The Pharma Innovation Journal 2021; 10(11): 1236-1241

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2021; 10(11): 1236-1241

www.thepharmajournal.com
Received: 03-09-2021
Accepted: 09-10-2021

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Assessment of physico-chemical properties from different blocks of Malappuram district in the state of Kerala

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Abstract
An Assessment of Physico-chemical Properties of soil of 'Malappuram District' an allied area of Kerala was carried out in 2020-21. The prime objectives of this study were to carried out the physico-chemical properties of soil at different depths of various sites of Malappuram District, to determine the nutrient status of these soil samples and provide Soil Health Card for farmers of the Malappuram District, Kerala. For the assessment 9 sampling sites were selected. Soil samples were collected with depth of 0-15cm, 15-30cm and 30-45cm respectively. Soil textural classes were sandy loam. The study revealed that Bulk Density ranges from 1.03 Mg m^{-3} -1.33 Mg m^{-3}, Particle Density ranges from 2.01 Mg m^{-3}-2.57 Mg m^{-3}, Pore space ranges from 42.21%-59.45%, Water Holding Capacity from 59.99%-72.06%. The pH value ranged from 5.33-6.53 and Electrical Conductivity ranged from 0.13 dS m^{-1}-0.21 dS m^{-1}. Organic Carbon ranged from 0.50%-0.87%. Nitrogen (N), Phosphorous (P) and Potassium (K) ranged from 107 kg ha^{-1}-180 kg ha^{-1}, 8.6 kg ha^{-1}-18.3 kg ha^{-1} and 39 kg ha^{-1}-117.33 kg ha^{-1} respectively. Calcium (Ca), Magnesium (Mg) and Sulphur (S) ranged from 9.06 cmol (p^{+}) kg^{-1}-16.8 cmol (p^{+}) kg^{-1}, 1.8 cmol (p^{+}) kg^{-1}-11.9 cmol (p^{+}) $kg^{-1}$and 18.6 kg ha^{-1}-67.6 kg ha^{-1}respectively. It clearly indicated that soil has good Water Holding Capacity and good physical condition. The pH of soil is acidic nature and the Electrical Conductivity was suitable for all crops. Organic Carbon ranged from medium to high. These soils have low Nitrogen, Potassium and Phosphorous ranged from low to medium. Calcium and magnesium are very sufficient in this soil. Sulphur is varying medium to high, most of the samples are high in Sulphur content. There is an including awareness of the need to pay greater attention in the role of macronutrients enhancement in the soil for good soil health and proper nutrition of plant so as to attain optimum economic yield and soil is suitable for all major tropical and sub-tropical crops.

Keywords: Malappuram district, physico-chemical properties, health, tropical, soil etc.

Introduction
The soil is the most important constituent for fulfillment of all the basic needs of human beings. Soil is an important component of our farming. An eminent position in global cultivation of wheat, rice, jawar, pulses, sugarcane, vegetables and fruits etc. is occupied by Indian agriculture and reason of physical, chemical condition of whatever land is indispensable for proper implementation of the other management practices. Thus, the Physico-chemical study of Soil is very significant because both physical and chemical properties bear upon the soil productivity. This, Physico-chemical study of soil is based on various parameters like pH, Electrical conductivity, soil texture, moisture, temperature, available Nitrogen, Phosphorus and Potassium. This knowledge will help to the people who are interested to work in agriculture field. Soil testing makes complete nutrient control possibility. Fertilizer experiments are being patterned to determine economically optimum rates of nutrients application. High yields with low production costs per unit are a must in modern farming. As a result, the demand on the soil has gradually increased. Soil testing lets farmers know how much and what kind of fertilizer they must apply to be sure of returns from their investments in other improved practices (Kekane, 2015) [10].

A globally acceptable and applicable definition and methodology of assessment of soil quality or soil health are still not in place. Further, the existing knowledge provides a better understanding of the current capacity of a soil, making predictions about capacity of the soil to continue to function under a range of stresses and disturbances. Another limitation of most of the available studies is that efforts have been made to measure soil characteristics in surface soil and not in the whole profile. A simultaneous analysis of physical, chemical and biological

characteristics of soil is required to evaluate sustainability or unsustainability of different management practices (Sparling *et al*. 2004) [19].

