JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue

JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)

An International Scholarly Open Access, Peer-reviewed, Refereed Journal

"Comprehensive Chemical Analysis and Assessment of Macro and Micronutrient Status of Agricultural Soil in Vadgaon Nimbalkar, Baramati Tehsil, Maharashtra"

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Abstract

This study titled "Comprehensive Chemical Analysis and Assessment of Macro and Micronutrient Status of Agricultural Soil in Vadgaon Nimbalkar, Baramati Tehsil, Maharashtra "evaluates ten soil samples collected from different agricultural fields. The analysis focused on soil pH, electrical conductivity (EC), organic carbon, calcium carbonate, macronutrients (N, P, K), and micronutrients (Fe, Mn, Zn, Cu). Results show that the soils are strongly alkaline (pH 8.39–8.81) and non-saline (EC 0.24–0.85 dS/m). Organic carbon remains low to medium (0.35–1.38%), indicating limited organic matter. Nitrogen is low to medium, phosphorus is consistently very low, while potassium shows wide variation from low to very high. Calcium carbonate content is moderately high (7.4–12.8%), typical of black cotton soils. Micronutrient analysis reveals deficiencies of iron and zinc, while manganese and copper remain within acceptable limits.

Overall, the soils of Vadgaon Nimbalkar are affected by high alkalinity, low organic matter, and deficiencies of N, P, Fe, and Zn. The study suggests the need for balanced fertilization, organic amendments, and micronutrient supplementation to improve soil fertility and support sustainable agriculture in the region.

Keywords: Soil fertility; Chemical analysis; Macronutrients; Micronutrients; Organic carbon; Alkalinity; Sustainable agriculture.

1. Introduction

Soil is one of the most important natural resources that supports plant growth, regulates ecological processes, and sustains agricultural productivity. It is a dynamic medium made up of minerals, organic matter, water, air, and living organisms and it is continuously shaped by environmental conditions and human activities.

Soil formation occurs through the combined action of climatic and biological factors such as temperature, rainfall, plants, animals, and microorganisms. These factors influence both the physical and chemical characteristics of soil. Physical properties such as texture, porosity, and moisture retention, along with chemical features like pH, electrical conductivity, organic carbon, and nutrient availability, play a crucial role in determining soil fertility and crop productivity.

Many researchers have emphasized the importance of soil chemical analysis for understanding soil health and guiding suitable land use and management strategies. Malik (2017) explained that climatic and biological factors influence soil formation and nutrient distribution, which directly affect soil productivity and ecological balance. Jency et al. (2023) stated that humus and other organic components improve soil fertility, while microbial activity strengthens soil suppressiveness and overall soil health. Sen et al. (2023) also showed that the physico chemical characteristics of soil influence the suppressiveness of soil borne diseases, which highlights the need for regular soil monitoring.

Several studies have examined the chemical properties of soils in different regions. Dandwate (2020) studied the soils of Sangamner city and found that most samples were neutral to slightly alkaline, with moderate levels of organic carbon, nitrogen, and phosphorus. These findings indicate the need for balanced nutrient management for sustainable agriculture. Ghare and Kumbhar (2021) examined soils from the Washim district and reported clear variations in pH, electrical conductivity, and nutrient content, showing that soil health depends strongly on local agricultural practices and environmental conditions.

Studies by Rahman et al. (2024) have highlighted the importance of evaluating soil nutrient status in order to understand the effects of different land use patterns. Their examination of riverbed soils showed differences in major and micronutrients, which supports the need for periodic soil testing for effective agricultural planning. More et al. (2022) pointed out that physico chemical properties of soil are central to improving soil quality and encouraging sustainable agricultural practices, especially in areas where human activities have caused soil degradation.

Findings from international studies also support the importance of soil chemical assessment. Umeri et al. (2017) observed variations in nutrient levels in forest soils in Nigeria and linked these differences to plant productivity and ecosystem functioning. Ali et al. (2010) discussed the importance of soil chemical characteristics in planning land use in the Delbo Wegene watershed of Ethiopia and demonstrated how soil studies can support sustainable resource management.

Considering the importance of soil fertility in agricultural development, especially in rural areas such as Vadgaon Nimbalkar, a detailed chemical analysis of soil is essential. Agriculture in the region depends heavily on soil nutrient availability, and changes in soil chemical properties can affect crop yield, fertilizer needs, and the long term sustainability of cultivated land. Therefore, the present study, titled Chemical Analysis of Soil in Vadgaon Nimbalkar, aims to assess important chemical parameters such as soil pH, electrical conductivity, organic carbon, nitrogen, phosphorus, potassium, and essential micronutrients. The results will help to understand

the current fertility status of the soils in the village and provide scientific recommendations for improving agricultural productivity and sustainable land management.

2. Study Area

The present study has been conducted in Vadgaon Nimbalkar, a rural village located in Baramati Tehsil of Pune District in Maharashtra. The village is situated at approximately 18.1411° north latitude and 74.3632° east longitude. Vadgaon Nimbalkar covers a total geographical area of about 1701 hectares and has a population of 7646 people as per the 2011 Census, with nearly equal distribution of males and females. The village lies around 25 kilometers from Baramati city, which serves as the nearest major urban and administrative center. The region experiences a semi arid climate with hot summers, mild winters, and limited rainfall concentrated mainly during the southwest monsoon season. Soils in Vadgaon Nimbalkar are primarily derived from the basaltic formations of the Deccan Traps and are commonly identified as black cotton soils or Vertisols. These soils have high clay content, good nutrient holding capacity, and distinct seasonal behavior, becoming very hard when dry and sticky when wet. Agriculture is the dominant occupation in the village, and farmers cultivate crops such as sugarcane, wheat, jowar, bajra, maize, and vegetables. Due to increasing pressure on land, intensive cropping, and dependence on surface and groundwater irrigation, soil fertility assessment has become essential. This combination of physical, climatic, and agricultural characteristics makes Vadgaon Nimbalkar an appropriate and representative location for a detailed chemical analysis of soil.

