Soil Fertility Problems and Strategies to Reduce Them in the Himalayan Region of India

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Introduction

The hill soils of the Indian Himalayan region vary widely in their kind and properties and are spread across the states of Jammu & Kashmir, Himachal Pradesh, Punjab, Uttar Pradesh, Bihar and the north-east hill region. The fertility of these soils suffers from various micronutrient deficiencies. Strategies are being developed to correct micronutrient deficiencies through fertilisation and other amendments, and are helping to achieve optimum crop productivity to a considerable extent in some areas. In this paper, the soil fertility problems resulting from micronutrient deficiencies or excess, and methods for their alleviation, are discussed by state.

Jammu and Kashmir (J&K)

Fertility Status

Ladakh, Jammu & Kashmir – Analysis of DTPA extractable micronutrients in soils (Entisols) in the cold-arid zone of Ladakh showed levels of Zn, Fe, Mn, and Cu ranging from 0.02 to 3.86, 1.56 to 14.6, 2.12 to 5.9, and 0.20 to3.7 mg kg^{-1} soil, respectively, with 30% of soils deficient in Zn and nearly 26% deficient in Fe (Jalali et al. 2000). Sub-tropical, intermediate, temperate, and cold-arid soils showed Zn deficiency in 22, 24, 18, and 30% of samples, respectively. In the Jammu region 31, 26, 23, 19, 13, and 10% of samples in Jammu, Rajouri, Doda, Kathua, Udhampur, and Poonch districts, respectively, showed Zn deficiency. The available Zn content in these soils ranged from 0.1 to 6.1 mg kg^{-1}. Further investigations revealed that about 51% of soils in the mid-hills were also deficient in Fe as well as 24% in Zn (Jalali and Sharma 2002; Jalali and Pareek 2003). In the soils of Kashmir, available Zn was higher in the high altitude (kandi) soils (0.37-0.60 mg kg^{-1}) than in the valley basin (0.15-1.0 mg kg^{-1}) and karewas (Hapludalfs) soils (0.27-0.80 mg kg^{-1}). The Zn status in almost all the soils was in the deficient range and that of Cu, Fe, and Mn in the adequate range (Jalali et al. 1989). Thus Zn deficiency is one of the major constraints in these soils. The content of available micronutrients decreased with pH and increased with soil organic matter (SOM) content. The magnitude of Zn deficiency decreased with increase in SOM content and increased with increase in soil $CaCO_3$ and pH (Jalali and Sharma 2002; Jalali et al. 1989).

Correction of deficiency

Field crops – The productivity of rice, wheat, maize, rapeseed, and mustard improved markedly with Zn application to the soils of the intermediate and sub-tropical zones in the Jammu region. Application of 4.4 kg ha^{-1} Zn as a top dressing gave maximum maize and rice grain yield responses of 48.5 and 17.9% respectively; the basal Zn application lead to wheat and rapeseed yield increases of 11.8 and 7.6%. The residual effects in the paddy-wheat cropping system lasted for two years (Jalali et al. 1999; Sharma et al. 2003; Jalali and Pareek 2003).

Fruit crops – The soils of citrus, mango, and guava orchards contained low available (DTPA) Zn (0.26-2.48 mg kg^{-1}). Some 53% of soil samples were deficient in Zn, whereas all the soils contained adequate levels of available Cu (0.22-2.54 mg kg^{-1}), Fe (4.5-63.5 mg kg^{-1}), and Mn (1.92-36.2 mg kg^{-1}). Leaf analysis also showed Zn deficiency in 40% of mandarin samples, 56% of mangoes, and 30% of guavas, but not in 'ber' samples. No deficiencies of Fe, Mn, or Cu were observed in the leaves. Deficiency of N, P, K, and S was also severe in orchard soils, up to 75, 45, 22, and 44% of samples, respectively; these appear to have masked the beneficial effects of Zn application to obtain optimum productivity. A strategy of correction of macronutrient deficiencies needs to be adopted while alleviating micronutrient deficiencies (Sharma et al. 2001; Jalali and Pareek 2003).

Himachal Pradesh (HP)

Fertility Status

Valley areas under wheat and rice cultivation – In the wheat growing areas of Suwan and Nurpur, Chhota Bhangal, Bath and Kulu, Jahu, Janjethi, Shimla, and Ponta, 28% of soil samples and 12% of wheat plant samples were deficient in Zn. In the Palam Valley, 66% of soils and 31% of wheat samples suffered from Zn deficiency; in the remaining area, 20-25% of the soils were deficient in Zn. In the rice-growing soils of Nurpur, Kangra, Bath and Kulu valley, the available micronutrient content in soils ranged from 1.6 to 50.0 mg kg^{-1} for Fe, 1.5 to 48.0 mg kg^{-1} for Mn, 0.1 to 7.8 mg kg^{-1} for Cu, and 0.3 to 1.5 mg kg^{-1} for Zn. Seventeen per cent of soil samples were deficient in Fe in the Kangra Valley; 1.3 and 20.0% were deficient in Cu in the Kangra and Bath valleys; and 20.0, 14.2, and 11.8% were deficient in Zn in the Bath, Kulu, and Kangra valleys respectively (Verma and Tripathi 1982, Tripathi et al. 1994).

