Received : 06.04.2023 | Accepted : 08.06.2023 | Online published : 01.07.2023
https://doi.org/10.54986/irjee/2023/jul_sep/92-97

IRJEE SOCIETY OF EXTENSION EDUCATION

RESEARCH ARTICLE

Economic Implications of Soil on Crop Production in Chandel District of Manipur, India

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ABSTRACT

For the analysis of the physico-chemical parameters of the soil of Chandel district, Manipur (India), a study was carried out at 26 villages. Collection of surface soil samples (0 to 30 cm) was done and studied for diethylene-triaminepentaacetate (DTPA)- extractable soils. The mean values for DTPA-extractable Zn, Cu, Mn, Fe and hot water extractable B in relation to some chemical properties in 26 representative soils was calculated. The mean values for DTPA-extractable Zn, Cu, Mn, Fe, and hot water extractable B were found to be 0.23, 0.55, 8.87, 22.93 and 0.48 mg kg^{-1}, respectively. The mean values of available N, P_2O_5, K_2O and SO_4-S were observed to be 495.7, 15.6, 241.3 and 1.7 kg ha^{-1}, respectively. It was seen that distribution of Zn, Cu, Mn, Fe and B were influenced positively by pH, EC, and organic carbon content of the soil. From the results of the study, it was found that the micro- nutrient cations were significantly correlated with each other suggesting a dynamic equilibrium among them. All the soil samples were sufficient in available micro-nutrient cations, except for zinc.

Key words: *Diethyline triamine pentaacetic acid; Zinc; Copper; Manganese; Iron; Boron.*

The soil in the state of Manipur belongs to 4 orders, 8 suborders, 13 greatgroups and 23 subgroups. The Inceptisols are observed to be the dominant soils followed by Ultisols, Entisols and Alfisols and occupy 38.4%, 36.4%, 23.1% of the total geographical area of the state, respectively.

Regular soil testing provides the important information about the nutrient availability of the soil upon which the experts' fertilizer recommendation for maximizing crop yield and productivity is made. Generally, zinc (Zn), copper (Cu), manganese (Mn), iron (Fe) and boron (B) are the essential micro-nutrients for plant growth. Through their involvement in various enzymes and other physiologically active molecules, these micro-nutrients are important for gene expression, biosynthesis of proteins, nucleic acids, growth substances, chlorophyll and secondary metabolites, metabolism of carbohydrates and lipids, stress tolerance, etc. (*Singh, 2004, Rengel, 2007 and Gao et al., 2008*).

The micro- nutrient availability to plants can be determined in direct uptake experiments or estimated with techniques that correlate the quantities of micro-nutrients extracted chemically from the soils (*Kabata-Pendias, 2001*). Micronutrient cycling is quite different among various terrestrial ecosystems (*Han et al., 2007*). After China, India is the second largest consumer of mineral fertilizers in the world, consuming about 26.5 million tons (*Jaga and Patel, 2012*). Micronutrients namely boron, chlorine, copper, iron, manganese, molybdenum, and zinc are used in small amounts, but they are as essential for the plant development and profitable crop production as the major nutrients. However, it has been found that the major focus of the Indian fertilizer sector policy is on primary (macro) nutrients. The application of essential plant nutrients particularly major and micro nutrients in optimum quantity and right proportion through correct and timely application is the perquisite for enhanced and sustained crop production. Therefore, it is important to understand the use behavior of fertilizers in the country over time as well as role of factors influencing fertilizer consumption at the national and regional / state level because intensity of fertilizer use varies from state to state and area to area. Shifting cultivation (SC) is the prevalent form of cultivation in North Eastern Region

(NER) of India and it is locally known as *jhuming* where as the cultivators are known as *jhumias*. Generally, shifting cultivation (SC) in its more traditional and integrated form is environmentally, ecologically, and economically viable system of agriculture as long as the population pressure is low enough and *jhum*/ fallow cycles are long enough to maintain soil health including fertility.