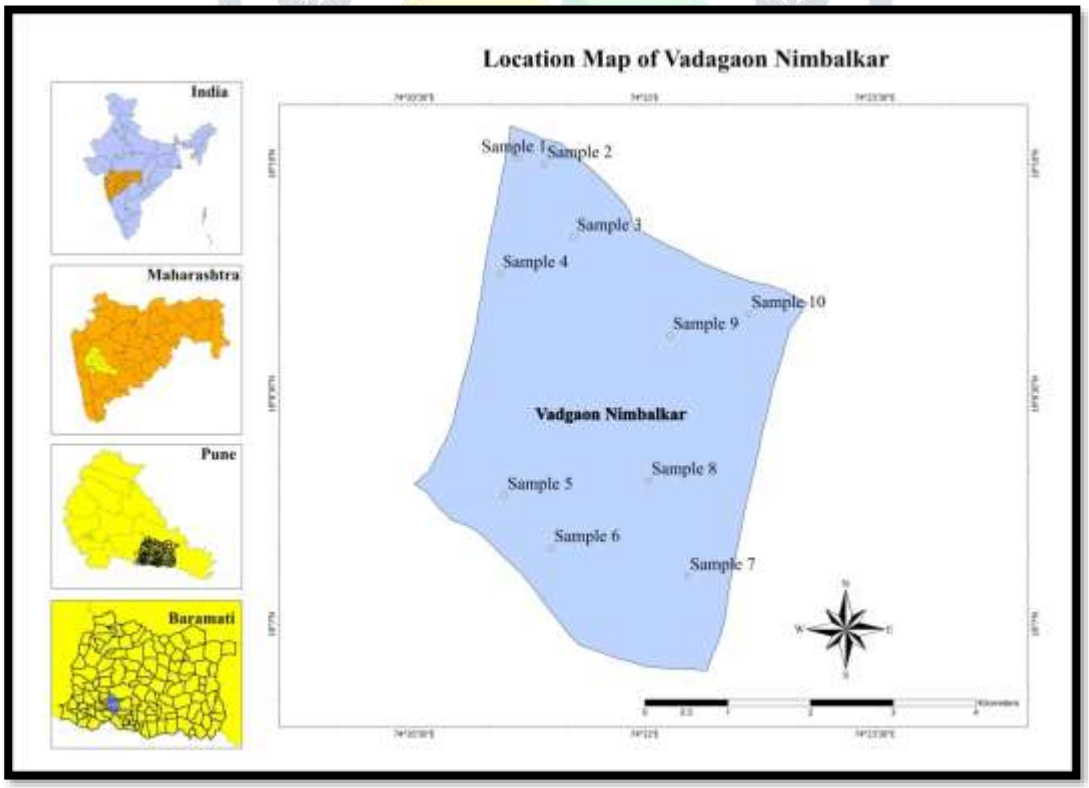

Figure 1: Location map of study area

3. Data and Methodology

3.1. Data Used in the Study

The study is based on both primary and secondary data. Primary data were collected directly from the agricultural fields of Vadgaon Nimbalkar, while secondary data were obtained from census reports, government publications, and relevant research studies. Secondary information on climate, population, agriculture, and land use helped in understanding the broader environmental and socio economic setting of the study area.

3.2. Soil Sample Collection

For the purpose of this research, a total of ten soil samples were collected from different agricultural fields across the village. These sites were selected to represent variations in cropping patterns, land use practices, and soil conditions within Vadgaon Nimbalkar. Each sample was collected from the surface layer at a depth of zero to fifteen centimeters, which is the most active zone for nutrient availability.

At each location, a composite soil sample was prepared by mixing soil taken from five to six points within the selected field. This approach helped to obtain representative samples and reduce local variation. All samples were placed in clean bags, labelled properly, and transported to the laboratory for chemical testing.

3.3. Laboratory Analysis of Soil

Standard soil testing procedures were followed for laboratory analysis. Soil pH and electrical conductivity were measured using a digital pH meter and conductivity meter after preparing a soil water mixture in the proportion of one to two point five. Organic carbon content was determined using the Walkley Black wet oxidation method.

Available nitrogen was analysed using the alkaline potassium permanganate method, while available phosphorus was estimated through the Olsen extraction method followed by colorimetric measurement. Available potassium was determined using flame photometry. Micronutrients such as zinc, iron, manganese, and copper were analysed using the diethylene triamine pentaacetic acid extraction method, and concentrations were obtained using an atomic absorption spectrophotometer.

3.4. Data Processing and Interpretation

The laboratory results were arranged in tabular form and compared with standard nutrient rating scales used for agricultural soils in Maharashtra. This comparison helped in identifying nutrient sufficiency, deficiency, and overall fertility status of the soils in Vadgaon Nimbalkar. The findings were interpreted in relation to local cropping patterns, irrigation practices, and soil management methods followed by farmers.