Kerala is divided into three geographical regions: Highlands, which slope down from the Western Ghats onto the Midlands of undulating hills and valleys into an unbroken 580 km long coastline with many picturesque backwaters, interconnected with canals and rivers. The wild lands are covered with dense forests, while other regions lie under tea and coffee plantations or other forms of cultivation. Most of the state is engulfed in rich greenery which ensures a very calming experience at all times. God's own country is all about beaches, backwaters, virgin forests, golden paddy fields and rich coconut groves. A 560 km long narrow stretch of tropical land lay carefully in the south-west coast of India; Kerala is adorned with dense tropical forests, cliffs, ghats, beaches, rocky coasts, backwaters, bays and 44 rivers of coruscating brilliance. Bestowed with a pleasant and equable climate throughout the year, Kerala is a tropical land where one can relax and be at ease. The Monsoons (June-September and October-November) and summer (February-May) are the seasons markedly experienced here, while winter is only a slight drop in temperature from the normal range of 28-32°C. The most common soils seen in Kerala are coastal alluvium, mixed alluvium, acid saline soils, laterite soils, black cotton soils, red soils, hill soils and forest soils (Moossa, 1994) [12].

Study site

Malappuram District consists of 3 natural divisions, lowland, midland and highland. The low land stretches along the sea coast, the midland in the Centre and the highland region towards the East and North eastern parts. The location of Malappuram District is 75° to 77° East longitude and 10° to 12° North Latitude, in the geographical mark. In area Malappuram District covers 3,554 km^2. It includes the Gross cropped area of 2365.97 km^2, the net cropped area of 1749.31 km^2 and the district has a total forest area of 758.84 km^2. The topography of the district is highly undulating; starting from the hill tops covered with thick forest on the East along the Nilgiris, it gradually slopes down to the valleys and the small hills, before finally ending on the sandy flat of luxuriant coconut groves in the west. The district has dry season from December to February, hot season from March to May, and the South west monsoon from October to November. The South west monsoon is usually very heavy and nearly 75% of the annual rains are received during this season. The climate is generally hot and humid; the range of temperature varying between 30^{0}C and 20^{0}C. The average annual rainfall is 290mm. Four important rivers of Kerala flow through Malappuram district. They are Chaliyar, Kadalundippuzha, Bharathapuzha and Tirurpuzha. Chaliyar has a length of 169 KMs and originates from Illambaleri hills in Tamil Nadu. Malappuram District consists of 7 Tehsils / Blocks and 94 grama panchayats. Soil sampling was done from total nine villages of three Tehsils / Blocks, namely Nilambur (Block 1), Eranad (Block 2) and Tirur (Block 3). Fig 1 shows the map of study sites.

