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Status of secondary andmicronutrient of block Hodal of district Palwal (Haryana)

Aman Kumar Athwal*[1], Rohtas Kumar[1], Anurag[2], and Robin Athwal[3]

[1]Department of Soil Science, COA, CCS Haryana Agricultural University, Hisar, India
[2]Department of Agrometeorology, COA, CCS Haryana Agricultural University, Hisar, India
[3]College of Agriculture, CCS Haryana Agricultural University, Hisar, India

ABSTRACT

In order to make an opinion about the secondary and micronutrient status of Hodal block soils (Palwal), 50 surface soil samples were collected with the help of auger and coordinates of each sample were recorded with the help of a global positioning system. The high spatial variability of nutrient distribution, which made it difficult to ensure representative sampling, and the lack of historical soil data, limiting long-term comparative analysis. The results indicated that the mean value of exchangeable calcium and magnesium was 4.05 and 7.92{Cmol (p^+) kg^{-1}}, respectively,and sulfur was 68.15 mg kg-1. The mean value of DTPA extractable zinc, iron, copper, manganese, and hot water-soluble boron was 0.64, 6.77, 0.82, 4.05, and 1.51 mg kg^{-1}, respectively. The majority of the soil samples of DTPA extractable Zn (90%), Fe(56%) and Mn (84%) were found under the deficient category, where soil samples of Cu(56%) and B (84%) were found under the sufficient category. The DTPA-extractable Zn exhibited a significant negative correlation with DTPA-extractable Cu and hot-water soluble B, while Cu showed a significant positive correlation with hot water-soluble B. Additionally, Ca demonstrated a significant positive correlation with electrical conductivity. This study provides essential baseline information on the nutrient profile of Hodal soils, offering a scientific foundation for developing targeted soil fertility and nutrient management strategies to improve crop productivity in the region.

Keywords: *Secondary nutrient, zinc, iron, copper, manganese and boron*

Introduction

India plays a pivotal role in global agriculture, serving as the primary livelihood for approximately 65% of its population. Agriculture forms the backbone of the Indian economy, with soil being the most fundamental resource for crop production [18]. Soil fertility is a fundamental factor influencing agricultural productivity, with secondary and micronutrients playing a crucial role in maintaining soil health and crop yield. Secondary and micronutrients such as sulfur (S), zinc (Zn), iron (Fe), manganese (Mn), copper (Cu), and boron (B) have a significant impact on plant growth and metabolic processes. Over the years, intensive agricultural practices, continuous cropping without proper nutrient replenishment, and the widespread use of high-yielding crop varieties have led to severe depletion of these nutrients in Indian soils [30]. Though the soils of Haryana are among the most arable soils in northern India, but still lack adequate nutrients for plant growth. Despite increased fertilizer use to cultivate high-yielding crop varieties, crops continue to extract more macro and micronutrients from the soil and ultimately leading to soil nutrient deficiency[30].

The Hodal block of Palwal district, an agriculturally intensive region, has witnessed decreasing soil productivity, which can be attributed to imbalanced nutrient management and soil degradation.

*Corresponding Author: ***Aman Kumar Athwal***

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Previous studies suggest that deficiencies of Zn and B are widespread in Haryana, affecting both soil quality and crop performance. However, limited research has been conducted on the spatial distribution of these nutrients in the Hodal block and their correlation with key soil physico-chemical properties such as pH, organic carbon, and calcium carbonate content. Since these properties directly affect nutrient availability, understanding their interactions is crucial for improving soil fertility management. This study aims to assess the soil nutrient status of the Hodal block(Palwal) along with its spatial variability and to establish its relationship with soil properties. The results will provide valuable insights for site-specific nutrient management strategies, ensuring sustainable agricultural productivity and long-term soil health improvement. Furthermore, the findings will contribute to the growing body of research on soil fertility in semi-arid regions, offering scientific guidance for policymakers, researchers, and farmers to adopt improved soil management practices. Since the nutrient status of soil reflects its capacity to supply nutrients to crops hence this approach aims to provide a comprehensive understanding of the region's soil health and support the development of targeted nutrient management strategies.

Materials and Methods

Site description

The study was carried out in the Hodal block of Palwal district, situated in the southern region of Haryana. Geographically, Hodal is positioned at 27°53′39″N latitude and 77°22′09″E longitude, with an average altitude of 190 meters (620 feet) above sea level.

