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Biochemical Health of Soil of a Wide Agricultural Land of Birbhum District in West Bengal

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Abstract

For many years soil analysis has been used as an aid to assess biochemical health of soil and plant nutrient management. Achieving and maintaining appropriate level of soil fertility, especially plant nutrient availability is of paramount importance if agricultural land is to remain capable of sustaining crop production at an acceptable level. The Birbhum district, known for its agricultural practices, faces several challenges related to pollution arising from farming activities. Soil sampling and analysis is the first of three important steps in managing the nutrients required by plants. The second is the interpretation of analytical data leading to the third step, recommendation for nutrient addition. In this paper we would like to explore the biochemical health of soil of Birbhum District having widespread agricultural land. Through analysis we would like to explore the availability of phosphorus, nitrogen and potassium, physical, physiochemical and chemical parameters of the agricultural soil. It will give a better future to poor farmers of this region through good production of crops and simultaneously the economic condition of this region will improve.

Keywords

Biochemical health, Soil analysis, Soil fertility, Plant nutrient, Agricultural land.

1. Introduction

The formation of soil is a complex process of weathering including dynamic function of parent material, climate, topography, biology and time. Geographical diversity influences the fertility and productivity of the soil [1-3]. The parent materials vary across the region to form soil clays with high reactivity. At the beginning of new millennium, global agriculture is at critical stage since daily we are facing several challenges including alarming increase of world population [4,5]. Environmental pollution and drastic effects of global warming led to the genetic erosion of biodiversity and malnutrition of agricultural field [6-8]. So, there is an increase in demand for soil analysis by applying modern techniques for better productivity of crops. Our target is to nourish the future generation of agricultural solders and to solve the emerging agricultural problems [9].

West Bengal has several backdrop agroclimatic zones comprising mainly of small farmers and firm entrepreneurs. One of them is Khujutipara, Nanoor region which is located in Birbhum district of West Bengal. Its geographical coordinates are 23.608^{o}N latitude and 87.892^{o}E longitude with an elevation of 60m above mean sea level, having a population around 2600. The surroundings of our college, Chandidas Mahavidyalaya are mainly agricultural land with a growing field of rice and potato. Population of this region is also very low and almost all belong to minority category. Most of them are farmer and their main source of income is cultivation. At this point, our responsibility comes to do some social work to help those poor farmers. As a chemist, nothing will be better than to investigate the biochemical health of soil which will be highly beneficial for cultivation purpose.

The prime focus of this paper is to assess the productivity status of soil and estimation of the available nutrients in the soil. To find out the suitability of soil for cultivation, it necessitates the determination of the acidity and alkalinity of concerned soil samples along with NPK analysis. Based on the results, the appropriate amount of required fertilizers will be recommended. Nevertheless, high quality soil analysis is the basis of planning of fertilizing and thus the efficacy of entire production cycle, which propagates in a high-quality yield and better firm management. The main objective is to obtain reliable information about the soil condition in a particular plot and its change over time.

In West Bengal, Bidhan Chandra Krishi Vishwavidyalaya (BCKV) is a renounced institute to carry out research in agricultural field. Dr. Prashanto Kumar Bandopadhay, Professor and Scientist of BCKV is involved in studying methods and strategies to characterize soils physically and hydraulically at various temporal and spatial scales. Carbon sequestration in soil and pseudo transfer functions for easy determination of physical properties of soil quality indicators are investigated by him. In addition, soil fertility and nutrient management studies are also conducted by the same research group [10]. Dr. Amal Chandra Das, Senior Professor from BCKV is also a soil scientist who mainly involved in studying soil microbiology. Pesticides/herbicides *vs* soil microbe interaction, microbial decomposition of organic matter, biological nitrogen fixation and microbiological transformations in soil ecosystem are studied by him [11]. Dr. Tapas Biswas and Dr. Pabitra Kumar Mani are also renounced expertise in soil chemistry from the same institute [12,13]. Dr. N. K Mandal from Burdwan University (B U) has enlightened the thrust area of soil science by integrated nutrient management technique for various cropping systems in several districts of WB [14]. Dr. RajnarayanSaha from NIT-Durgapur has worked on diversified areas of environmental chemistry such as soil analysis, water treatment, pollution control etc.15-17 Dr. A.K Biswas from Indian Institute of Soil Science (IISS), mainly working on phosphorus chemistry in soils and developed methods for soil organic carbon and N turnover model in light of C saturation and stabilization theory. He is also investigating relative soil quality index to access soil health under different agro-ecoregions of the country [18]. Dr. Brahma S. Dwivedi from Indian Agricultural Research Institute (IARI) is another great scientist in the field of soil chemistry. His work involves soil and plant analysis for heavy metals and pollutant elements with an advisory board for balance fertilizer use and management of problematic soils [19]. *Kubala-kukuset al* from Poland have introduced X-ray spectrometry and X-ray microtomography techniques for multi-elemental soil sample analysis. *Paolo Porto et al.* have studied the recent changes in soil redistribution rate within a small catchment in southern Italy [21]. *Jian Li et al* from China have evaluated thyroid-disrupting activities in soil sample. Interestingly, a recombinant thyroid receptor (TR) gene yeast assay combined with Monte Carlo simulation were used to evaluate and characterize soil samples [22]. *Shiping Wang et al* have explored innovative sampling design for monitoring soil organic carbon in Tibetan grasslands [23]. Isotopic analysis of soil samples from archaeological site has done by Gregory D. Lattanzi and Gary E. Stinchcomb of USA