Vegetable growing soils – In the major off-season vegetable growing area in the Spiti valley and Kinaur district, 16-42% of soil samples were deficient in available Fe, 18-34% in Mn, and 11-65% in Zn (Parmar et al. 1999). The availability of Fe and Mn decreased significantly with increase in soil pH and $CaCO_3$ content and that of Zn with increase in pH. The availability of all three micronutrients increased with increase in SOM content.

Orchard soil – The soils in the apple orchards of the Shimla Hills had 35 and 70% Zn deficiency, 30 and 94% B deficiency, and 50 and 35% Mo deficiency in surface and sub-surface soils respectively. Thus the nutrient status of sub-soil needs to be taken into account when ascertaining the fertility status of orchard soils (Bhandhari and Randhawa 1985). In another study, Sharma and Bhandhari (1995) observed that only available B was low in 57% of soil samples from a group of Delicious apple orchards. Leaf analysis indicated that 11, 5, and 40% of orchards were low in Zn, Cu, and B respectively. The high deficiency of B is attributed to an acidic soil reaction coupled with the high humidity of the region.

Typical pedons (profiles) – In ten typical pedons, available Zn content varied from 0.1 to 2.8 and 0.4 to 4.8 mg kg^{-1}, available Cu from 6.2 to 40.5 mg kg^{-1}, and available Fe from 3.8 to 52.5 mg kg^{-1} respectively. Most of the pedons were deficient in Zn only. The availability of micronutrients generally increased with increase in soil organic matter and decreased with increase in soil depth (Tripathi et al. 1994).

Correction of deficiency

Potato – Nearly 76% of the brown hill soils of the potato-growing areas were deficient in Zn and 31% in Cu. In these soils, the response of potato to addition of Zn, Cu, Fe, Mn, B, and Mo ranged between 1.0 and 7.6, 2.2 and 6.1, 1.1 and 4.0, 1.5 and 3.9, 3.2 and 4.4, and 1.0 and 3.5 t ha^{-1}, respectively. Zn efficient potato varieties have also been identified (Grewal and Trehan, 1990).

Wheat – In Palampur soils, wheat showed a significant response to Cu application of 107 kg ha^{-1}, and paddy to Zn and Fe of 456 to 764 kg ha^{-1}. In Kangra, Palampur, and Kulu districts, a significant response (242-276 kg ha^{-1}) of maize to Zn application was observed (Kanwar and Randhawa 1974).

Punjab (Sub-mountain Areas)

Litchi orchard soils – A study on the nutritional status of litchi orchards in the sub-mountain districts of Hoshiarpur, Gurdaspur, and Ropar showed 97, 14, 3, and 3% of orchards to have a low or medium fertility status for Mn, Zn, Cu, and B, respectively. None were deficient in Fe. Thus the major deficiencies were in Mn and Zn and application of these might improve the yield of litchi fruit (Hundal and Arora 1993).

Uttar Pradesh (UP)

Foothill Terai soils – Zinc deficiency is a serious soil fertility constraint in the foothill Terai soils of Uttar Pradesh; field-scale deficiency of Zn in rice was recorded for the first time in these soils. A long-term fertiliser experiment (LTFE) with an intensive rice-wheat-cowpea cropping system on these soils (Mollisols) depleted the available Zn from adequate (2.77 mg kg^{-1}) to deficient level (<1.0 mg kg^{-1}) after 12 years. Application of 11 kg Zn ha^{-1} restored the soil Zn fertility status and improved the productivity of the system by 0.48t ha^{-1}. Application of 15t FYM ha^{-1} annually also maintained the Zn level in the adequate range and improved the productivity by 0.44t ha^{-1} (Nand Ram 1998). Thus the strategy to reduce the Zn deficiency problem on such Mollisols is to apply either Zn fertiliser or FYM to achieve a sustainable high productivity of the system. In a similar LTFE in Himachal Pradesh on Typic Hapludoll under a maize-wheat system, there was no Zn or other micronutrient deficiency even after 25 years. Thus the emergence of micronutrient soil fertility problems depends on the soil type and the cropping system. Clear Zn deficiency symptoms have been observed in maize, pulses, and citrus fruits in these areas. The deficiency problem arises after one year of growth in citrus orchards when the root system reaches down deep below the plough layer to a layer low in available Zn. The available Zn content and distribution in six soil series of Nainital Terai soils representing poor, imperfect, and moderately well drained soils was deficient, ranging from 0.08 to 0.60 mg kg^{-1} soil. Available Zn decreased with soil depth and was mainly regulated by the SOM content (Vittal and Gangwar 1974; Bhardhawaj and Prasad 1981).