The area experiences an extreme climate, with summer temperatures averaging 36°C, monsoon temperatures around 22°C, and winter temperatures typically around 15°C. Comprising 34 villages, Hodal forms part of the productive Indo-Gangetic plain. The soils in this region are predominantly alluvial. Major crops cultivated include wheat, rice, sugarcane, and cotton, along with substantial cultivation of pulses, vegetables, and fruits. Approximately 90% of the agricultural land is irrigated, primarily using groundwater and the Western Yamuna Canal.

Soil Sampling and Analysis

Fifty surface soil samples (0–15 cm depth) were randomly collected from farmers' fields belonging to 34 villages in the block. Each sample location was georeferenced using a handheld GPS device and depicted in Figure 1.These collected soil samples were air-dried, crushed with a wooden pestle and mortar, and sieved through a 2 mm sieve. Processed soil samples were analysed for pH and electrical conductivity (EC) by the method given by [15] was determined by wet digestion metho [38] and calcium carbonate ($CaCO_3$) was determined according to [27]. Available Ca and Mg were determined by the versenate titration method given by [4]. Sulfur (S) was estimated by using calcium chloride and analyzed using a spectrophotometer at 420 nm [5]. The DTPA-Extractable Micronutrients (Zn, Fe, Cu, Mn) were determined using the method given by [21] and their content was estimated on an atomic absorption spectrophotometer. The hot water-soluble boron was estimated by the method given by [2] and the content was estimated on a UV-VIS spectrophotometer.

Data Visualization: Site map (Fig. 1) was prepared using ArcGIS software (Esri). The correlation graph was prepared using the *corplot* package [7] in R Software [34] and other graphs were prepared using Microsoft Excel software (2021).

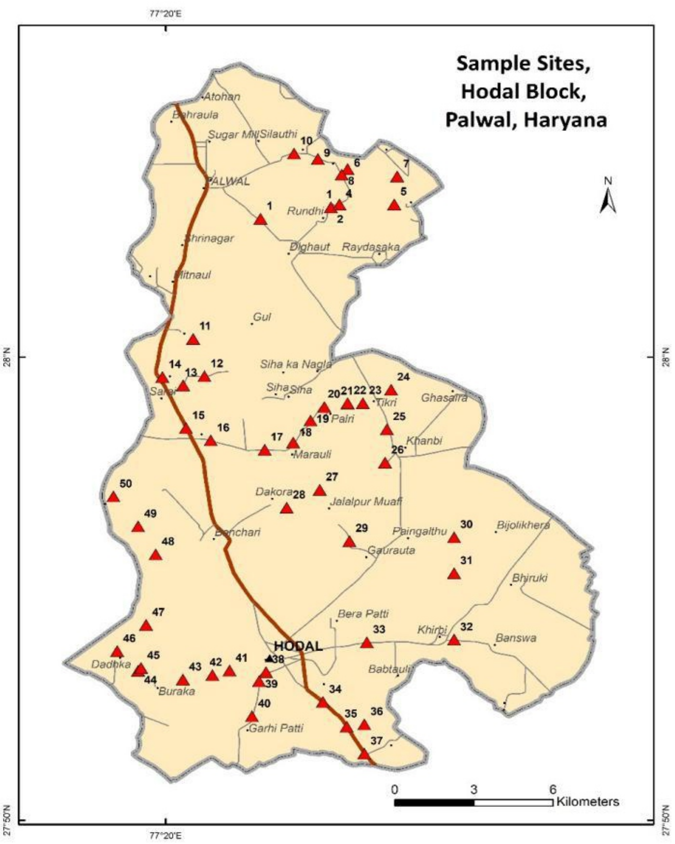

Fig 1. Location map of the Hodal block

Result and Discussion

Soil pH

Soil acidity and alkalinity are essential for optimizing crop productivity, with soil pH serving as a key indicator of all acid-base reactions occurring within the soil environment [24]. The pH of the Hadal block ranged from 7.90 to 8.90, indicating slightly to moderately alkaline conditions (Table 2). The neutral to alkaline pH may be attributed to the reaction of applied fertilizer material with soil colloids, which resulted in the retention of basic cations on the exchangeable complex of the soil [25]. Additionally, variations in soil pH may result from the combined effects of natural and human-induced factors, which influence spatial and temporal changes within a small region over a short period [39].