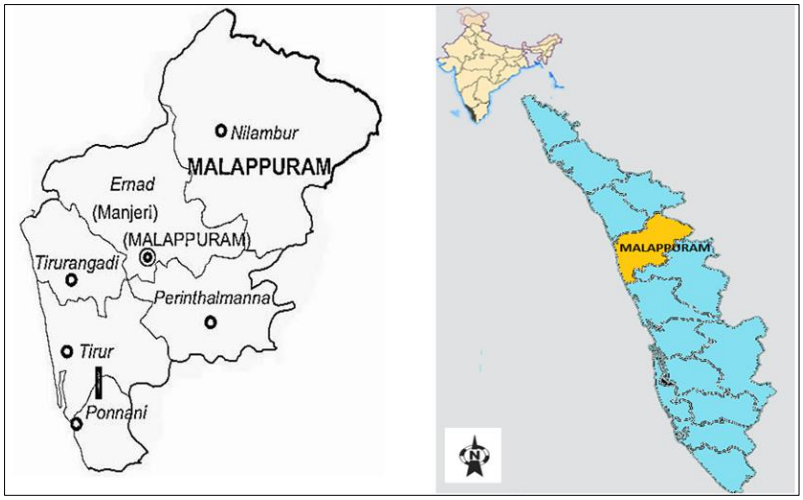

Fig 1: Map showing Study Sites

Methodology

A total of 27 soil samples were collected from different site using soil auger, screw auger and khurpi at the depth of 0-15cm, 15-30 cm and 30-45 cm. The collected soil samples were air dried in shade, clods were broken with wooden mallet and powdered soil is then sieved with 2mm sieve and analysed for Physico-chemical parameters in laboratory. The physical parameters include soil colour, soil texture, bulk density, particle density, pore space, water holding capacity, whereas chemical parameters include pH, Electrical conductivity, Organic Carbon, Macro-Nutrients (N, P, K, Ca, Mg, S). Soil textural class was determined by using Bouyoucos Hydrometer (Bouyoucos, 1927) [2]. Bulk density, Particle density, Water holding capacity was determined by using Graduated Measuring Cylinder method (Muthuaval *et al*., 1992) [13]. pH was estimated with the help of Digital pH meter after making 1:2 soil water suspension (Jackson, 1958). Electrical Conductivity was estimated with the help of Digital Conductivity meter (Wilcox, 1950) [23]. Percent Organic Carbon was estimated by Wet Oxidation method (Walkley and Black, 1947). Available Nitrogen was estimated by Alkaline Potassium Permanganate method, using Kjeldahl apparatus (Subbiah and Asija, 1956) [20], available Phosphorus was estimated by Olsen's extraction followed by Spectrophotometric method (Olsen *et al*., 1954) [15], available Potassium was estimated by Neutral normal Ammonium Acetate extraction followed by Flame photometric method (Toth and Prince, 1949) [21], Exchangeable Ca^{2+} and Mg^{2+} were estimated by Normal Ammonium Acetate saturation method (Cheng and Bray, 1951), available Sulphur was estimated by Turbidimetric method followed by Spectrophotometric analysis (Chesnin and Yien, 1950) [5].

Result and Discussion

Soil Texture (%): The texture of a soil is important because it determines soil characteristics that affect plant growth. Three of these characteristics are water-holding capacity, permeability, and soil workability. Water-holding capacity is the ability of a soil to retain water. The soil texture Sandy loam was found in all villages in three depths of 0-15, 15-30, 30-45cm. The sand, silt and clay percentage varied from 70.1-77.1 sand, 12.3-23.7 silt and 9.2-13.8 clay in Sandy loam.

Bulk Density (Mg m^{-3}): Bulk density reflects the soil's ability to function for structural support, water and solute movement, and soil aeration. Bulk density is also used to convert between weight and volume of soil. The study revealed that Bulk Density ranges from 1.03 - 1.33 Mg m^{-3}. The range and mean values of Bulk density and other Physical properties are given in Table 1.

Particle Density (Mg m^{-3}): Particle density varies according to the mineral content of the soil particles. It does not usually very a lot in most soils. The study revealed that Particle Density ranges from 2.01 Mg m^{3}-2.57 Mg m^{-3}. The particle density decreases with the increasing soil depth. Fig.2 shows Village-wise variation of Bulk density and Particle density.

Water Holding Capacity (%): The Water Holding Capacity of different depth varied from 59.99 - 72.06%. These variations were due to the silt, clay and organic carbon content and low Water Holding Capacity in sandy soils due to high sand and less silt content. The irregular trend of Water Holding Capacity with depth was due to the illuviation and eluviation of finer fraction in different horizons.

Soil pH (1:2): The study revealed that pH value ranged from 5.33-6.53 and the pH of soil is acidic nature. This range is a result of many factors, including a soils parent material and the amount of yearly rainfall an area receives. The reduction of soil pH value is due to production of acids by bacterial action in anaerobic or nitrification processes in the soil. Most cultivated plants enjoy slightly acidic conditions with a pH of about 6.5.

Soil EC (dS m^{-1}): The study revealed that Electrical Conductivity ranged from 0.13 - 0.21 dS m^{-1} and the Electrical Conductivity was suitable for all crops. Saline effect is mostly negligible in soils. The range and mean values of Electrical Conductivity and other Chemical properties of soils of different villages of Malappuram district are given in Table 2.

Organic Carbon (%): The study revealed that Organic Carbon ranged from 0.50 - 0.87% which falls in medium to high range. Soil organic carbon is a measurable component of soil organic matter. Organic matter makes up just 2-10% of most soils mass and has an important role in the physical, chemical and biological function of agricultural soils. Higher soil organic carbon promotes soil structure or tilth meaning there is greater physical stability.