Hill districts of Almora, Pithoragarh and Chamoli – The micronutrients Zn, Cu, Fe, Mn, Mo, and B were deficient in 74, 20, 17.3, 20, 18.6 and 24% of soil samples, respectively, from the three hill districts of Almora, Pithoragarh, and Chamoli (Rawat and Mathpal 1981). The availability of these micronutrients decreased significantly with increase in soil pH and $CaCO_3$, and increased with increase in organic C content.

Valley soils of the Garhwal Division – The soils of the Bageshwar and Garur valleys of the Kumaon Division and Ranichauri area of Garhwal Division of UP contained 2.6 to 30.8 mg kg^{-1} of available Fe (NH_4OAc extractable) and were thus considered well supplied with Fe, taking 2.0 mg Fe kg^{-1} as the critical limit (Kumar et al. 1981). Normally, however, 4.5 mg Fe kg^{-1} is taken as the critical limit, and according to this all the soils of Garur fall into the deficient category.

Correction of deficiency

Rice and Potato – A significant response of rice grain was observed to 5 kg Zn ha^{-1} in a rice-wheat system on Zn deficient deep alluvial soil in Doon Valley of UP, and of wheat grain to a residual level of 10 kg Zn ha^{-1}. Considering the net return and Zn use efficiency, 7 kg Zn ha^{-1} is recommended for rice-wheat rotation to achieve optimum yield and return (Bhardhawaj and Prasad 1981). In acid soil at Ranichauri, Tehri Garwal, potato responded to the application of B (Dwivedi and Dwivedi 1992).

Bihar

Chhotanagpur plateau soils – These soils are highly acidic and deficient in Mo. Soil applications of 1.0 to 1.5 kg Mo ha^{-1} to cauliflower significantly increased the curd yield by 14-18%, although whiptail malady – the Mo deficiency disorder – caused crop losses of only 1-2% during the winter (rabi) season. In another field experiment with cauliflowers on a red sandy loam soil (Ultic Haplustalf, pH 5.2, available Mo deficient), both 0.1% foliar and 1.0 kg Mo ha^{-1} soil application significantly increased the curd diameter and weight (Kotur 1995).

North-Eastern Hill Region

This area includes the states of Meghalaya, Tripura, Assam, Manipur, and Sikkim.

Meghalaya

Soils

East-Khasi hill soils – Boron deficiency is a commonly observed micronutrient disorder in the Alfisols or acid soils in humid regions. With acute B stress in these soils, application of B decided the success or failure of crops (Dwivedi et al. 1990b). Available B was determined using six extractants. Of these, only four: mannitol-$CaCl_2$, hot-water soluble (HWS), HWS-boiling, reflex, and DTPA-NH_4HCO_3 were found promising with respective critical limits of 1.0, 0.7, 0.7, and 0.6 mg kg^{-1}. Soils testing below these critical limits responded significantly to B fertilisation (Dwivedi et al.1993).

Rice soils – About 35% of rice growing acid soils were deficient in B and 17% in Zn. However, the content of available Mn, Fe, Cu, Co, and Mo was in the adequate range (Nongkynrih et al. 1996).

Soils under different land-use systems – The total and available micronutrient status of soils of the Ri-bhoi district of Meghalaya under various land-use systems – ‘bun’ cultivation, terrace, natural forest, and valley land – was assessed. Burning under bun cultivation led to a decrease in available Fe, Zn, and Cu, and increased Mn content four-fold (Venkatesh et al. 2003). Total micronutrients also increased on burning. However, the level of available and total micronutrients after three years of bun cultivation was almost the same as the initial status. The highest contents of available Fe, Zn, and Cu and lowest of Mn were observed in valley land soils.

Transformation of Zn – Transformation of applied Zn into different forms was investigated in six wetland acid rice soils (pH 5.0-5.7, organic C 0.9-5.1%). Close to 4.2, 23.1, 19.6, 18.8, and 19.6% of Zn was transformed into water soluble and exchangeable, organically complexed, manganese oxide, amorphous sesquioxide, and crystalline sesquioxide bound forms respectively. Submergence caused a gradual decrease in all the forms of Zn. Thus the bulk of the applied Zn transformed into strongly-bound forms and only a small portion remained available to plants. Plants drew Zn largely from the Mn oxide fraction. The transformation of applied Cu in these soils was similar (Singh et al. 1999; 1999a).