4. Results

4.1 Interpretation of Macronutrient Parameters

4.1.1. Soil pH

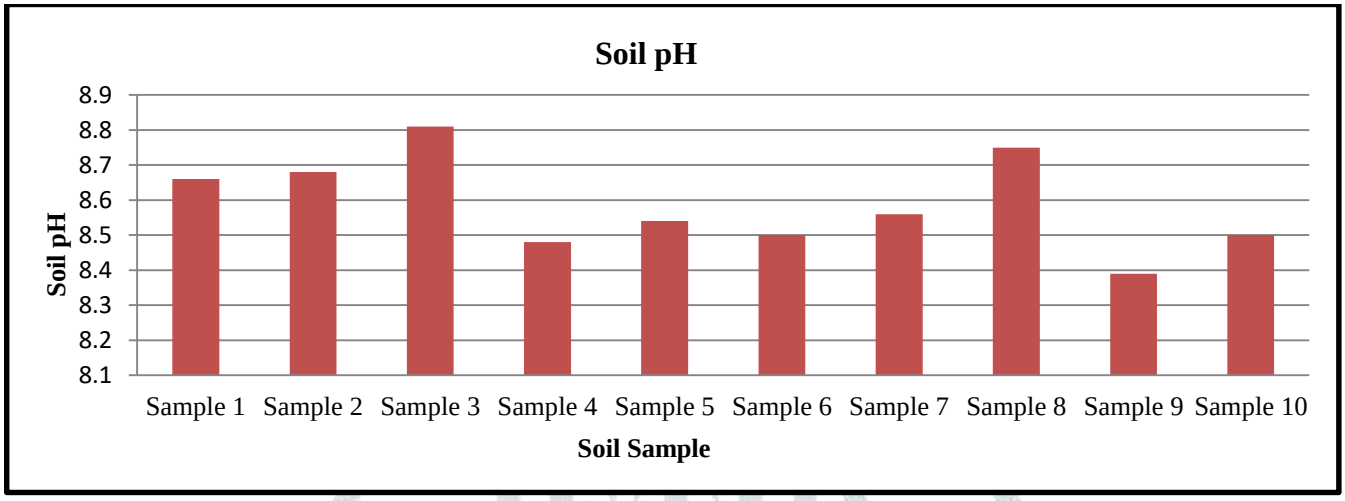

Figure 2: Soil pH Variation across Samples in Vadgaon Nimbalkar

Soil pH in all ten samples ranges from 8.39 to 8.81, which shows that the soils of Vadgaon Nimbalkar are strongly alkaline. Sample 3 and Sample 1 have the highest pH values, while Sample 9 has the lowest. Alkaline soils are known to reduce the availability of several important nutrients, especially iron, zinc, manganese, and phosphorus. Such high pH may also affect the efficiency of fertilizers, making nutrient management essential for crop growth.

1.1.2. Electrical Conductivity

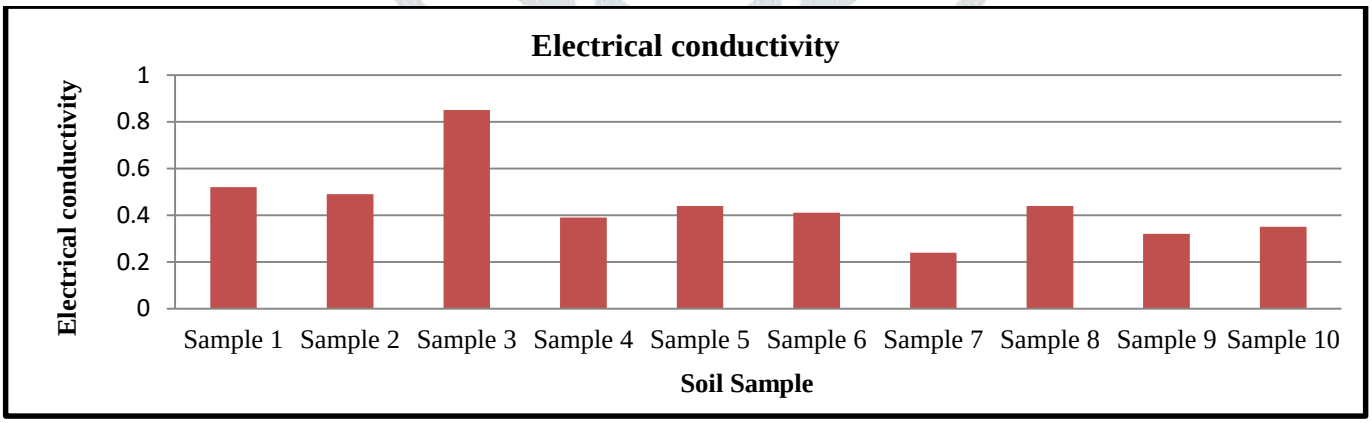

Figure 3: Electrical Conductivity (EC) Levels of Soil Samples across Vadgaon Nimbalkar

Electrical conductivity ranges from 0.24 to 0.85 deci siemens per meter. Sample 3 shows the highest value, and Sample 7 shows the lowest. All samples fall within the safe non saline limit, which means the soils do not

have any salt accumulation that would harm crop growth. Non saline soils support normal germination and allow farmers to cultivate a wide range of crops without salinity problems.

4.1.3. Available Nitrogen

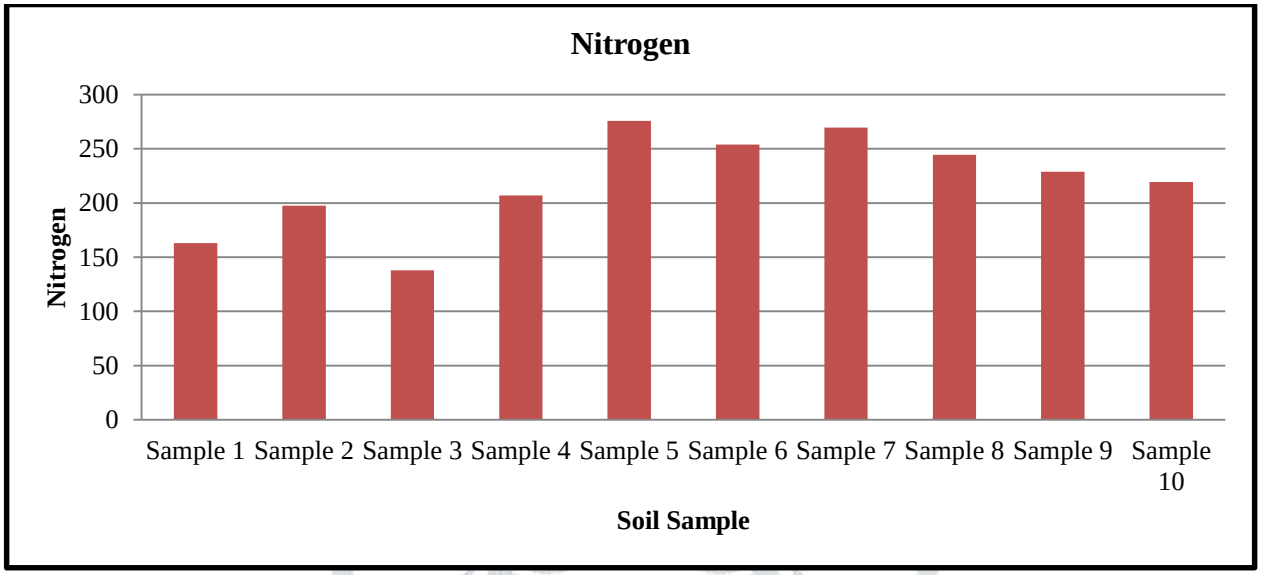

Figure 4: Nitrogen Content of Soil Samples across Vadgaon Nimbalkar

Available nitrogen varies from 137.98 to 275.96 kilograms per hectare. Sample 3 has the lowest nitrogen content, while Samples 5 and 7 show comparatively higher values within the medium range. Nitrogen is the most important nutrient for leaf development and overall vegetative growth. The low to medium nitrogen values indicate that the soils require regular nitrogen supplementation through urea, compost, or farmyard manure to achieve good crop productivity.