Rice is the major staple food crop of the state and is grown in 90% of the total cultivated area during the summer (kharif) season. In order to obtain its maximum yield, the recommended dose of minerals is 60:40:30 kg of N, P2O5, and K2O ha-1. Application of major nutrients (nitrogen, phosphorus, potassium) is the trend in fields; as a result of which, the crops have begun responding to micronutrient fertilizers. Low organic carbon, multinutrient deficiency, skewed nutrient application, low organic matter status, lack of knowledge and innovation in product development have posed tremendous challenge in crop nutrition solution. Intensification of agriculture coupled with use of high analysis fertilizers, devoid of secondary and micronutrients has led to widespread deficiency of these nutrients which has further aggravated the situation because of restricted or no application of organic manures. The deficiency of sulphur, zinc and boron is very common in many states (*Singh et al., 2021*).

Sincere and continuous efforts have been made through the All India Coordinated Research Project on Micronutrients to delineate the soils of India regarding the deficiency of micronutrients. As of now, about 48.1% of deficiency has been found in the Indian soils in diethylene-triaminepentaacetate (DTPA) extractable zinc, 11.2% in iron, 7% in copper and 5.1% in manganese. Apart from these, deficiencies of boron and molybdenum have also been reported in some areas. Fortunately, areas with multi-micronutrient deficiencies are limited, and very often simple fertilizers are sufficient to exploit the potential of crops and cropping systems (*Gupta, 2005*).

Judicious application of mineral fertilizers is very often the most advantageous and the easiest manner to increase crop yields and their deficiency causes several forms of disorders in many commercially important crops (*Duarah et al., 2011*). Keeping in view the above importance of mineral fertilizers for crop growth and yield, this present study on the existing status of soil macro and micro nutrients was carried out with the following objectives (i) Assessment of the macronutrients, such as, NH_4^+, $H_2PO_4^-$, K^+ and $SO4^=$ and micronutrients, that is, Zn^+, Cu^+, Mn^{++}, Fe^{++} and B^{+++} distribution on the surface soils and (ii) Exploration of the existing relationships among micro-nutrients with other soil properties.

METHODOLOGY

The present study was done for assessment of some macro and micro-nutrient status of the soils of Chandel district of Manipur (India). The total geographical area of the district is 496 sq. km having 2.22 per cent of the total geographical area of the state. The district of Chandel (24°40' N latitude and 93°50' E longitude), is in the south-eastern part of Manipur and has a sub-tropical climate which is characterised by hot summer and cold winter. The mean annual temperature is above 22˚C and the summer temperature ranges from 35 to 46˚C. The mean annual precipitation varies from 2000 to 2400 mm.

The area falls under warm, humid agro-ecological zone with thermic ecosystem and length of growing period is around 300-330 days. The vegetation is predominantly pine including woody and herbaceous species. The soil types of Chandel district are generally coarser, ranging from fine loamy, loamy to sandy in texture and deep in soil depth. Soils of the study area fall under the categories of three major soil orders: ultisol, inceptisol and alfisols. For the study, collection of 10 representative soil samples (0 to 30 cm) from 26 villages of the district was done. To avoid any contamination of the soil samples, the collection was done with wooden tools. For each composite sample, 8 spots were dug out. Thereafter all the soil samples were stored in properly labelled polythene bags for further analysis. The soil pH and electrical conductivity (EC) were determined by potentiometery and direct reading conductivity meter using 1:2.5 soil water suspensions (*Jackson, 1973*). The composite soil samples were analyzed for available nitrogen (*Subbiah and Asija, 1956*), available P_2O_5 (*Bray and Kurtz, 1945*), neutral ammonium acetate extractable K_2O (Jackson, 1973), organic carbon (*Walkley and Black, 1934*), and available SO4-S (*Chesnin and Yien, 1951*). An Atomic Absorption Spectrophotometer was used to determine the available Zn, Cu, Mn and Fe extracted with DTPA (*Lindsay and Norvell, 1978*). Also, UV-VIS Spectrophotometer was used to estimate the hot water-soluble B (*Wear, 1965*). Simple correlation coefficient was used to establish the relationships between various soil properties and micro-nutrients distribution.