Table 1: Assessment of Physical properties of Soils from different blocks of Malappuram District

Village Name	Textural Class	Bulk Density (Mg m^{-3})		Particle Density (Mg m^{-3})		Water Holding Capacity (%)	
		Range	Mean	Range	Mean	Range	Mean
Nilambur							
Nilambur Muncipal (V_1)	Sandy loam	1.17-1.33	1.25	2.22-2.85	2.52	59.52-65.00	62.14
Karulai (V_2)	Sandy loam	1.17-1.25	1.22	2.22-3.00	2.57	50.00-68.38	59.99
Chungathara (V_3)	Sandy loam	1.11-1.25	1.17	2.17-2.25	2.21	60.60-62.85	61.35
Eranad							
Edavanna (V_4)	Sandy loam	0.95-1.17	1.04	2.00-2.22	2.12	67.56-77.14	72.06
Perakamanna (V_5)	Sandy loam	1.00-1.05	1.03	2.00-2.51	2.17	65.78-63.51	70.44
Therattammal (V_6)	Sandy loam	1.00-1.11	1.03	2.22-2.50	2.31	61.76-69.23	65.03
Tirur							
Vettom (V_7)	Sandy loam	1.25	1.25	2.14-2.53	2.29	51.61-61.29	58.06
Thalakkadu (V_8)	Sandy loam	1.33	1.33	2.16-2.67	2.50	63.33-66.66	64.44
Thiruvegappura (V_9)	Sandy loam	1.07-1.11	1.09	1.81-2.22	2.01	54.76-63.41	57.72

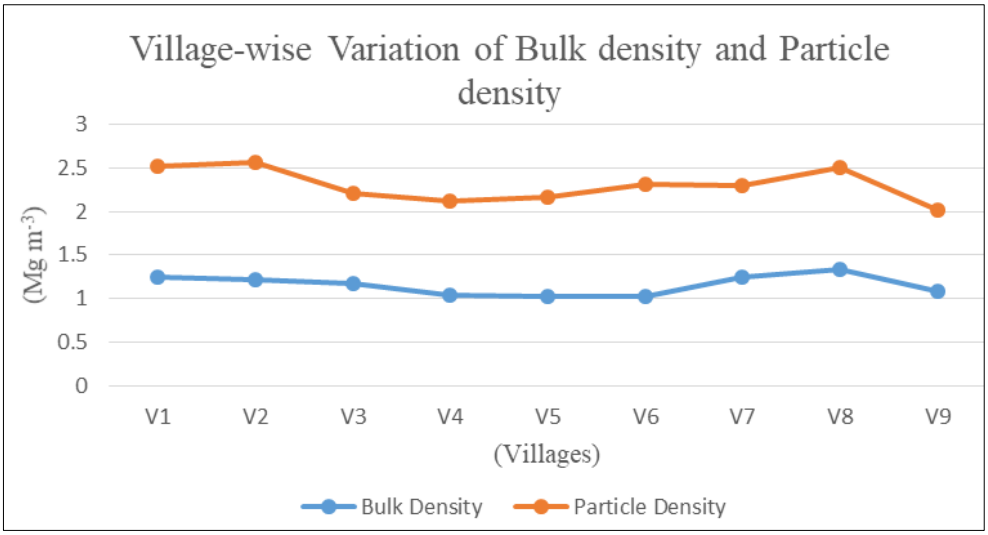

Fig 2: Graphical representation of Bulk density and Particle density in soils of Malappuram district

Table 2: Assessment of Chemical properties of Soils from different blocks of Malappuram District

Village Name	Soil pH (1:2)		Electrical Conductivity (dS m^{-1})		Organic Carbon (%)	
	Range	Mean	Range	Mean	Range	Mean
Nilambur						
Nilambur Muncipal (V_1)	5.7-5.8	5.73	0.15-0.18	0.16	0.68-0.88	0.80
Karulai (V_2)	5.9-6.1	6.03	0.14-0.17	0.15	0.65-0.86	0.74
Chungathara (V_3)	5.4-6.0	5.63	0.15-0.19	0.17	0.64-0.87	0.79
Eranad						
Edavanna (V_4)	5.5-5.8	5.66	0.13-0.17	0.15	0.41-0.68	0.50
Perakamanna (V_5)	5.2-5.5	5.33	0.17-0.19	0.18	0.86-0.89	0.87
Therattammal (V_6)	5.4-5.7	5.53	0.16-0.19	0.17	0.41-0.87	0.57
Tirur						
Vettom (V_7)	5.7-6.5	6.16	0.13-0.15	0.13	0.41-0.80	0.54
Thalakkadu (V_8)	6.4-6.7	6.53	0.13-0.16	0.14	0.40-0.68	0.56
Thiruvegappura (V_9)	5.3-6.2	5.80	0.15-0.28	0.21	0.67-0.84	0.77

Available Nitrogen (kg ha^{-1})

The study revealed that Available Nitrogen ranged from 107 - 180 kg ha^{-1} and these soils are low nitrogen in all villages. Nitrogen is really important for plant growth, plant food processing (metabolism) and the creation of chlorophyll. Nitrate is the form of nitrogen most used by plants for growth and development. This form is not lost as easily from the soil. The range and mean values of all the primary nutrients are given in Table 3.