4.1.4. Available Phosphorus

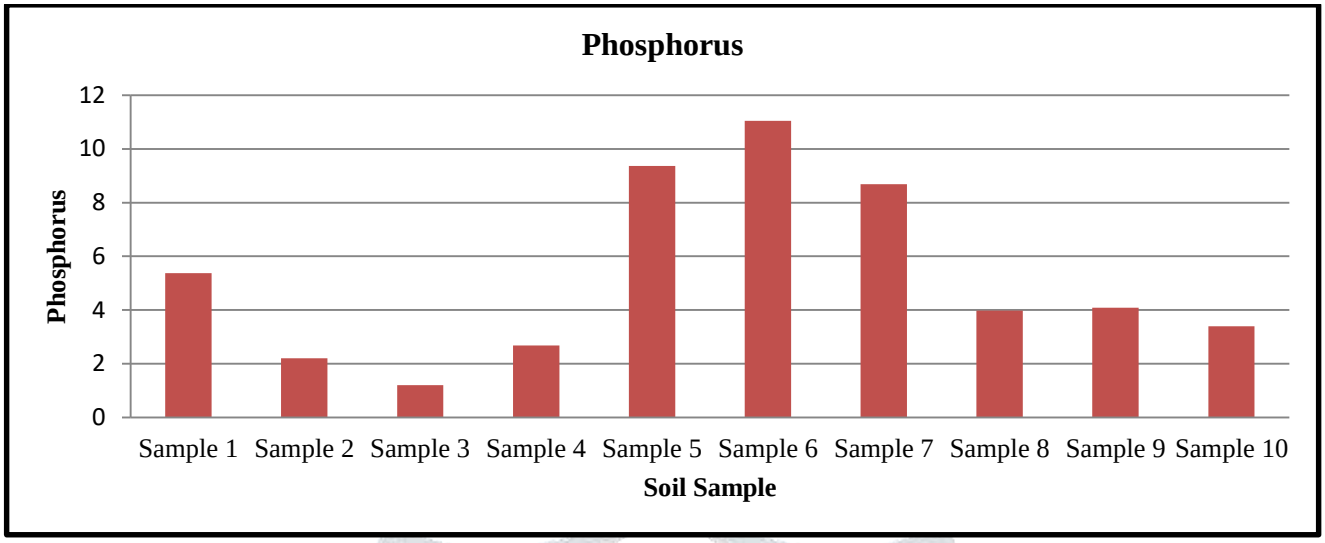

Figure 5: Phosphorus Levels of Soil Samples across Vadgaon Nimbalkar

Available phosphorus values range from 1.20 to 11.04 kilograms per hectare. Sample 3 shows the lowest phosphorus level, while Sample 6 shows the highest. However, even the highest value remains low for agricultural soils. Low phosphorus availability can slow down root development, reduce flowering, and limit grain and fruit production. The results show that phosphorus deficiency is common in all fields and requires correction through proper fertilization.

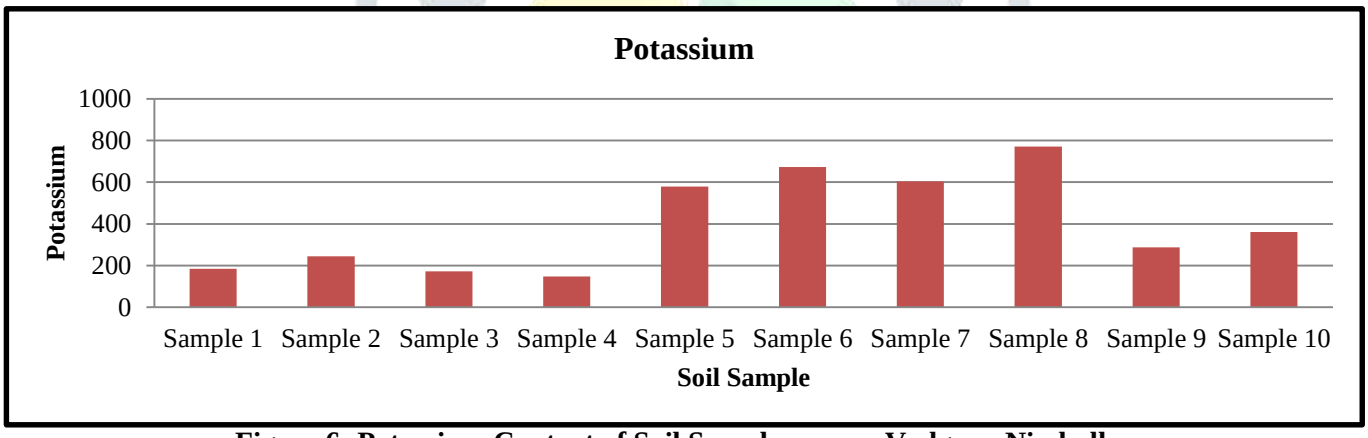

Figure 6: Potassium Content of Soil Samples across Vadgaon Nimbalkar

4.1.5. Available Potassium

Potassium content shows a wide range from 147.84 to 770.56 kilograms per hectare. Samples 1, 3, 4, and 9 fall in the low to medium category, indicating that these fields need potassium supplementation. Samples 5, 6, 7, and 8 show very high potassium values, with Sample 8 having the highest. Potassium is important for disease resistance and water regulation in plants. The large variation suggests differences in fertilizer application or irrigation water quality across the fields.