Correction of deficiency

Boron in pea-wheat cropping system – The direct and residual effect of liming (1.5, 3.0, and 6.0t ha^{-1}) and of B (1.5, 3.0, and 6.0 kg ha^{-1}) on the yield of pea and corn grown in a sequence were studied in a field experiment on a sandy loam acid Alfisol at Barapani, Meghalaya. Concentration of B in plant parts increased appreciably with increasing rates of B application but decreased with increasing rates of lime. Application of B significantly increased the hot-water soluble B from 0.24 to 0.89 mg kg^{-1} soil, but increasing rates of lime application significantly decreased B from 0.66 to 0.41 mg kg^{-1} (Dwivedi et al. 1990b; 1992; 1993). Direct application of 1.5 kg B ha^{-1} significantly increased the pod and stover yield of peas (Dwivedi et al. 1992). A sharp decline in yield occurred at higher rates of applied B, suggesting it has a toxic effect for peas. Liming accentuated B deficiency in the absence of applied B because of fixation of soluble B on Al and Fe oxides as a result of increase in pH, but lime cured the toxic effect arising from high rate of B application. Application of 1.5 kg B ha^{-1} and 3.0t lime ha^{-1} gave optimum pea productivity, but the residual effect of 1.5 kg B ha^{-1} was insufficient to meet the need of the succeeding corn crop. The residual levels of 3.0 - 4.5 kg B ha^{-1} and 1.5t ha^{-1} of lime met the B requirements of corn to produce significantly higher yields and are recommended. Concentration of B in plant parts increased appreciably with increasing rates of B application but decreased with increasing rates of lime. .

Boron in summer and winter season crops – Direct and residual effects of 0, 0.5, 1.0, and 1.5 kg B ha^{-1} in four summer (rainy) season (kharif) and winter (rabi) crops were studied on B deficient sandy-loam acid Alfisols (pH 5.05, organic C 1.65%, hot-water soluble B 0.18 mg kg^{-1}) at Barapani (Dwivedi et al.1990b). The cropping sequences were rice-lentil; finger-millet-pea; composite maize-mustard; and soybean-linseed. Boron concentration in the shoots, grains, and straw increased progressively with rates of B application. As a result, grain yields increased significantly for all crops up to 1.0 kg B ha^{-1}, beyond which the yield of maize and finger-millet decreased sharply. This shows that the gap between the toxicity and adequacy limits of B are quite narrow for these crops. The magnitude of response to B was maximum in finger-millet (1.5t ha^{-1}), followed by rice (1.93t ha^{-1}), maize (1.98t ha^{-1}), and soybean (0.43t ha^{-1}). The succeeding winter crops in the rotation also responded significantly to residual levels of 1.0 kg B ha^{-1}, except for linseed which responded down to a 1.5 kg B ha^{-1} level. The crops differed in response; the maximum was in linseed followed by mustard, peas, and lentils. Both Ca and Mg affected the B availability or its use by crops, as revealed by a significant antagonistic relationship between the grain yield and the Ca/B (r= –0.53*) and Mg/B (r= –0.65**) ratios in crops.

Zinc and Copper in Rice – Rice responded to Zn and Cu significantly; application of 5 mg Zn kg^{-1} and 1.25 mg Cu kg^{-1} soil gave the optimum yield. The dry-matter rice yield, and Zn and Cu concentration in the plants were significantly correlated with initial DTPA extractable Zn and Cu. Soil testing below the critical level of 1.2 mg Zn kg^{-1} and 0.7 mg Cu kg^{-1}, and plants testing below 35.9 mg Zn kg^{-1} and 7.0 mg Cu kg^{-1} needs application of Zn and/or Cu to obtain optimum rice yield (Dwivedi et al. 1990a; Singh et al. 1999, 199b; Singh and Nongkynrih, 2000).

Tripura

The fertility status with respect to available Zn, Cu, Fe, and Mn was higher in lowland than in upland soils, whereas B and Mo contents were higher in upland than in lowland soils. However, all the micronutrient cations were in the adequate range. Nearly 29% soils were deficient in B and 50% in Mo. As soil pH increased, available Zn, Cu, and B content decreased significantly in upland soils. The available Cu and Fe content increased with increase in organic C, while that of Zn and Mo decreased (Datta and Gupta, 1984; Datta and Munna Ram, 1993).