RESULTS AND DISCUSSION

Two hundred and sixty surface soils (0 to 30 cm) of Chandel district, Manipur (India) were studied. The results of soil pH, EC, organic carbon (OC), available N, P2O5, K2O, SO4-S and DTPA- extractable Zn, Cu, Mn, Fe and hot water extractable B are presented in Fig 2. The analysis of the soil test result shows that the pH of the soils varied from 4.4-6.8 (with a mean value of 5.8), EC ranged from 0.01-0.25 dSm^{-1} (with a mean value of 0.03 dSm-1) and organic carbon content varied from 0.22-2.02 % with a mean value of 0.68 %. The available N, P2O5, K2O and SO4-S ranged from 219.5-878.1 (with a mean of 495.7), 3.9-96.2 (mean of 15.6), 69.4-542.1 (mean value being 241.3) and 0.4-3.9 (with a mean of 1.7) kg ha^{-1}, respectively. The soils were found to be very strongly acidic to neutral in reaction. The acidic nature of the soil of the district might be due to the high rainfall which could have led to leaching losses of bases from the surface soils. On top of that, application of nitrogenous fertilizers in the fields and decomposition of organic matter could have contributed to the soil acidity. The wide variation of EC in the soils might be due to the variable concentration of basic cations in the soils. Luxuriant growth of grasses along with the seasonal decomposition of vegetative parts and roots could be the reason for the high organic carbon content in the soil. It was observed that the chemical properties of the soils were positively and significantly correlated with each other pH, EC and available P_2O_5.

Available micronutrients status and influence of soil chemical characteristics

Iron: Available Fe contents in the surface soils varied from 3.751 to 56.65 mg kg^{-1} with a mean value of 22.93 mg kg^{-1} (Fig 1). All the soils had significant amount of Fe considering 4.5 mg kg^{-1} as critical limit as suggested by *Lindsay and Norvell (1978).* It showed positive and significant correlations with pH (r = 0.627**), EC (r = 0.687**), OC (r = 0.540**), available N (r = 0.728**), available P_2O_5 (r = 0.645**), K_2O (r = 0.750**), SO_4-S (r = 0.597**). Similar findings were also reported by *Verma et al. (2005), Jiang et al. (2009) and Bassirani et al. (2011*)