4.1.6. Sodium

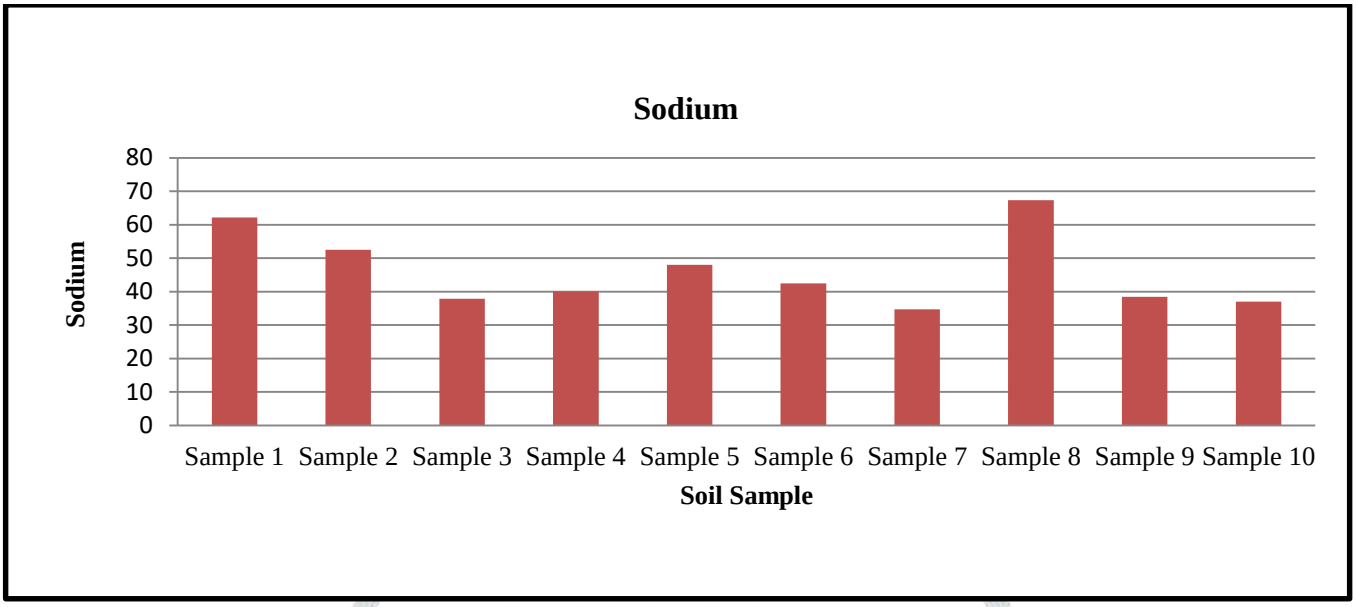

Figure 7: Sodium Concentration of Soil Samples across Vadgaon Nimbalkar

Sodium values range between 34.7 and 67.3 parts per million. Sample 8 shows the highest, and Sample 7 shows the lowest value. All values fall within the safe range and do not indicate any sodicity problem. Normal sodium levels mean the soils do not face structural issues such as crusting, swelling, or poor water infiltration. This allows normal cultivation without soil degradation due to sodium.

4.1.7. Calcium Carbonate

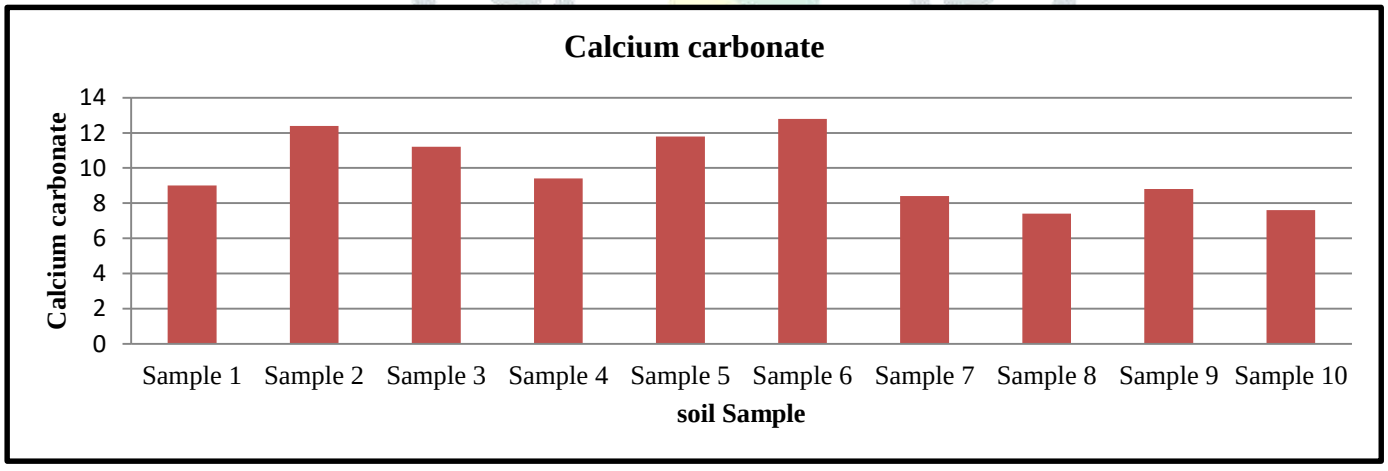

Figure 8: Calcium Carbonate (%) of Soil Samples across Vadgaon Nimbalkar

Calcium carbonate content ranges from 7.4 to 12.8 percent. Sample 6 has the highest value, and Sample 8 has the lowest. High calcium carbonate content is common in black cotton soils and contributes to alkalinity. It can reduce the availability of phosphorus and micronutrients by fixing them in unavailable forms. These results suggest that phosphorus and micronutrient frtilizers may be less effective unless organic matter is also increased.