Assam

Fertility status

Alluvial, bheel, forest and tea soils – Micronutrient status was evaluated in seven soil profiles from old alluvium in Nowgong, new alluvium in Tejpur, forest soil in Gauhati, hill soils in Diphu and Naysbunglow, tea garden soil in Jorhat, and bheel soil in Cachar. Available B content in these profiles varied from 0.02 to 1.43 mg kg^{-1} and all the surface soils contained sufficient B. The available Mo varied from 0.015 to 0.053 mg kg^{-1} soil and was in the range of deficiency to marginal fertility. Available Cu ranged between 0.87 and 2.50 mg kg^{-1}. Cu content was the lowest and organic C the highest in bheel soils. The forest, hill, and bheel soils were rated low in available Cu, the result of the high intensity of weathering and leaching in these acid soils (Chakraborty et al. 1979, 1980, 1981). Available Cu increased significantly with increase in pH (r= 0.524*). Available Zn ranged from 4.8 to 16.9 mg kg^{-1} soil and its fertility status was high. Deficiency of B ranged between 5 and 65% and was higher under fruit and field-crop ecosystems (42-65%) than under pasture- (32-45%) and forest ecosystems. Available B was less in high than in low rainfall areas of lateritic soils (Borkakati and Takkar 2000).

Correction of deficiency and toxicity

Boron and Mo – Toria (rapeseed *Brasssica campestris*) did not respond to the application of B and Mo at the Regional Agricultural Research Station, Shillongani, and Nagaon, Assam. But their application significantly increased the oil content (Patgiri 1995).

Manipur

Fertility Status – The fertility status of Zn, Cu, Fe, and Mn in seven profiles from Manipur indicated inadequate or marginally adequate levels of available Zn only (Sen et al. 1997).

Sikkim

The available micronutrient status in 44 soil samples (pH 4.2-5.9, organic matter 2.0-8.4%) from the eastern, western, and southern districts revealed adequate Zn, Fe, and Mn levels; their content ranged from 0.47 to 3.0, 5 to 210, and 0.05 to 6.2 mg/kg, respectively. The available Cu content ranged between 0.05 and 0.5 mg/kg; about 33% of the soils were Cu deficient (Khera and Pradhan, 1980). Total and available Cu and Mn and available B content decreased, and that of available Zn and Fe in soil increased markedly with increase in altitude. About 85 and 94% of soils were deficient in B and Mo respectively. These soils were sufficient in Zn, Cu, Fe, and Mn (Yashoda, and Avasthe 1995).

Orchard soils – The micronutrient cation status of soils and trees (leaf samples from non-bearing twigs) from 32 mandarin orchards in the acidic hilly terrain of the high-rainfall area of Sikkim was assessed (Patiram et al. 2000). Although the soils contained sufficient available Zn (2.9-11.8 mg kg^{-1}), Cu (0.4-5.1 mg kg^{-1}), Fe (6.8-110.6 mg kg^{-1}),and Mn (252-1822 mg kg^{-1}) in surface soil, the leaves in 33% of the orchards were low in Zn and Mn, but sufficient in Cu and high to excess (80%) in Fe. Leaf analysis appears to be a useful tool for determining the nutritional status of mandarin trees or the fertility status of soils, and for this there is a need to establish their critical levels.

Iron Toxicity

Occurrence of wetland rice bronzing disease – Acid Alfisols are widely distributed in the states of HP, UP, J&K, and Meghalaya, and in the east Khasi hills and the narrow valleys of Tripura. These soils generally exhibit widespread occurrence of bronzing disease in rice grown under wetland conditions. The visual symptoms of the disease are brown spots spread over almost the entire leaf surface, which later curls and dries. Under greenhouse conditions, the disease has been shown to result from excessive concentration of Fe in diseased plants, 805 mg kg^{-1} compared to 480 mg kg^{-1} in the normal plants (Verma and Tripathi 1984). Submergence is mainly responsible for this disorder. Incorporation of 3t lime ha^{-1} delayed the bronzing symptoms and sustained the yield in HP. In Tripura and the east Khasi hill soils of the Meghalayas, rice bronzing disease is much more prevalent in soils with shallow water tables (<40 cm), high in organic C (>2.99%), and low in pH (<5.5) (Singh et al. 1992). Severe Fe toxicity symptoms in plants were closely associated with a 3.1 fold level of Fe in diseased compared to normal plants and high active Fe (>1.2%) and organic C (2.99%) content, continuous submergence, and impeded soil drainage conditions (Singh et al. 1992). Iron toxicity was responsible for the low yields of rice in these soils (Prasad and Ram 1985). In Assam, application of As-benomyl, a systemic fungicide, alone and with FYM, significantly retarded the decrease in redox potential which appreciably decreased available Fe and Mn and their total uptake in rice. As a result Fe toxicity decreased and grain and straw yield of rice markedly increased (Bhattacharya et al. 1996).