Manganese: Available Mn in the surface soils ranged

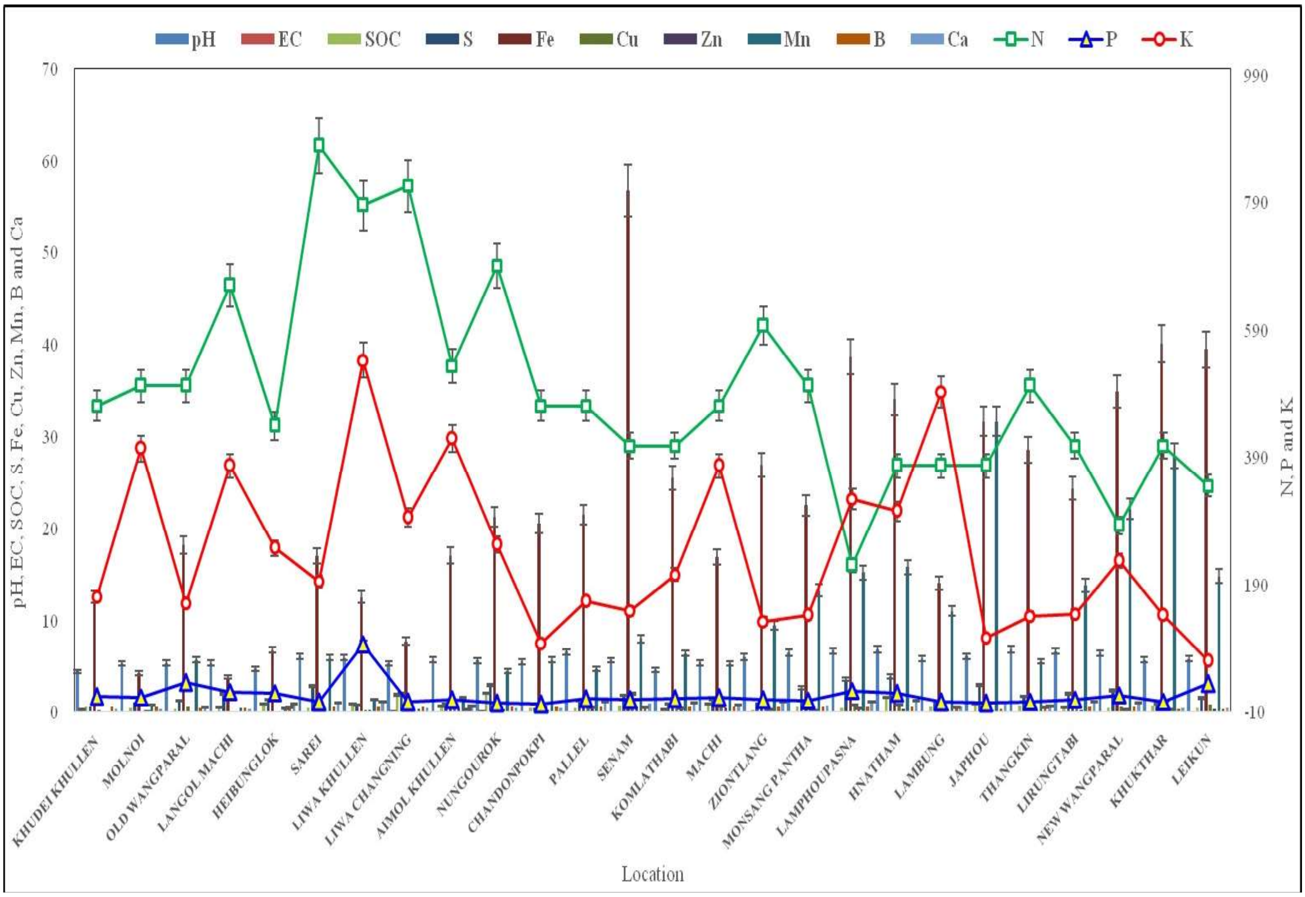

Fig 1. Location specific major chemical characteristics of the soils in Chandel District

from 0.078 to 31.605 mg kg^{-1} with a mean value of 8.87 mg kg^{-1}. Considering 1.0 mg kg^{-1} as critical limit for Mn deficiency (*Lindsay and Norvell, 1978*), all the soil samples were found to have sufficient amounts of available Mn. In simple correlation coefficient studies (Fig 2), available Mn showed significant and positive correlation coefficients with pH (r = 0.811 **), EC (r = 0.621 **), OC (r = 0.840 **), N (r = 0.703 **), P (r = 0.737 **), K (r = 0.920 **), SO_4-S (r = 0.835 **). Available Mn also had positive significant correlations with other micro-nutrient cations content in the soils. Soil micro-nutrient cations like Fe (r = 0.721 **), Cu (r = 0.705 **) and Zn (r = 0.728**) were found to have significant correlation with available Mn, suggesting variation in their distribution dependent upon common soil factors (*Follect and Lindsay, 1970*).

Copper: Available copper content in the surface soils varied from 0.08 to 1.974 mg kg^{-1} with a mean value of 0.55 mg kg^{-1}. All the soils were found to be in adequate range, considering 0.2 mg kg^{-1} as critical limit for Cu deficiency (*Lindsay and Norvell, 1978*). The micro-nutrient cation exhibited significant and positive correlation coefficient with pH (r = 0.644**), OC (r = 0.749**), available N (r = 0.646**), available P_2O_5 (r = 0.503**), available K_2O (r = 0.724*), SO_4-S (r = 0.692**) and positive and significant correlations with another micro- nutrient cation like Fe (r = 0.518 **). Similar finding was observed by *Singh et al. (2006), Verma et al. (2007), Jiang et al. (2009)* and *Bassirani et al. (2011).*