[24]. This review article discusses the difference between the composition of samples, the influence of procedures with respect to the preparation of samples as regards their morphology and, finally, a quantitative analysis have made [20].

2. Results and Discussion

2.1. pH and Electrical Conductivity (EC) of Soil

First, we have to know what is soil *p*H and EC? It's commonly beneficial to describe an environment, like a body of water or soil, by gauging its pH and electrical conductivity (EC). *p*H indicates the acidity of water or soil through its hydrogen ion concentration, calculated as the negative logarithm of that concentration or *p*H = -log[H^+], where the brackets around the H^+ symbolize "concentration". The *p*H of a material ranges on a logarithmic scale from 1-14, where pH 1-6 are acidic, pH 7 is neutral, and pH 8-14 are basic. Lower *p*H corresponds with higher [H^+], while higher *p*H is associated with lower [H^+]. Soil *p*H measurement methods include using a *p*H meter (typically by combining soil with water or a salt solution) or employing a dye to observe colour changes, matched with a *p*H chart for determination. The latter technique often involves a kit equipped with essential chemicals [25].

Electrical conductivity (EC) measures the dissolved substances in a liquid solution, indicating how well these substances can conduct an electric current within that solution. EC is measured in units called Siemens per unit area (e.g. mS/cm, or miliSiemens per centimetre), and the higher the dissolved material in a water or soil sample, the higher the EC will be in that material. Soil electrical conductivity (EC) can be assessed using electrodes directly inserted into the soil or by drawing out soil water through a lysimeter—an instrument utilizing suction to extract soil or groundwater. Groundwater EC can also be determined by employing a probe inserted into a well (a perforated tube in the ground for measuring water table height) or a piezometer (a tube solely open at the base, assessing water potential at a specific depth). The electrode approach involves a specialized set of probes, two of which administer electrical current into the soil while the other two measure the resulting voltage drop. To determine soil water EC, lysimeter, well, or piezometer-extracted water is measured. Alternatively, a probe connected to a meter can be lowered into a well or piezometer to assess liquid EC in that manner [26,27].

Table 1: Soil pH and EC values of different regions of Birbhum district [28,29]

Investigated Area	Sample No.	*p*H	EC(dSm^{-1})
Mayureswar	S1	5.86	0.02
	S2	4.74	0.03
	S3	5.71	0.02
	S4	5.15	0.04
Nalhati-1	S1	6.35	0.02
	S2	6.71	0.07
	S3	6.54	0.02
	S4	6.37	0.01
Bolpur	S1	4.70	0.02
	S2	4.99	0.02
	S3	5.28	0.02
	S4	5.42	0.02
Md Bazaar	S1	4.79	0.02
	S2	4.83	0.02
	S3	6.18	0.04

	S4	4.74	0.01
Rajnagar	S1	5.23	0.05
	S2	5.79	0.07
	S3	5.72	0.02
	S4	5.30	0.02

In a recent study, *M. Sahu et al* reported the pH levels of the surface soils (0-15 cm) in the investigated areas of Mayureswar, Nalhati-1, Bolpur, Mohammad Bazaar, and Rajnagar blocks (Table1) varied between 4.86 to 6.02, 5.18 to 7.03, 4.23 to 6.21, 4.03 to 6.19, and 5.11 to 6.84, respectively. These readings indicated a range from extremely acidic to neutral, with the majority of soils being moderately acidic (53%) to strongly acidic (36%) in nature.[28] *Shukla et al* also noticed comparable findings in the soils of Pamgarh block within the Janjgir-Champa district [29].