Summary and Conclusions

This paper highlights micronutrient soil fertility problems and strategies to reduce these in the Himalayan region of India. Zn deficiency is one of the major constraints to high productivity of field and fruit crops in the soils of Jammu and Kashmir. Copper, Fe, Mn, B and Mo deficiency has not been reported. The productivity of rice, wheat, maize, and rapeseed improved markedly with Zn application. In the soils of HP, fertility problems have been observed with respect to all the micronutrients, but the problem of Zn and Cu was more predominant in wheat, rice, maize, and potato growing soils and of B in some apple orchards. Application of these micronutrients markedly improved the productivity of crops. Zn efficient potato varieties have also been identified. In UP, Zn deficiency has been a serious soil fertility constraint in the foothill (Mollisol) Terai soils. Soil-cropping systems determined the emergence of specific micronutrient fertility problems. Intensive cultivation using the rice-wheat-cowpea system on Terai soils depleted the available Zn from adequate to deficient level after 12 years. Application of Zn or FYM restored the depleted Zn status of soil and markedly improved the productivity of the system. But in a similar experiment on Typic Hapludoll under the maize-wheat system in HP, neither Zn nor any other micronutrient deficiency appeared even after 25 years of cultivation. In Bihar, deficiency of Zn, Cu, and Fe has been shown in hill and forest soils. In the North-Eastern Hill Region, micronutrient fertility problems, largely of B and Zn, have been observed in the acid soils of Assam, Meghalaya, Tripura, and Sikkim. Significant responses have been observed of rice and wheat to B and Zn and of mustard to B application alone and together with lime amendment. Coarse-textured soils, soils low in organic C, and soils located in high rainfall areas contain less available B than fine-textured soils, or soils high in organic C. In Assam, deficiency of B ranged between 5 and 65% and was higher under fruit and field-crop ecosystems (42–65%) than under pasture (32-45%) and forest ecosystems. Available B was less in high than in low rainfall areas of lateritic soils. Deficiency of the macronutrients N, P, K, and S also occur in orchards and need to be managed together with micronutrients to fully realise the benefits of micronutrient input. The micronutrient status of sub-soil or a profile, and leaf analysis, need to be taken into account while ascertaining the fertility status of orchard soils. Residual effects of Zn, B, and lime or FYM amendments have been observed and need to be taken into account in the fertiliser schedule for specific soil-cropping systems. The soil properties pH, organic C, texture, and $CaCO_3$ appreciably regulated the available status of micronutrients in all the soils. Iron toxicity, a bronzing disease in wetland rice, is a serious soil fertility problem in Meghalaya, HP, and Tripura. It originates from high active Fe, high organic C, and shallow water table and impeded drainage conditions.

References

Bhandhari, A.R.; Randhawa, N.S. (1985) 'Distribution of available micronutrients in soils of apple orchards of Himachal Pradesh'. In *J. Indian Soc. Soil Sci.,* 33:171-173

Bhardhawaj, S.P.; Prasad, S.N. (1981) 'Response of rice-wheat rotation to zinc under irrigation condition in Doon Valley.' In *J. Indian Soc. Soil Sci.,* 29: 220-234

Bhattacharya, D.; Baruah, T.C.; Barthakur, H.P. (1996) 'Effects of benomyl and FYM on redox potential, available iron and manganese of a flooded soil and yield of rice'. In *J. Indian Soc. Soil Sci*., 44: 112-115

Borkakati, K.; Takkar, P.N. (2000) *Forms of Boron in Acid Alluvial and Lateritic Soils in Relation to Ecosystems and Rainfall Distribution*. Paper presented at Int. Conf. on Management of Natural Resources for Sustainable Agricultural Production in the 21st Century, 12th February 2000, New Delhi, India.

Chakraborty, S.K.; Sinha, H.; Prasad, R. (1979) 'Copper status of soils of Assam'. In *J. Indian Soc. Soil Sci*., 27: 83-84

Chakraborty, S.K.; Sinha, H.; Prasad, R. (1980) 'Distribution of boron and molybdenum and their relationship with certain properties of soils from Assam'. In *J. Indian Soc. Soil Sci.,* 30: 92-93

Chakraborty, S.K.; Sinha, H.; Prasad, R. (1981) 'Zinc status of soils of Assam'. In *J. Indian Soc. Soil Sci*., 29: 377-378

Datta, M.; Bhattacharya, D.K.; (2001) 'Soil fertility- a case study of shifting cultivation sites in Tripura'.