Available Phosphorus (kg ha^{-1})

The study revealed that Available Phosphorus is ranged from 8.6 - 18.3 kg ha^{-1} and Phosphorus ranged from low to medium. Phosphorus is one of the major plant nutrients in the soil. It is a constituent of plant cells, essential for cell division and development.

Available Potassium (kg ha^{-1})

The study revealed that Available Potassium is ranged from 39 - 117.3 kg ha^{-1} and Potassium low in all villages. Potassium is a critical nutrient that plants absorb from the soil, helps stalks to grow upright and sturdy, improves drought tolerance and helps plant get through the winter. Fig.3 shows Village-wise status of Primary nutrients.

Exchangeable Ca [cmol(p^+) kg^{-1}]

The study revealed that Exchangeable Calcium ranged from 9.06 -16.8 cmol (p^+) kg^{-1} and Calcium are very sufficient in this soil. Calcium contributes to soil fertility by helping maintain a flocculated clay and therefore with good aeration. The range and mean values of Exchangeable Ca and other Secondary nutrients are given in Table 4.

Exchangeable Mg [cmol(p^+) kg^{-1}]

The study revealed that Exchangeable Magnesium ranged from 1.8 -11.9 cmol (p^+) kg^{-1} and Magnesium are very sufficient in this soil. Magnesium is an essential plant nutrient. It has a wide range of key roles in many plant functions including the photosynthesis process, as it is a building block of the chlorophyll which makes leaves appear green. Fig.4 shows Village-wise status of Secondary nutrients.

Available Sulphur (kg ha^{-1})

The study revealed that Available Sulphur ranged from 18.6 - 67.6 kg ha^{-1}. Sulphur is varying medium to high, most of the samples are high in Sulphur content. Sulphur is an essential element in forming proteins, enzymes, vitamins and chlorophyll in plants. It is crucial in nodule development and efficient nitrogen fixation in legumes.

Table 3: Assessment of Primary nutrients in Soils from different blocks of Malappuram District

Village Name	Available Nitrogen (kg ha^{-1})		Available Phosphorus (kg ha^{-1})		Available Potassium (kg ha^{-1})	
	Range	Mean	Range	Mean	Range	Mean
Nilambur						
Nilambur Muncipal (V_1)	140-191	161	11-17	14.3	35-47	41
Karulai (V_2)	162-192	180	16-21	18.3	68-115	86
Chungathara (V_3)	102-140	118.6	14-19	16.3	35-41	39
Eranad						
Edavanna (V_4)	127-184	157.6	9-16	13.3	54-61	56.3
Perakamanna (V_5)	127-152	139.6	8-13	10.6	41-54	45.3
Therattammal (V_6)	102-165	131.3	8-13	10.3	82-135	117.3
Tirur						
Vettom (V_7)	114-156	132.3	6-11	8.6	47-81	63
Thalakkadu (V_8)	127-192	168.3	13-15	14	41-81	63.3
Thiruvegappura (V_9)	102-114	107	10-13	10	98-108	102.6