Electrical conductivity

Electrical conductivity provides a measure of the salt concentration in soil [25]. In the Hodal block, EC of soils ranged from 0.12 to 4.40 dS m^{1}, with a mean value of 1.07 dS m^{1} (Table 2). The normal EC levels can be attributed to the leaching of salts into deeper soil layers, reflecting good soil quality and suitability for agricultural activities [25].

Soil Organic Carbon

Organic carbon plays a crucial role being the source of essential plant nutrients (released through microbial decomposition). It providesa better environment by supplying nutrients to the plants, improves water infiltration and retention, sustains soil microflora and fauna, and aids in the retention and cycling of applied fertilizers [16]. In the soils of the Hodal block, OC contents ranged from 0.25% to 1.33%, with an average value of 0.73% (Table 2). Considering the critical limit of OC of < 0.4%, 0.4-0.75 and > 0.75% as low, medium and high, out of the total 50 samples, 4%were categorized as low, 52% as medium and 44% as high (Fig. 2). As the majority of samples (52%) fell into the medium range, indicating potential for improvement in OC content to enhance soil organic carbon by incorporating organic matter-rich materials. The low OC levels in 4% of the samples could be attributed to the rapid decomposition of organic matter under hyperthermic conditions, creating highly oxidative environments [33].

Calcium Carbonate

Calcium carbonate contents in the soils of the Hodal block ranged from nil to 3.20%, with an average value of 0.15% (Table 2). Most soil samples exhibited no detectable calcium carbonate content. The absence may be attributed to intensive farming practices and tubewell irrigation, which likely promote the leaching of calcium carbonate and its subsequent accumulation in deeper soil horizons [10].

Soil Texture

The textural class of soil is crucial for determining crop suitability and predicting soil responses to environmental and management practices. In the Hodal block, soil texture was classified as sandy loam to loam (Table 2). This variation in texture can be attributed to differences in parent material and varying degrees of weathering [28].

Macronutrient status of Hodal block soils

Calcium and Magnesium

In the soils of Hodal block, Ca and Mg content ranged from 2.50 to 8.00 and 3.00 to 17.00 cmol(p^+) kg^{1}, with a mean of 4.05 and 7.92 cmol(p^+) kg^{1}, respectively (Table 2).

All samples were classified as sufficient in Ca and Mg, reflecting the calcareous nature of these soils. The sufficiency of these cations is attributed to minimal leaching of bases, moderate to high organic carbon levels.The high soil pH and calcareous nature further enhance cation retention [26].

Sulphur

The S content in the soils ranged from 38.23 to 96.11 mg kg^1, with a mean value of 68.15 mg $kg^{1\ 1}$ (Table 2). According to already established soil test ratings for S(given in Table 1), 6% of the samples were classified as marginally sufficient, 12% as adequate, and 82% as high in S content (Fig 3). As the majority of the samples fell under high Scategory, indicating an abundant supply of this nutrient. The high S status in the soil can be attributed to the favorable conditions of high pH and calcareousness, which enhance S availability [19]. Additionally, the continuous application of S-containing fertilizers, such as $ZnSO_4$, likely contributes to this elevated sulfur content [13].

Micronutrient status of Hodal block soils

Zinc

The DTPA-extractable Zn content in the Hodal block ranged from 0.26 to 0.99 mg kg^1, with a mean value of 0.64 mg kg^{-1} (Table 2). According to the soil test ratings for Zn (Table 1), 2, 40, 48 and 10% of the samples were classified as acute deficient, deficient, latent deficient, and marginally sufficient category (Fig 4). None of the sampleswere found under the adequate or high Zn category. The majority of the samples i.e. 90% (acute+deficient+latent deficient) exhibited a deficiency in Zn. The deficiency of Zn is more commonly found in arid regions where soils are low in organic carbon and exhibit high pH levels [29]. The 10% of samples that were classified as marginally sufficient are probably collected from the area where the application of zinc fertilizer has been practiced by the farmers in recent years.

Iron

The DTPA-extractable Fe content in the Hodal block ranged from 2.16 to 12.30 mg kg^1,with a mean value of 6.77 mg kg^1. Based on soil test ratings for available Fe (Table 1), out of 50 samples, 4% were acute, 26% deficient, 26% latent deficient, 14% marginal sufficient, 14% adequate 16% high in iron (Fig. 4).The majority of the soil samples i.e. 56% (acute+deficient+latent deficient) were deficient in iron content. The low content of available iron in soil due to their alkaline in nature and light in their textural class[22]. and another probable reason of low iron status may be attributed to current moisture stress conditions, which convert ferrous (Fe^2+) iron into ferric (Fe^3+) iron [31].