4.1.8. Organic Carbon

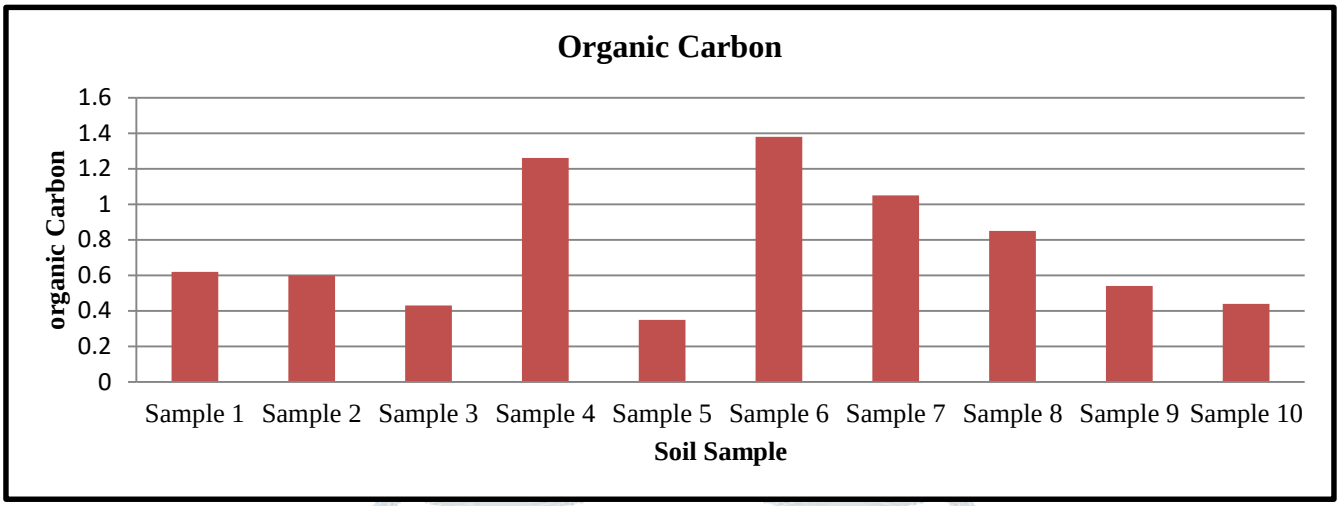

Figure 9: Organic Carbon (%) of Soil Samples across Vadgaon Nimbalkar

Organic carbon values range from 0.35 to 1.38 percent. Samples 5 and 3 have the lowest organic carbon, while Sample 6 has the highest. Samples 4, 6, 7, and 8 shows relatively better organic carbon compared to others. Organic carbon is essential for improving soil structure, moisture retention, and nutrient availability. Most samples fall in the low to medium range, indicating that the soils need continuous addition of organic matter through compost, green manures, crop residues, and farmyard manure.

Overall findings indicate that the soils of Vadgaon Nimbalkar are alkaline, low in nitrogen and phosphorus, variable in potassium, moderate in sodium, high in calcium carbonate, and generally low in organic carbon. Sample wise comparison shows a clear pattern: high potassium in Samples 5, 6, 7, and 8, low nitrogen in Samples 3 and 1, very low phosphorus in Samples 3 and 2, and better organic carbon in Samples 6, 4, 7, and 8. These results highlight the need for balanced nutrient management and increased organic matter to improve soil fertility and support sustainable agricultural production in the study area.

4.2 Interpretation of Micronutrient Parameters

4.2.1. Iron

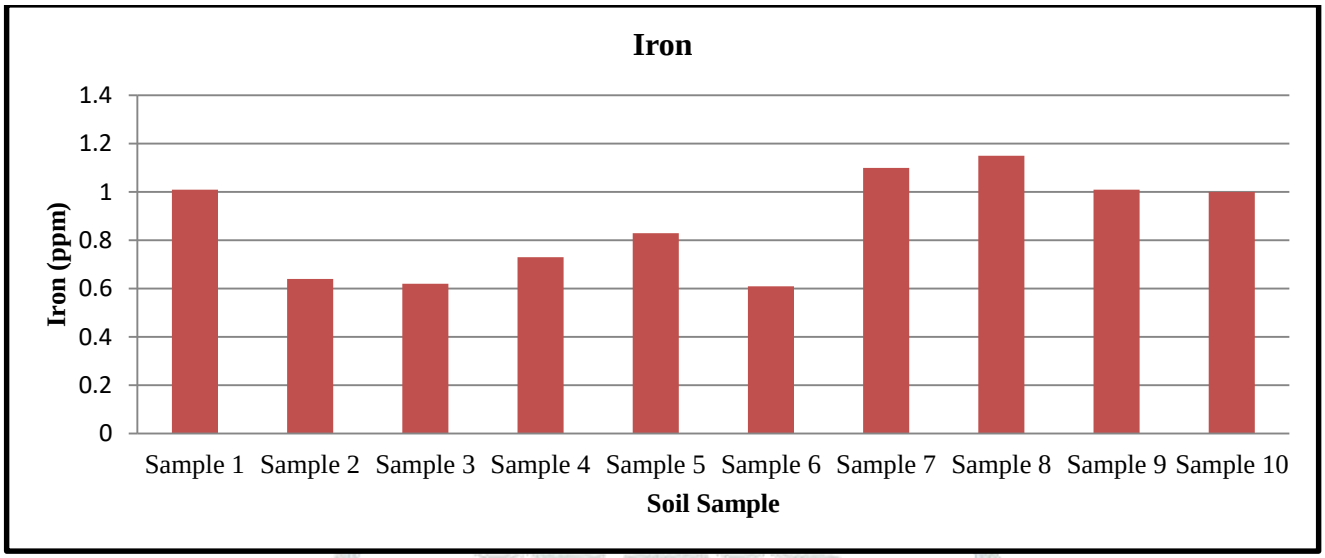

Figure 10: Iron (Fe) Concentration of Soil Samples across Vadgaon Nimbalkar

Iron values in the ten soil samples range from 0.62 to 1.15 parts per million. Sample 3 shows the lowest iron content, while Sample 8 shows the highest value. All samples remain below the recommended iron level for agricultural soils, which indicates a widespread iron deficiency in Vadgaon Nimbalkar. This deficiency is commonly seen in alkaline soils because high pH reduces iron solubility. Low iron affects chlorophyll formation and can lead to yellowing of leaves, especially in crops such as sorghum, maize, sugarcane, and vegetables. The results show that iron supplementation through ferrous sulphate or organic matter addition is necessary in most fields.