Zinc: Available Zn in the studied surface soils ranged from 0.021 to 0.557 mg kg^{-1} with a mean value of 0.23 mg kg^{-1}. This is in conformity with the findings by *Raina et al. (2003*) in apple growing soils of Himachal Pradesh, India. Some per cent of the studied soils were categorized under deficient categories, considering 0.6 mg kg^{-1} as critical limit of available Zn as suggested by *Takkar and Mann (1975*). The average available zinc showed significant and positive correlation coefficient with pH (r = 0.823**), EC (r = 0.525 **), OC (r = 0.576**), available N (r = 0.664**), available P_2O_5 (r = 0.581**), available K_2O (r = 0.828*), SO_4-S (r = 0.615**) and also positive and significant correlations with another micro- nutrient cation like Fe (r = 0.713 **) and Cu (r = 0.638 **). This finding is in similarity with the earlier findings of *Venkatesh et al. (2003), Verma et al. (2005)* and *Sharma and Chaudhary (2007)*. It was also found to show positive and significant correlation with other micronutrient cations. This result is also like the findings of *Bassirani et al. (2011*). The amount of zinc required for alleviating zinc deficiency varied with severity of deficiency, soil types, nature of crops and cultivars. In most instances, the ideal dose was found to be 5.5 kg zinc ha^{-1}. The deficiency of zinc can be best alleviated with the use of 11 kg Zn ha^{-1} for wheat, rice and maize; 5.5 kg Zn ha^{-1} for soybean, mustard, raya, sunflower and sugarcane and with 2.5 kg Zn ha^{-1} for groundnut, ragi, gram, linseed, green gram, lentil etc.

Boron: The hot water-soluble B content in the surface soils varied from 0.26 to 0.53 mg kg^{-1} with a mean value of 0.48 mg kg^{-1}. Available B in soils of different states of India was found to vary from traces to 12.2 mg kg^{-1} (*Das, 2000*). The available boron showed significant and positive correlation coefficient not only with available K_2O (r = 0.566*), SO_4-S (r = 0.577**) but also positive and significant correlations with other micro- nutrient cations like Fe (r = 0.515 **) and Cu (r = 0.524 **). Correlation studies clearly show that the chemical properties of the soils influence the boron content in the soils. Thus, the relationship between the soil properties and hot water-soluble boron was found to be positive and in significant correlation with other micronutrient cations. (Fig 1).

The immediate and potential availability of micronutrient cations were found to be affected by organic matter and manure applications (*Rengel, 2007*). The micro nutrient cations were found to react with certain organic molecules to form organo-metallic complexes as chelates and soluble chelates could increase the availability of the micro-nutrients and provide protection from precipitation reactions. These chelates were found to be synthesized by the roots of the plants and released to the surrounding soil. Quite often, the chelate may also be present in the soil humus layer or may be added to the soil as synthetic compound to enhance the micronutrient availability (*Brady and Weil, 2002*). In this present study, positive and significant correlation of soil organic matter related to chemical indices, including soil organic carbon and nitrogen was done with DTPA-extractable micro- nutrient cation (Fig 2). It was observed that DTPA-extractable micro- nutrient cations were positively and significantly correlated with the soil pH. This might be due to leaching losses of water-soluble micro-nutrients with the study area receiving intense and high rainfall hitch could have