Copper

The DTPA-extractable Cu content in the soils of the Hodal block ranged from 0.11 to 2.19 mg kg^1, with a mean value of 0.82 mg kg^1. Based on the soil test ratings for available Cu (Table 1), 4,16, 24, 16, 16, and 24 of the samples were categorized under acutely deficient, deficient, latent deficient, marginally sufficient, adequate, and high categories (Fig 4). The majority of the soil samples i.e., 56% (marginally sufficient, adequate, or high) were found to be sufficient in Cu could be due to good management practices, which align with the findings of [23]. This low copper availability in the soil, i.e.44% the samples, can be attributed to the relatively high soil pH, which contributes to copper deficiency.

Manganese

The DTPA-extractable Mn levels in the soils of the Hodal block ranged from 2.73 to 7.00 mg kg^1, with a mean value of 4.05 mg kg^1. (Table 2).Based on the soil test ratings for Mn availability (Table 1), 84% of the samples were classified as latent deficient, 12% as marginally sufficient, and 4% as adequate in Mn status (Fig. 4). The majority of the soil samples i.e. 84% were found to be deficient in Mn. The low availability ofMn in these soils can be attributed to the alkaline nature of the soil, as higher pH levels tend to reduce the availability of Mn [17]. Additionally, the light texture of these soils, which undergoes cycles of wetting and drying, further contributes to the low levels of available manganese.

Hot water-soluble Boron

Boron is an essential non-metallic micronutrient vital for the normal growth and development of plants .In the soils of the Hodal block, HWS B levels ranged from 0.44 to 3.64 mg kg^1, with a mean of 1.51 mg kg^1. (Table 2).Based on soil test ratings for B availability (Table1), 2% of the samples were classified as deficient, 14% as latent deficient, 58% as adequate, and 26% as high in boron status (Fig. 4). A significant majority of the samples 84% (adequate+high) were found to be sufficient in boron content. This sufficiency is likely due to the fact that water-soluble boron content in soils generally increases with soil pH, though this relationship is not always consistent [36]. Additionally, as the pH rises, boron adsorption by soil components also increases, reaching its maximum in alkaline pH ranges [11 12]

Table 1. Critical limits of secondary and micronutrients in the soil (Shukla et al., 2019)

Nutrients	Acute	Deficient	Latentdeficient	Marginalsufficient	Adequate	High
$CaCl_2$-S	≤10	>10-≤20	>20 -≤30	>30 -≤40	>40-≤50	>50
DTPA- Zn	≤0.3	>0.3 -≤0.6	>0.6 -≤0.9	>0.9 -≤1.2	>1.2-≤1.8	>1.8
DTPA- Fe	≤2.5	>2.5 -≤4.5	>4.5 -≤6.5	>6.5 -≤8.5	>8.5- ≤10.5	>10.5
DTPA- Cu	≤0.2	>0.2 -≤0.4	>0.4 -≤0.6	>0.6 -≤0.8	>0.8-≤1.0	>1.0
DTPA- Mn	≤1	>1-≤3	>3 -≤5	>5 -≤7	>7 -≤9	>9
HWS- B	< 0.2	0.2 – 0.5	0.5 – 0.7	0.7-0.9	0.9 – 1.10	> 1.10

Table 2. Soil fertility status of Hodal block

Parameters	Range	Mean	Parameters	Range	Mean
pH	7.90-8.90	8.23	S ($mgkg^{-1}$)	38.23-96.11	68.15
EC (dSm^{-1})	0.12-4.40	1.07	Zn ($mgkg^{-1}$)	0.26-0.99	0.64
OC(%)	0.25-1.33	0.73	Fe ($mgkg^{-1}$)	2.16-2.30	6.77
$CaCO_3$(%)	0 -3.20	0.15	Cu ($mgkg^{-1}$)	0.11-2.19	0.82
Ca {cmol (p^+) kg^{-1}}	2.50 - 8.00	4.05	Mn ($mgkg^{-1}$)	2.73-7.00	4.05
Mg {cmol (p^+) kg^{-1}}	3.00 -17.0	7.92	B ($mgkg^{-1}$)	0.44-3.64	1.51