All soil samples exhibited a normal condition (EC < 1.0 dSm-1) (Table 1) conducive to plant growth. This normal EC level could be attributed to the leaching of soluble salts into lower soil layers as reported by M. Sahu *et al*. [28].

2.2. Soil organic C

Soil organic carbon (SOC) signifies the carbon content remaining in the soil following organic matter decomposition. This factor serves as a crucial indicator in evaluating soil health as it directly influences soil quality and food production. It serves as a natural energy reservoir sourced from soil organic matter, recognized as a highly esteemed biopolymer within the Earth. SOC significantly enhances soil biological, chemical, and physical characteristics, including water retention, structural stability, and soil quality. Moreover, it plays a critical role in the generation of organic acids essential for soil mineral dissolution, aiding plant accessibility to nutrients while also influencing nutrient leaching [30,31].

In the studied region of Birbhum district, the organic carbon content averaged between 0.18 to 0.81%, with an overall mean of 0.60%. Notably, the soils in east Ramchandrapur Mouza of Mayureswar block (Table 2) exhibited the highest organic carbon content, while Jaljaliya Mouza of Bolpur block recorded the lowest levels. This discrepancy might be attributed to the higher sand content in the soils of the latter block, aligning with *Singh et al.'s* earlier findings [28,32].

2.3. Available Sulfur of Soil

Sulfur is linked to the cultivation of crops with exceptional nutritional and market value. Across India, sulfur deficiencies are prevalent. The intensified agricultural practices involving high-yield varieties, multiple cropping, and the use of high-analysis sulfur-free fertilizers, combined with limited or no application of organic fertilizer, have led to the depletion of soil sulfur reserves. Soils lacking sufficient sulfur cannot independently supply the required amount to meet crop demands, leading to sulfur-deficient crops and suboptimal yields [33]. Sulfur plays a role in the creation of chlorophyll, glucosides, and glucosinolates (such as mustard oils). Additionally, it contributes to activating enzymes and sulphydryl (SH) linkages, which serve as the source of pungency in onions, oils, and other substances [34]. Sulfur ranks as the fourth most crucial nutrient in Indian agriculture, following nitrogen, phosphorus, and zinc [35]. Its primary role lies in synthesizing proteins, oils, vitamins, and flavorful compounds within plants. Sulfur is a component of three amino acids—Methionine (21% S), Cysteine (26% S), and Cystine (27% S)—which form the fundamental units of protein. Approximately 90% of plant sulfur is contained within these amino acids [36].

According to *M. Sahu et al* the soil in the study area exhibited varying sulfur (S) content, ranging from 7.97 to 21.80 kg ha^{-1}, 17.01 to 22.31 kg ha^{-1}, 10.56 to 22.33 kg ha^{-1}, 13.31 to 22.35 kg ha^{-1}, and 10.31 to 21.93 kg ha^{-1} [20]. The mean S content was measured at 12.71 kg ha^{-1}, 19.75 kg ha^{-1}, 17.36 kg ha^{-1}, 18.98 kg ha^{-1}, and 16.82 kg ha^{-1} across the Mayureswar, Nalhati-1, Bolpur, Mohammad Bazar, and Rajnagar blocks, respectively (Table 2). Notably, the lowest S value of 7.97 kg ha^{-1} was found in east Ramchandrapurmouza within the Mayureswar block, while the highest value of 22.35 kg ha^{-1} was observed in the soils of DukshinGopinathpurmouza in Bolpur block, as well as Fullaipur and Tanshulimouza in Mohammmad Bazaar block. This indicates a deficiency in available sulfur content within the soils of Birbhum district, aligning with findings from *Ghosh et al*. [37].