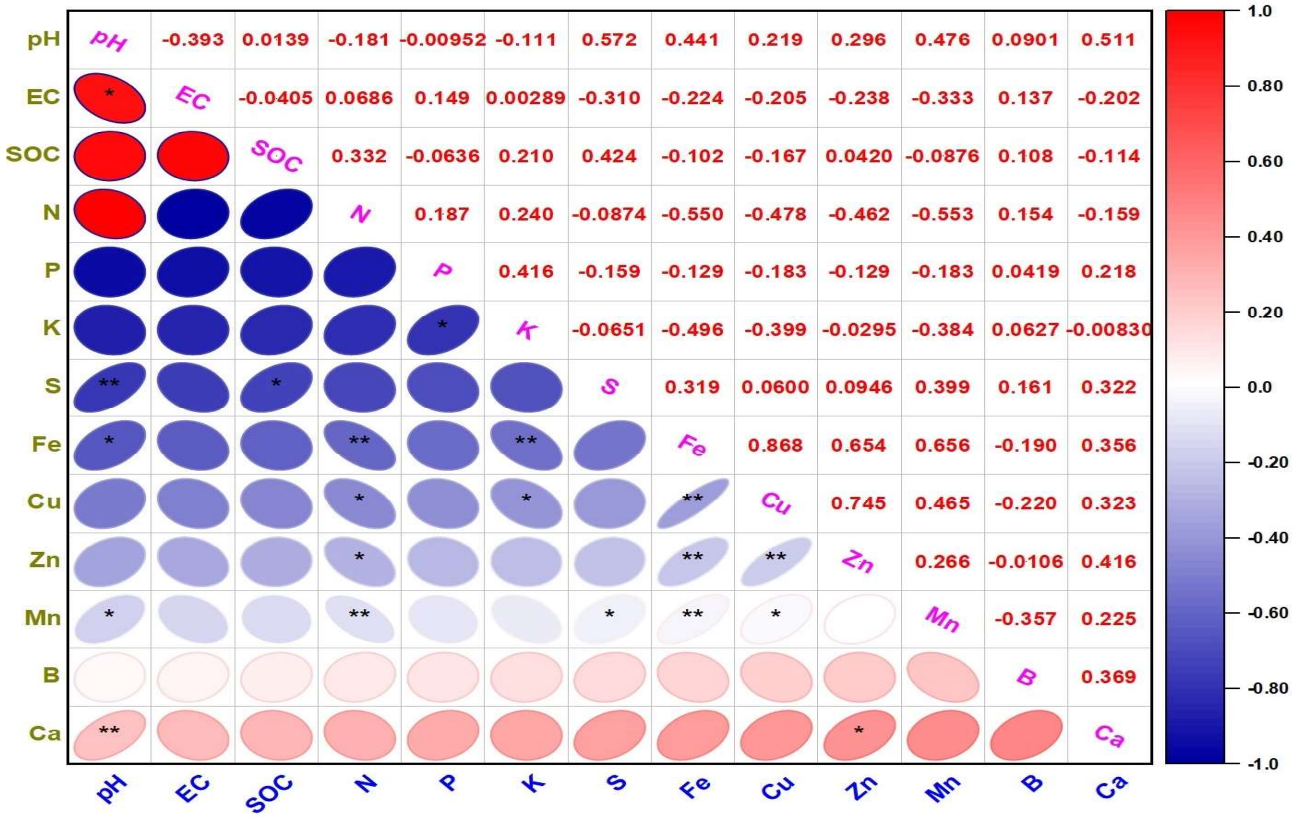

Fig. 2. Correlation between diverse soil parameters

led to the low content of micro- nutrients in the soils even though these micro- nutrients are most soluble and readily available under the acidic condition.

CONCLUSION

In the hill districts of the state of Manipur, deficiency of macronutrients and micronutrients often hinders the productivity and sustainability. Soil acidity is a prime factor for low productivity of major crops in this area as availability of the nutrients is a problem in this type of soil. Severe deficiencies of phosphorus, calcium, magnesium, molybdenum and toxicities of aluminum and iron are reported in acidic soils. So, soil acidity management is very much important in Northeast India for increasing productivity of the crops. Integrated use of balanced inorganic fertilizers in combination with lime and organic manures improves the soil physical environment that is suitable for achieving higher productivity of crop in intensive cropping system of the region (*Bordoloi, 2021*). Role of micronutrients in balanced plant nutrition is well established. Micronutrients are very important for maintaining soil health and in increasing productivity of crops (*Rattan et al. 2009*). From this study, it was observed that soil pH changed from very strongly acidic to nearly neutral. Organic carbon, available nitrogen and potassium were found to be high and available phosphorus underwent a variation from very low to very high in status. Among the micronutrients, soils are having a high concentration of Fe, some soils are low in Zn and B availability. It was indicated by *Shukla et. al,* (*2020*)*,* that the highest crop response in terms of yield was found with timely application of nutrients through water soluble fertilizers. Thereafter, recommendations on soil fertility management through rational use of manure, fertilizers, and amendments to make agriculture more productive and sustainable were given to the farmers of the district.

CONFLICTS OF INTEREST

The authors have no conflicts of interest.

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