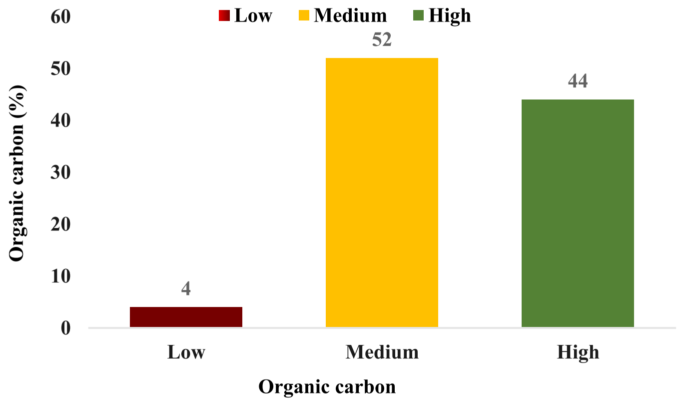

Fig 2. OC status of Hodal block

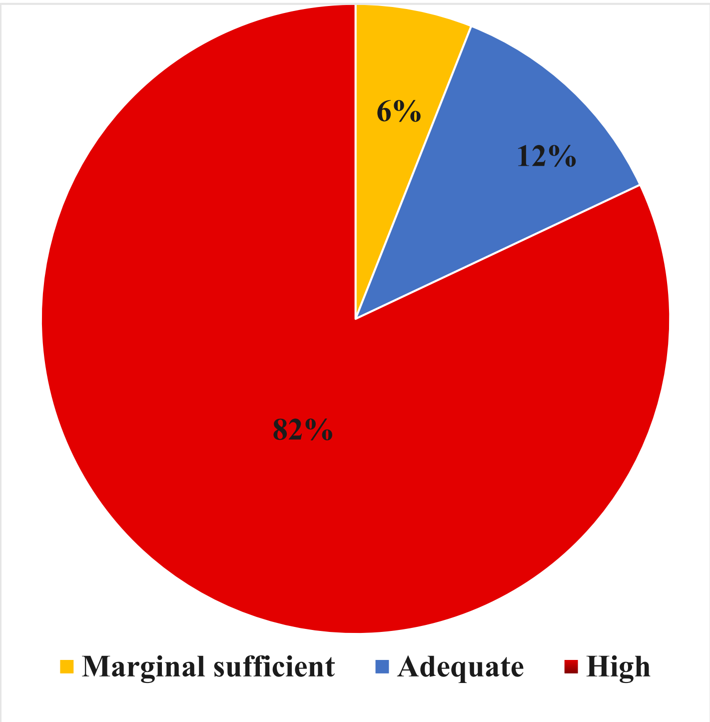

Fig 3. Distribution of Sulphur (%) under different categories in Hodal block

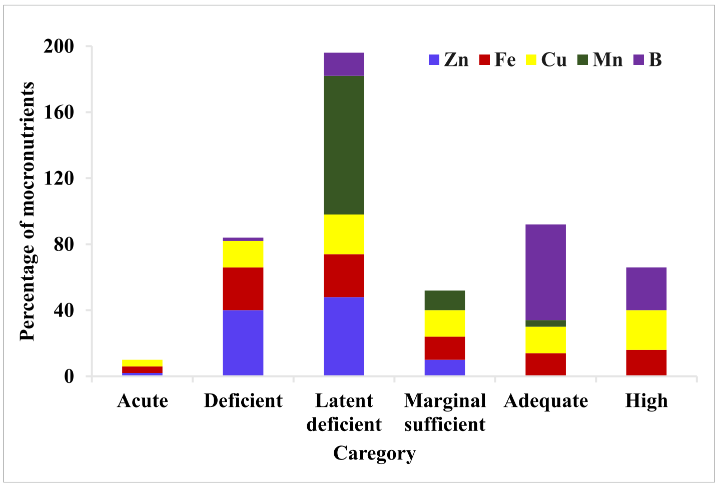

Fig 4. Percentage of micronutrients under different category in Hodal block

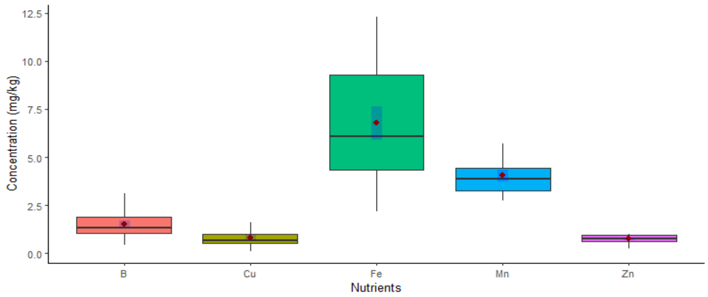

Fig 5. Boxplot of micronutrient (showing the confidence interval of the mean for each nutrient)