4.2.2. Manganese

Manganese content varies from 1.33 to 5.23 parts per million. Sample 4 shows the lowest value, while Sample 1 shows the highest manganese content. Although Sample 1 falls in a better range, most other samples remain in the low category. Manganese is essential for photosynthesis and enzyme activity. Low manganese levels may lead to pale leaves, slow growth, and reduced yield in crops. The results indicate that manganese deficiency can occur in several fields and may require corrective measures such as manganese sulphate application.

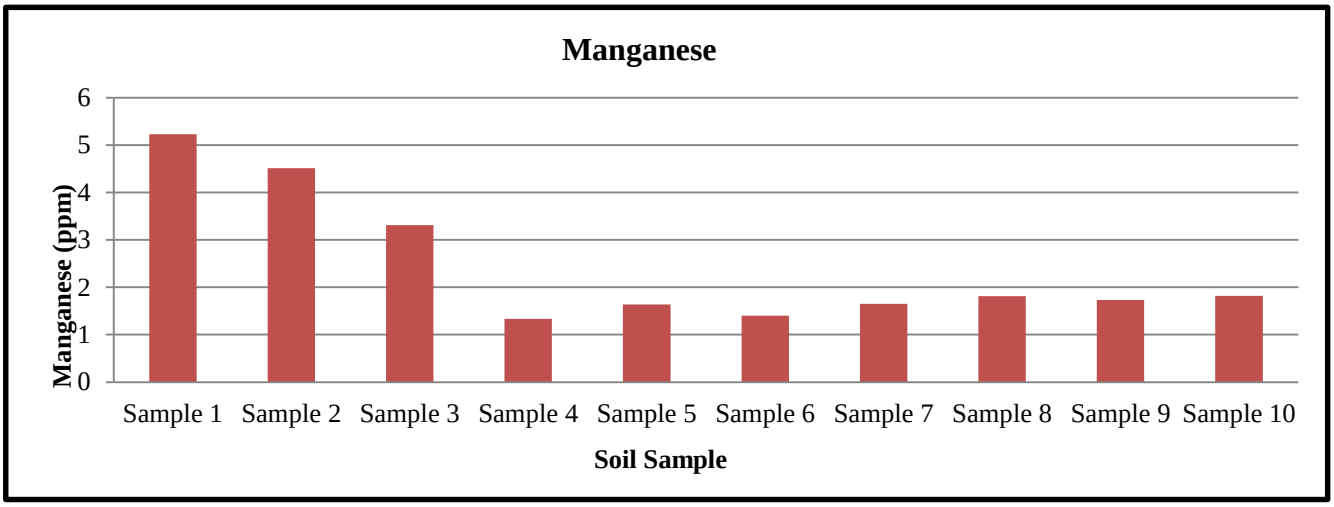

Figure 11: Manganese (Mn) Levels of Soil Samples across Vadgaon Nimbalkar

4.2.3. Zinc

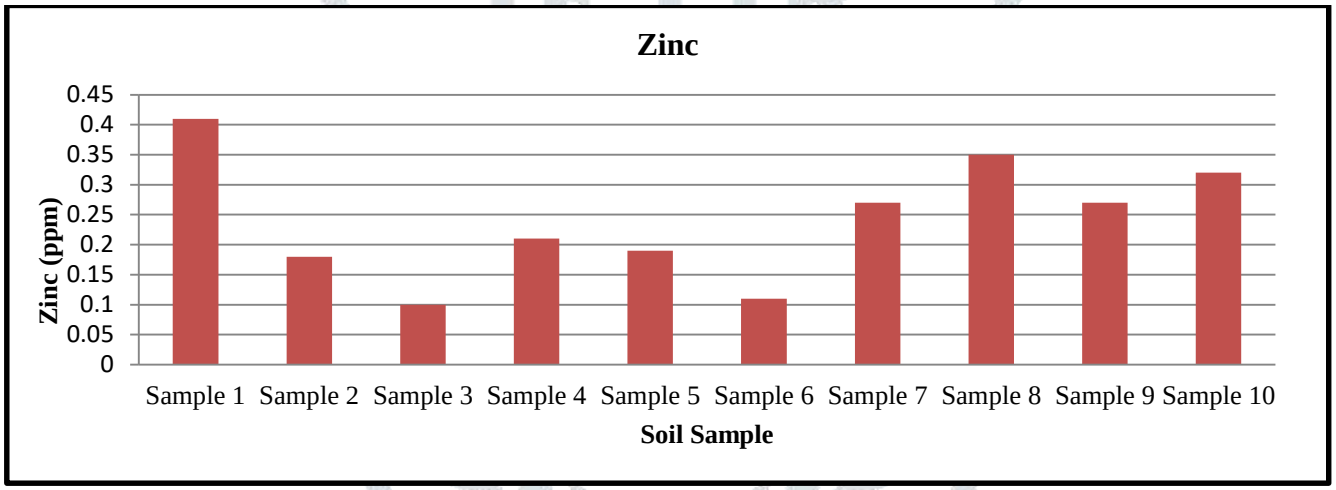

Figure 12: Zinc (Zn) Status of Soil Samples across Vadgaon Nimbalkar

Zinc values range from 0.10 to 0.41 parts per million. Sample 3 has the lowest zinc content, while Sample 1 shows the highest. All samples fall below the recommended zinc range for normal plant growth, which shows that zinc deficiency is the most severe micronutrient problem in the study area. Zinc is essential for hormone production, root development, grain formation, and disease resistance. Deficiency may cause stunted plants, poor tillering, and reduced seed size. The results confirm the need for zinc sulphate application and improvement of organic matter to enhance zinc availability.