In *J. Indian Soc. Soil Sci.,* 49: 104-109

Datta, M.; Gupta, R.K. (1984) 'Studies on P, Ca, Zn and Fe content in soil and plant tissues as influenced by pressmud and lime'. In *J. Indian Soc. Soil Sci.,* 32: 450-458

Datta, M.; Munna Ram (1993) 'Status of micronutrients in some soil series of Tripura'. In *J. Indian Soc. Soil Sc.,* 41: 776-777

Dwivedi, B.S.; Munna Ram; Singh, B.P.; Das, M.; Prasad, R.N. (1990a) 'Evaluation of soil and tissue tests for predicting response of rice to Zn in acid alfisols'. In *Indian J. Agric. Sci.,* 60:122-127

Dwivedi, B.S.; Munna Ram; Singh, B.P.; Das, M.; Prasad, R.N. (1990b) 'Differential response of crops to boron fertilization in acid alfisols'. In *Indian J. Agric. Sci*., 60:122-127

Dwivedi, B.S.; Munna Ram; Singh, B.P.; Das, M.; Prasad, R.N. (1992) 'Effect of liming on boron nutrition of pea (*Pisum sativum* L.) and corn (*Zea mays* L.) grown in sequence in an acid alfisol'. In *Fertilizer Research,* 31: 257-262

Dwivedi, B.S.; Munna Ram; Singh, B.P.; Das, M.; Prasad, R.N. (1993) 'Comparison of soil tests for predicting boron deficiency and response of pea to boron application on an acid alfisol'. In *J. Indian Soc. Soil Sci*., 41: 321-325

Dwivedi, G.K.; Dwivedi, M. (1992) 'Efficacy of different modes of application of copper, zinc and boron to potato'. In *Ann. Agric. Res.,* 13: 1-6

Grewal, J.S; Trehan, S.P. (1990) 'Micronutrients for potatoes.' In *Tech. Bull., Central Potato Research Institute, Shimla,* 23:24

Hundal, H.S.; Arora, C.L. (1993) 'Nutrient status of lichi (*Lichi chinensis* Sonn) orchards in submontaneous area of Punjab.' In *J. Indian Soc. Soil Sci.,* 41: 778-779

Jalali, V.K.; Gupta, J.P.; Gupta, R.D.; Khajaria, B.B. (1999) 'Chemical pools of zinc in intermediate zone of Jammu region and response of maize to zinc'. In *Applied Biological Res.,* 1:167-169

Jalali, V.K.; Gupta, J.P.; Razdan, H.K. (2000) 'Distribution of micronutrient cations in soils of cold arid zone of Ladakh'. In *Indian J. Agric. Sci.,* 70: 128-130

Jalali, V.K.; Pareek, N. (2003) 'Need of micronutrient research in hill soils of western Himalayas with special reference to Jammu and Kashmir'. In *Indian Life Sci.,* 4(1&2): 1-10

Jalai, V.K.; Sharma, M.P. (2002) 'Status of available micronutrient cations in soils of mid-hill intermediate zone of Jammu region'. In *Indian J Agric. Sci*., 72: 616-618

Jalali, V.K.; Talib, A.R.; Takkar, P.N. (1989) 'Distribution of micronutrients in some benchmark soils of Kashmir at different altitude'. In *J. Indian Soc. Soil Sci*., 37: 465-469

Kanwar, B.B.; Tripathi, B.R. (1984) 'Zinc content in soils and wheat plants in agriculturally important valleys of Himachal Pradesh'. In *J. Indian Soc. Soil Sci*., 47: 374-377

Kamwar, J.S.; Randhawa, N.S. (1974) 'Micronutrient research in soils and plants: a review'. In *Tech. Bull. (Agric.), Indian Council of Agricultural Research,* 50: 1-60

Khera, M.S.; Pradhan,H.R. (1980) 'Micronutrient status of soils of Sikkim and some inter-nutritional relationship.' In *J. Indian Soc. Soil Sci.,* 47: 374-377

Kumar, S.; Omanwar, P.K.; Sachan, R.S.; Sharma, R.B. (1981) 'Iron status of some soils of Kumaon and Garhwal, Himalaya.' In *J Indian Soc. Soil Sci*., 29:266-67

Kotur, S.C. (1995) 'Effect of liming and modes of molybdenum application on the response of cauliflower to molybdenum in an alfisol.' In *J Indian Soc. Soil Sci*., 43:286-298

Nand Ram (1998) 'Effect of continuous fertilizers use on soil fertility and productivity of a mollisol.' In *Proc. Nat. Workshop on Long-term Soil Fertility Management through Integrated Plant Nutrient Supply,* Swarup, A.; Reddy, D.; Prasad, R.N. (eds) p 335. Bhopal (India): Indian Institute of Soil Science

Nongkynrih, P.; Dkhar**,** P.S.; Khathing, D.T. (1996) 'Micronutrient elements in acid alfisols of Meghalaya under rice cultivation'. In *J. Indian Soc. Soil Sci.,* 44: 455-457