The descriptive statistics for the micro nutrients in the soil samples from the Hodal block of Palwal district revealed considerable variability (Fig 5). Zinc in soils of the Hodal block ranged from 0.26 to 0.99 mg/kg, with a mean and median value of 0.75 and 0.78 mg/kg, respectively. The Fe content has a broader interquartile range and its content varied from 2.16 to 12.30 mg/kg, with a mean median of 6.77and 6.07 mg/kg, suggesting variability in its availability. The Cu contents were found between 0.11 and 2.19 mg/kg, with a mean and median of 0.83 and 0.69 mg/kg, respectively. The Mn and B content varied from 2.73 to 7.00 and 0.44 and 3.64 mg/kg. The mean value for Mn and B in the Hodal block was 4.05 and 1 51 mg/kgand that of the median was 3.90 and 1.34 mg/kg, respectively. The data emphasizethe heterogeneity in nutrient status, necessitating targeted soil management practices to ensure optimal crop nutrition.

Correlation between soil properties and nutrient content

Correlation studies, as presented in (Fig. 6), revealed that B was significantly negatively correlated with Zn (r = -0.47***). This negative correlation may be attributed to the high levels of zinc in the soil, which potentially decreased the residual available boron relative to the zinc content (Aref, 2010). Zinc also showed a negative correlation with Cu (r = -0.40**), likely due to the antagonistic interaction between Zn and Cu [22]. On the other hand, copper was highly significantly positively correlated with boron (r = 0.89***), which could be due to chelation processes that ensure the co-availability of both elements in favorable soil conditions.s[8]. Furthermore, a moderate positive correlation was observed between Ca and EC (r = 0.33*), a result that aligns with the study by [2]

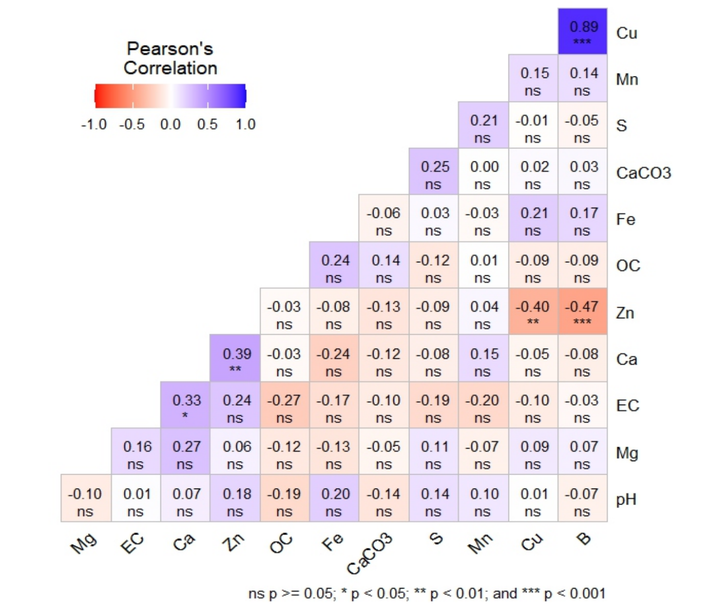

Fig. 6. Pearson's correlation between soil properties and nutrient content in the soil of the Hodal block

Conclusion

The study provides an in-depth knowledge of soil properties encompassing highlighting significant variations in micronutrient and secondary nutrient status of the Hodal block of the district Palwal. Among secondary and micronutrients, the most targeted nutrient that may influence the crop yield is Zn, followed by Fe and Cu. The findings emphasize the need for tailored soil management practices to address these nutrients to enhance soil fertility and crop productivity of the block.However, for a better option about the increment in the crop production of the block, analysis for other nutrients (N,P, and K) is required.

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