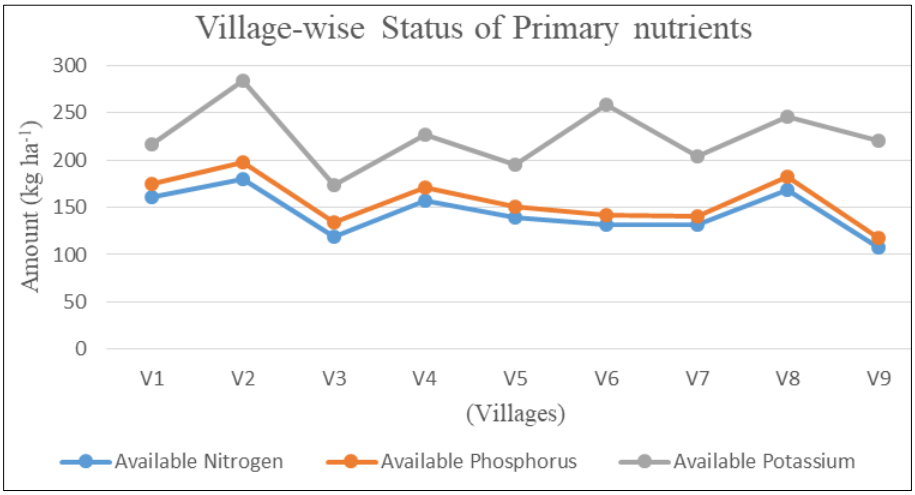

Fig 3: Graphical representation of Primary nutrients status in soils of Malappuram district

Table 4: Assessment of Secondary nutrients in Soils from Different Blocks of Malappuram District

Village Name	Exchangeable Ca [cmol(p$^+$) kg^{-1}]		Exchangeable Mg [cmol(p$^+$) kg^{-1}]		Available Sulphur (kg ha^{-1})	
	Range	Mean	Range	Mean	Range	Mean
Nilambur						
Nilambur Muncipal (V_1)	7.05-19.6	12.7	6.4-19.04	11.9	25-112	58.3
Karulai (V_2)	10.8-21.3	16.8	6.7-14.4	10.3	58-69	63.6
Chungathara (V_3)	7.05-17.9	14.2	3.6-5.1	4.1	40-79	59
Eranad						
Edavanna (V_4)	8.4-9.6	9.06	5.7-6.7	6.1	8-30	18.6
Perakamanna (V_5)	9.2-12.9	10.6	6.0-9.6	8.1	38-86	67.6
Therattammal (V_6)	9.2-9.6	9.4	1.4-2.5	1.8	18-86	46.6
Tirur						
Vettom (V_7)	8.8-14.4	11.2	7.3-12.9	9.3	36-97	63.6
Thalakkadu (V_8)	10.8-12.5	11.8	5.1-6.7	5.8	36-69	47
Thiruvegappura (V_9)	12.05-14.5	13.5	6.8-7.02	6.9	18-25	21.3

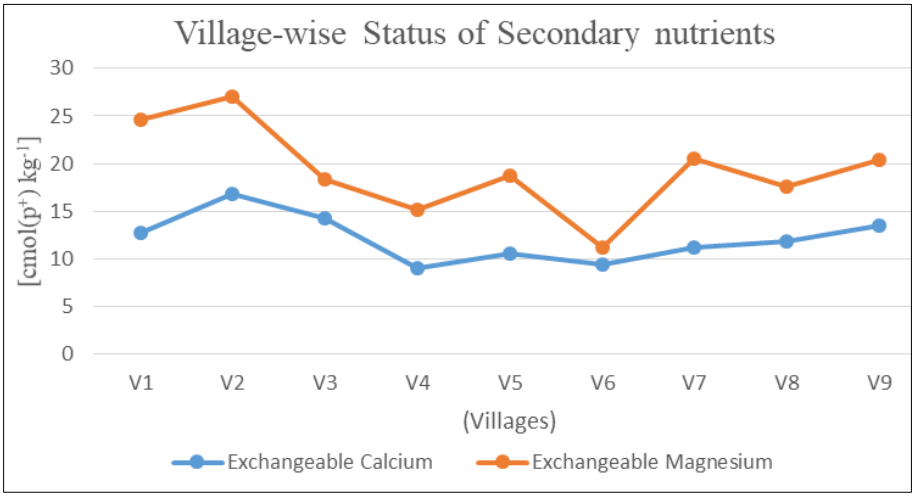

Fig 4: Graphical representation of Secondary nutrients status in soils of Malappuram district

Conclusion

It was concluded that soil parameters studied during the course of investigation clearly indicated that soil has good water holding capacity and good physical condition. The pH of soil is acidic in nature and the Electrical conductivity was suitable for all crops. Organic carbon ranged from medium to high. These soils have low Nitrogen in all villages. Phosphorus ranged from low to medium. It is low in four villages and found medium in five villages. Potassium is low in all villages. Calcium and magnesium are very sufficient in this soil. Sulphur varied from medium to high. Most of the samples are high in Sulphur content. The main reason for lack of macronutrients is leaching due to high amount of precipitation in the area and nutrient uptake by plants. There is a need to pay greater attention in the role of macronutrients enhancement in the soil for good soil health and proper nutrition of plant so as to attain optimum economic yield for all major tropical and sub-tropical crops.