4.2.4. Copper

Copper content ranges between 0.42 and 1.22 parts per million. Sample 6 shows the lowest copper value, while Sample 1 shows the highest. Although copper values are slightly better than zinc and iron, several samples are still near the lower limit of the sufficient range. Copper is required for reproductive growth, enzyme activity,

and lignin formation in plants. Low copper levels may reduce stem strength and affect flowering and fruiting in crops. The results indicate that copper deficiency is moderate and may be corrected through copper based fertilizers if required.

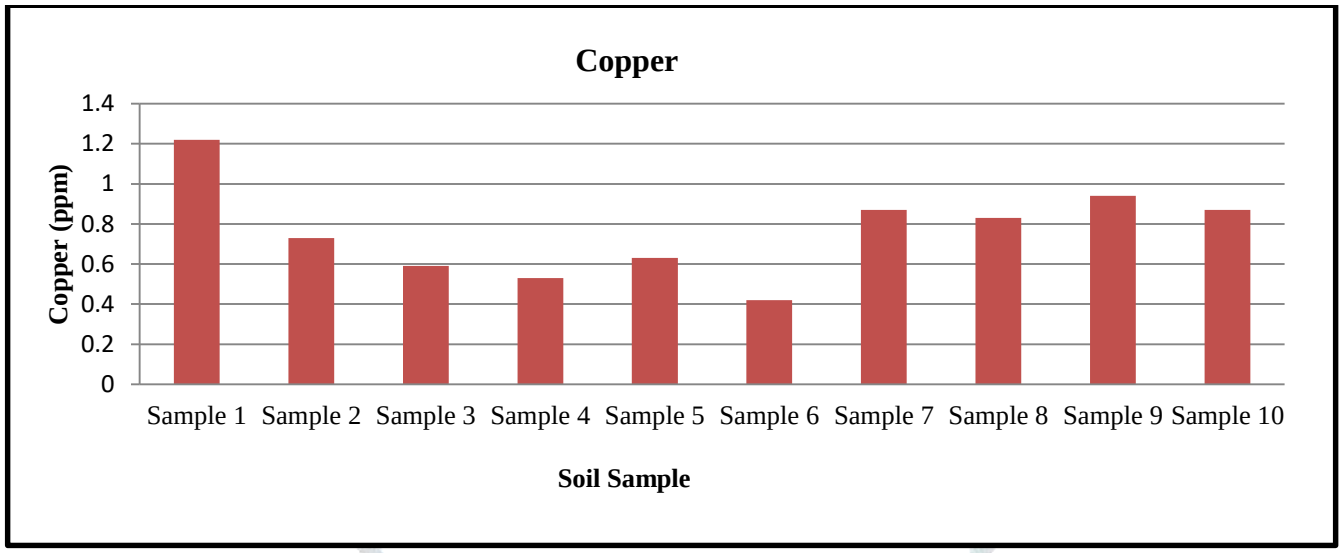

Figure 13: Copper (Cu) Concentration of Soil Samples across Vadgaon Nimbalkar

The overall micronutrient status of the soils in Vadgaon Nimbalkar shows that iron, manganese, zinc, and copper are generally low across the study area. Zinc and iron show the most severe deficiencies, followed by manganese, while copper deficiency is moderate. High soil pH and high calcium carbonate content in the soils are the main reasons for the low availability of these micronutrients. This condition highlights the importance of adopting micronutrient management practices such as zinc sulphate, ferrous sulphate, and manganese sulphate application along with organic matter addition to improve nutrient availability.

5. Conclusion

The chemical analysis of soils from Vadgaon Nimbalkar shows that the agricultural fields of the village are affected by several nutrient related limitations that can influence crop productivity. The soils are strongly alkaline in nature, with pH values above 8.3 in all samples. Such alkaline conditions reduce the solubility and availability of many essential nutrients, especially micronutrients. Electrical conductivity values remain within the safe non saline range, which indicates that the soils are suitable for general crop cultivation without any salinity related restrictions.

Among the macronutrients, nitrogen and phosphorus are consistently low across all samples. Nitrogen values fall in the low to medium range, indicating inadequate supply for supporting vigorous plant growth. Phosphorus levels are very low in nearly all samples, which may restrict root development, flowering, and overall crop yield. Potassium shows wide variation, with some fields having very high potassium and others showing low to medium levels. Organic carbon content is also low to medium in most samples, indicating poor organic matter

status, reduced soil structure stability, and limited capacity to retain moisture and nutrients. Calcium carbonate levels are high, which further contributes to nutrient fixation, particularly of phosphorus and micronutrients.

The micronutrient analysis reveals that iron, manganese, zinc, and copper are generally low in availability. Zinc and iron deficiencies are the most severe, with all samples recording values below the recommended limits for crop growth. Manganese and copper also show low to medium availability. The widespread deficiency of micronutrients is largely a result of the high pH and high calcium carbonate content of the soils, which reduces their solubility and plant uptake.

Overall, the soils of Vadgaon Nimbalkar require balanced and corrective nutrient management. The results indicate the need for regular application of nitrogen and phosphorus based fertilizers, along with targeted amendments such as zinc sulphate, ferrous sulphate, and manganese sulphate to correct micronutrient deficiencies. Increasing organic matter through farmyard manure, compost, green manures, and crop residue incorporation will also improve soil structure, moisture retention, and nutrient availability. A combination of these measures will help improve soil health and enhance agricultural productivity in the study area.

6. Acknowledgement

We express my sincere gratitude to the Krishi Vigyan Kendra (KVK) Soil Testing Laboratory for their valuable support and assistance in carrying out the chemical analysis of soil samples. We are thankful to my teachers and the Department of Geography, tulajram Chaturchand College, Baramti for their constant guidance throughout this study. We also acknowledge the cooperation of the farmers of Vadgaon Nimbalkar for helping me during field data collection. Our heartfelt thanks to our friends and colleagues for their encouragement. Finally, we are grateful to all who directly or indirectly contributed to the successful completion of this research work.

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