Table 2. Soil organic C % and Available Sulfur values of different regions of Birbhum district. [32,37]

Investigated Area	Sample No.	Organic C (%)	Available S(kg/ha)
Mayureswar	S1	0.54	21.81
	S2	0.81	14.36
	S3	0.72	10.11
	S4	0.62	10.64
Nalhati-1	S1	0.54	19.15
	S2	0.75	22.32
	S3	0.74	21.28
	S4	0.68	22.12
Bolpur	S1	0.42	19.15
	S2	0.32	17.56
	S3	0.55	10.64
	S4	0.44	10.57
Md Bazaar	S1	0.73	14.36
	S2	0.54	19.47
	S3	0.75	22.34
	S4	0.61	21.28
Rajnagar	S1	0.50	12.41
	S2	0.74	16.32
	S3	0.69	15.43
	S4	0.75	21.79

A comparative study of available S with surrounding district of Birbhum was carried out by *G.K Ghosh et al*. [38] Birbhum district shows the highest deficiency, with 87% of exterior soil samples and 67% of underground soil samples in Burdwan district falling into the low sulfur range. Using the critical level approach, the available sulfur deficiency in surface soils across different districts ranks as follows: Birbhum (87%), Bankura (38%), Burdwan (33%), and Purulia (9%). For sub-surface soils, the deficiency order stands at Burdwan (67%), Bankura (57%), Birbhum (40%), and Purulia (26%).38

2.4. Available N, P, K of Soil

Soil nutrients play a pivotal role in sustaining healthy plant growth, and among these, NPK—nitrogen (N), phosphorus (P), and potassium (K)—are fundamental elements. Nitrogen is essential for leaf and stem development, aiding in the synthesis of proteins and chlorophyll. Phosphorus promotes strong root development, supports flowering, and aids in energy transfer within plants. Potassium contributes to overall plant health by regulating water uptake, improving disease resistance, and enhancing the synthesis of carbohydrates. The presence and balance of NPK in soil are crucial factors influencing crop productivity and plant vitality. Regular assessment and supplementation of these nutrients are vital for maintaining fertile soils and ensuring optimal agricultural yields [39,40].

The determination of N, P, and K values in the sample relies on the absorption of light specific to each nutrient. Employing an optical transducer as a detection sensor, the setup integrates three LEDs as light sources and a photodiode as the light detector. Each LED emits light at a wavelength tailored to match the absorption band of the respective nutrient. As the nutrient absorbs the LED light, the photodiode captures the reflected light from a reflector and converts it into a current. This system operates using an Arduino microcontroller for data acquisition, converting the transducer output into a digital display reading. Through testing on various soil samples, this optical transducer effectively categorizes the NPK soil content into High, Medium, and Low levels [41].

Available Nitrogen

In the Mayureswar block, all soils fell within the medium category for available N content. In Nalhati-1 block, 85% of soils were in the medium category, with the remaining 15% categorized as low for available N content. Bolpur block showed a range from low (40%) to medium (60%) available N content. Contrastingly, in Md Bazaar, 60% of samples were categorized as low, while 40% fell into the medium category for accessible N content. Rajnagar block exhibited 90% of soils in the low category and the remaining 10% in the medium category for available nitrogen content. The highest observed N content was in the soils of Dukshin Gopinathpur Mouza within the Bolpur block (399.96 kg ha^{-1}), while the lowest value was recorded in Khayarakuri Mouza of Md. Bazar block (128.79 kg ha^{-1}). These findings strongly suggest a notably low efficiency of applied N, likely due to various loss mechanisms such as NH_3 volatilization, denitrification, chemical and microbial N-fixation, leaching, and runoff [28].

Available Phosphorous

The available phosphorus (P) in the study area showed a range from an average of 16.42 to 28.93 kg ha^{-1}, with a mean of 22.45 kg ha^{-1}. Across the Mayureswar, Nalhati-1, Bolpur, Mohammad Bazaar, and Rajnagar blocks, the available P status varied from 22.66 to 38.71 kg ha^{-1}, 21.73 to 30.98 kg ha^{-1}, 16.07 to 29.27 kg ha^{-1}, 11.05 to 22.28 kg ha^{-1}, and 10.62 to 23.45 kg ha^{-1}, respectively, within the soils of Birbhum district. In Mayureswar block, 85% of soils were categorized as low in available P content, with 15% falling into the moderate category, while all soil samples from the other four regions were classified as low. The lowest availablephosphorus content was observed in soils from Ganeshpurmouza of Rajnagar block (10.61 kg ha^{-1}), while the highest value (38.70 kg ha^{-1}) was recorded in soils from Talwanmouza of Mayureswar block. Factors affecting available phosphorus content in soils include past fertilization, pH levels, organic matter content, soil texture, various soil management practices, and agronomic methods [28,42].