Parmar, D.K.; Sharma, V.; Sharma, K.D.; Sharma, T.R. (1999) 'Micronutrient status of vegetable growing pockets in cold desert area of Himachal Pradesh' In *J. Indian Soc. Soil Sci.,* 47: 280-283

Patgiri, D.K. (1995) 'Effect of boron, sulphur and molybdenum on *Toria* (*Brassica campestris* L) in a Typic Haplaquept'. In *J. Indian Soc. Soil Sci.,* 43: 295-296

Patiram, Upadhyaya, R.C.; Sing, C.S.; Munna, R. (2000) 'Micronutrient cation status of mandarin (*Citrus reticulata* Blanco) orchard of Sikkim'. In *J. Indian Soc. Soil Sci*., 48: 246-249

Prasad, R.N.; Ram, M. (1985) 'Soils of north-eastern hill region and their management' In *Soils of India and their management*, pp. 266-283. New Delhi: The Fertilizer Association of India

Rawat, P.S.; Mathpal, K.N. (1981) 'Micronutrient status of some soils of UP hills'. In *J. Indian Soc. Soil Sci*., 29: 208-214

Sen, T.K.; Dubey, P.N.; Maji, A.R.; Chamuah (1997) 'Status of micronutrients in some dominant soils of Manipur'. In *J. Indian Soc. Soil Sci.,* 45: 388-390

Sharma, J.C.; Bhandari, A.R. (1995) 'Mineral nutrient status of apple orchards in Himachal Pradesh'. In *J. Indian Soc. Soil Sci.,* 43:236-241

Sharma, R.K.; Jalali, V.K.; Koul, R.K. (2001) 'Nutrient indexing of (*Citrus reticulata* Blanco)' In *Life Sci. Reporter,* 3: 34-36

Sharma, R.K.; Jalali, V.K.; Gupta, J.P.; Pareek, N.; Wali, P. (2003) 'Zinc status and its response to various crops in soils of different agro-climatic zones of Jammu and Kashmir'. In *J. Res. SKUAST (J),* 2(1): 75-80

Singh, A.K.; Khan. S.K.; Nongkynrih, P. (1999a) 'Transformation of zinc in wetland rice soils in relation to nutrition of rice crop.' In *J. Indian Soc. Soil Sci.,* 47: 248-253

Singh, A.K.; Khan, S.K.; Nongkynrih, P. (1999b) 'DTPA-extractable Zn, Cu, Mn, and Fe in wetland rice soils and their availability to rice under submergence'. In *J. Indian Soc. Soil Sci*., 47: 381-383

Singh, A.K.; Khan. S.K.; Nongkynrih, P. (1999c) 'Critical limit of zinc deficiency for predicting response of rice to zinc application on wetland rice soils of Meghalaya'. In *J. Indian Soc. Soil Sci.,* 47: 567-569

Singh, A.K.; Nongkynrih, P. (1999) 'Distribution and transformation of copper in wetland soils and its availability to rice plant'. In *J. Indian Soc. Soil Sci.,* 47: 452-457

Singh, A.K.; Nongkynrih, P. (2000) 'Critical limit of copper for predicting response of rice to copper application on wetland rice soils of Meghalaya'. In *J. Indian Soc. Soil Sci*., 48: 406-408

Singh, B.P; Dass, M.; Dwivedi, B.B.; Prasad, R.N. (1992) Characteristic of Fe-toxic soils and affected plants in Meghalaya. In *J. Indian Soc. Soil Sci*., 40: 426-428

Tripathi, D.; Singh, K.; Upadaya, G.P. (1994) 'Distribution of micronutrients in some representative soil profiles of Himachal Pradesh'. In *J. Indian Soc. Soil Sci*., 42: 143-145

Verma, T.S.; Tripathi, B.R. (1982) 'Relationship of micronutrient elements in soils growing rice'. In *J. Indian Soc. Soil Sci*., 30: 89-91

Verma, T.S.; Tripathi, B.R. (1984) 'Bronzing disease of rice, its causes and remedial measures in acid alfisols of Himachal Pradesh'. In *J. Indian Soc. Soil Sci*., 32: 504-506

Yashoda, A.; Avasthe, R.K. (1995) 'Altitudinal distribution of micronutrients in the soils of Sikkim'. In *J. Indian Soc. Soil Sci.,* 47: 374-377

Venkatesh, M.S.; Majumdar, B.; Kumar, K. (2003) 'Status of micronutrient cations under various land use systems of Meghalaya'. In *J. Indian Soc. Soil Sci*., 51: 60-64

Vittal, K.P.R.; Gangwar, M.S. (1974) 'Zinc in soil profiles of nainital Tarai'. In *J. Indian Soc. Soil Sci*., 22: 151-155