organisms and possibly unassimilated material into faeces [22]. The chemical composition of microorganism feces differs from the ingested food [6]. For example, Collembola feces contained more than 40 times more nitrogen NO_3 than the fungi and algae they fed on [23]. Although faeces provide a surface that is exposed to colonization by microorganisms [2], a change in carbon chemistry can affect the rate of decomposition. Fauna also participates in the decomposition and incorporation of manure.

Effects on nutrient balance

Soil and plant chemistry and their interactions influence behavioral and developmental responses in insect herbivores [24]. The mineral balance hypothesis [25] posits that pest problems are associated with crop nutrient imbalances and destruction of soil life. Excess soluble nitrogen (N) in the soil increases cellular nitrogen, ammonia, and amino acids in plants, resulting in a temporary accumulation of free nitrogen, sugars, and soluble amino acids that promote the growth and reproduction of insect pests and diseases. Beanland *et al*. [25] considered biologically healthy soil essential for balanced plant uptake of mineral nutrients, especially micronutrients, and that micronutrient deficiencies inhibit protein synthesis and lead to nutrient accumulation in plant tissue that promotes pests and diseases.

In addition, soils with high SOM content and biodiversity have an improved capacity to absorb and store water, thereby reducing water stress. Water stress increases susceptibility to insects, hypothetically by limiting protein synthesis [24], which in turn increases soluble N in leaves, making tissues more nutritious for many insects [26]. Furthermore, inefficient biochemical pathways in such plants lead to the accumulation of simple sugars, free amino acids and peptides, providing an enriched diet for arthropod herbivores. In laboratory experiments, any deleterious effects of soil enrichment on herbivorous insects were at least partially mediated by plants [27]. Consistent with the mineral balance hypothesis, the mineral content of plant leaves explained 40–57% of the variation in beetle populations observed in field plots [28].

CONCLUSION

Soil health is a key factor in maintaining food security. Soil scientists and microbial ecologists often recognize the role of microorganisms in decomposition and mineralization cycles, but pay less attention to the role of micro- and meso-invertebrates. Bacteria and fungi, are well-known for their role in decomposition and mineralization cycles, contributing to nutrient availability for plants. Insects affect SOM directly by fragmenting detritus, indirectly by affecting microbial activity, and affect fluxes between different SOM pools by multichannel feeding. Soil health is a key factor in maintaining food security. Soil nutrients are exchanged between organic matter, water, and soil, and these form the basic component of soil fertility. the obtained results of this study show that organic carbon, minerals and microbes were moderate in amount to maintain soil water holding capacity and fertility. We strongly agree with soil fauna in food webs and biogeochemical models to increase our understanding of soil function. Understanding the impacts of environmental change on relationships between soil fauna and ecological function is critical to the future sustainability of global food and fiber production systems, particularly in the context of global climate change.

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