Available Potassium

The available potassium (K) content within the soils of the study area showcased a range from 130.72 to 201.78 kg ha^{-1}, averaging at 163.54 kg ha^{-1}. Across the Mayureswar, Nalhati, Bolpur, Mohammad Bazar, and Rajnagar blocks within Birbhum district, the values spanned from 103.63 to 147.72 kg ha^{-1}, 213.97 to 287.13 kg ha^{-1}, 95.27 to 189.31 kg ha^{-1}, 100.43 to 136.10 kg ha^{-1}, and 140.32 to 248.77 kg ha^{-1}, respectively. The average values for these blocks stood at 122.67 kg ha^{-1}, 254.33 kg ha^{-1}, 127.38 kg ha^{-1}, 117.19 kg ha^{-1}, and 196.13 kg ha^{-1}, respectively.[20] These results seasoned the finding as depicted by *Shukla* (2011) [21] in the Alfisols orders of Pamgarh block in Janjgir-Champa district (C.G.) [43].

Table 3. Soil NPK values of different regions of Birbhum district [28]

Investigated Area	Sample No.	Available N Kg/ha	Available P Kg/ha	Available K Kg/ha
Mayureswar	S1	319.94	33.20	110.60
	S2	396.39	38.70	139.25

	S3	371.30	33.67	129.46
	S4	348.01	32.18	124.60
Nalhati-1	S1	371.30	30.22	223.37
	S2	396.39	29.90	287.12
	S3	388.03	29.34	283.99
	S4	346.21	29.11	260.24
Bolpur	S1	292.71	19.67	154.32
	S2	321.13	21.99	188.34
	S3	346.21	22.56	127.27
	S4	342.88	21.03	119.19
Md Bazaar	S1	296.04	19,04	124.84
	S2	229.14	15.92	107.63
	S3	332.84	21.28	136.09
	S4	237.50	16.74	108.43
Rajnagar	S1	195.69	20.82	240.34
	S2	237.50	21.81	178.80
	S3	245.86	13.20	179.96
	S4	294.64	19.94	171.90

2.5. Water holding capacity

The gaps between soil particles, known as pores, play a crucial role in allowing the movement and holding of gases and moisture within the soil profile. The soil's capacity to hold water is closely linked to the size of its particles; in clay soil, water molecules bind more tightly to the fine particles compared to sandy soil, where the coarser particles allow for less retention [44,45].

The predominant soil type in the area consists mainly of old alluvium and red lateritic soil with exposed granite veins in certain locations. The old alluvium is found alongside layers of clay, gravel, and sand, containing medium inorganic matter, phosphate, and medium to high levels of potash. However, the water holding capacity of the soil is very poor [46].

3. Conclusion

The findings of the current study led to the conclusion that the soils in Birbhum district exhibit a soil reaction ranging from strongly acidic to neutral. Additionally, they are non-saline in nature and possess a soil texture that varies from silt loam to silt. To achieve higher crop yields, farmers often employ excessive amounts of pesticides and fertilizers, leading to significant environmental issues and potential harm to soil health. The proportion of nitrogen, phosphorus, and potassium is a crucial indicator in crop production, distinguishing between balanced and unbalanced fertilization. Therefore, the application of balanced fertilizers is crucial for achieving optimal crop yield. The interplay of soil bio-chemical properties directly influences both food productivity and environmental quality. Consequently, having a fundamental understanding of soil bio-chemical properties is essential for sustainable agricultural practices. Now it is easier to determine the amount of required fertilizer to achieve the high-quality yield. In determining the amount of nutrients, at the best condition, soil can adopt upto 80 % of N, 40% of phosphorous, 60 % of K, 40 % of Mg. Soil organism present in soil organic matter function better for different vital process in soil. Finally, our country is agriculture based, so this paper will be very much beneficial for future of our country.

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