Acknowledgement

The author would like to avail the opportunity to thank the Hon'ble Vice Chancellor, HoD of the Department of Soil Science and Agricultural Chemistry, Naini Agricultural Institute, Sam Higginbottom University of Agriculture,

Technology and Sciences, Prayagraj, U.P. for providing necessary support and desired equipment's for this research work.

Conflict of Interest

As a Corresponding Author, I Amjad A, confirm that none of the others have any conflicts of interest associated with this publication.

References

1. Black CA. Methods of Soil Analysis Part – II. Chemical and microbiological properties. Agronomy Monograph No. 9. American Society of Agronomy, Inc. Madison, Wisconsin, USA 1965, 18-25.
2. Bouyoucous GJ. The hydrometer as a new method of the mechanical analysis of soil. Soil Science 1927;23:343-353.
3. Brady NC, Weil RR. The nature and properties of soils (11th edition). Prentice hall. New York 1996.
4. Chesnin L, Yien CH. Turbidimetric determination of available sulphates. Proceedings of Soil Science Society of America 1950;14:149-51.
5. Das DK. Introductory Soil Science, 2nd Edition Kalyani Publishers, New Delhi 2004.
6. Jackson ML. Soil Chemical Analysis. Prentice Hall of India Pvt. Ltd., New Delhi 1973.
7. Jacob Joffe S. Pedology, second edition. Pedology publication, New Brunswick, New Jersey, plates 1949;30:662.
8. Jaiswal P. Soil plant and water analysis. Third Revised Edition. New Delhi-110 002: Kalyani publishers 2011.
9. Kekane SS, Chavan RP, Shinde DN, Patil CL, Sagar SS. A review on physico-chemical properties of soil. International journal of chemical studies 2015;3(4):29-32.
10. Lindsay WL, Norvell WA. Development of DTPA soil test for zinc, iron, manganese and copper. Soil Sci. Soc. Am. J 1978;42:421-428.
11. Moossa PP. Modelling of carbofuran movement and sorption in soils with varying physico-chemical properties. Department of Soil Science and Agricultural Chemistry, College of Agriculture, Vellayani 1994.
12. Muthuval P, Udayasooriyan C, Natesan R, Ramaswami PR. Introduction to soil Analysis, Tamil Nadu Agriculture University, Coimbatore-641002, 1992.
13. Obalum ES, Nwite CJ, Watanabe Y, Charles A. Comparative topsoil characterization of sawah rice fields in selected inland valleys around Bida, north-central Nigeria: physico-chemical properties and fertility status. Tropical Agriculture and Development 2012;56(2):39-48.
14. Olsen SR, Cole CV, Watanabe FS, Dean LA. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. USDA Circular No. 939, 1954.
15. Schoonover JE, Crim JF. An Introduction to Soil Concepts and the Role of Soils in Watershed Management. Journal of Contemporary Water Research & Education 2015;154(1):21-47.
16. Soil Survey Staff. Soil Survey Manual, United States Department of Agriculture Handbook No. 18, Washington, USA 1951, 851-857.
17. Soil Survey Staff. Soil Taxonomy-A Basic system of soil classification for making and interpreting soil surveys. Second Edition. Agricultural Handbook No. 436, United States Department of Agriculture, Washington, D. C., USA 1999, 460.
18. Sparling GP, Schipper LA, Bettjeman W, Hill R. Soil quality monitoring in New Zealand Agriculture, Ecosystems and Environment, Elsevier 2004;104(3):523-534.
19. Subbiah BV, Asija GL. A rapid procedure for the estimation of available nitrogen in the soil, Current Science 1956;25:259-260.
20. Toth SJ, Prince AL. Estimation of Cation exchange capacity and exchangeable Ca, K and Na content of soil by Flame photometer technique. Soil Science an Interdisciplinary Approach to Soil Research 1949;67(6):439-446.
21. USDA (United States Department of Agriculture), Soil Conservation Services, Soil Survey Staff. Soil Taxonomy: a basic system of soil classification for making and interpreting soil surveys. Agriculture Handbook No. 436. Washington D.C., USA: US Government printing office 1994, 754.
22. Wilcox LV. Electrical conductivity. American Water Works Association J 1950;42:775-776.