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Total and Extractable Manganese and Iron in Some Cultivated Acid Soils of India: Status, Distribution and Relationship with Some Soil Properties*1

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ABSTRACT

A total of 400 surface soil (0–15 cm) samples were collected from cultivated soils representing four soil series, namely, Hariharapur, Debatoli, Rajpora and Neeleswaram in Orissa, Jharkhand, Himachal Pradesh and Kerala states of India, respectively, and were analyzed to measure the contents of total and extractable Mn and Fe, to establish the relationship among total and extractable Mn and Fe and soil properties, and to characterize the spatial distribution pattern of Mn and Fe in some cultivated acid soils of India. The contents of total as well as extractable Mn and Fe varied widely with extractants and soil series. However, the amounts of Mn or Fe extracted by diethylene triamine penta-acetic acid (DTPA), Mehlich 1, Mehlich 3, 0.1 mol L^{-1} HCl and ammonium bicarbonate DTPA (ABDTPA) were significantly correlated with each other ($P < 0.01$). Based on the DTPA-extractable contents and the critical limits (2 mg Mn kg^{-1} soil and 4.5 mg Fe kg^{-1} soil) published in the literature, Mn and Fe deficiencies were observed in 7%–23% and 1%–3% of the soil samples, respectively. The content of soil organic carbon (SOC) had greater influence on total and DTPA-extractable Fe than did soil pH. Geostatistical analysis revealed that total and DTPA-extractable Mn and Fe contents in the acid soils were influenced by soil pH, SOC content, and exchangeable cations like potassium, calcium and magnesium. Spatial distribution maps of total and DTPA-extractable Mn and Fe in soil indicated different distribution patterns.

Key Words: micronutrients, extractant, geostatistical analysis, spatial variability

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Contents of manganese (Mn) and iron (Fe) in comparison to the other micronutrients in plant tissues are normally higher (Mortvedt, 2000). Both Mn and Fe play a pivotal role in plant metabolism (Marschner, 1995). Mn and Fe together play an important role in the establishment of organic mantle, the humified top soil layer that covers the surface of earth and serves as the nurturing house for the plant roots, and microbes (Bartlett and James, 1993). Hence, information regarding the content of these metals in soils and their availability to plants is important for improving crop production and maintaining food quality (Adriano, 2001). Over the years, deficiencies of Mn and Fe in soils have been reported worldwide (Katyal and Vlek, 1985; Welch *et al.*, 1991) including in alkaline soils of India (Gupta, 2005; Behera *et al.*, 2009b). Normally, toxicities of Mn and Fe occur in acid minerals and waterlogged/flooded soils. Mn deficiency can occur in plants grown on coarse-textured sandy soils and overlimed acid soils (Martens and Westermann, 1991). Like Mn, Fe deficiency can also occur in plants grown on acid soils (Mortvedt, 1975). Out of 142 million ha of arable land in India, acid soils cover about 49 million ha spreading over 24 states of the country (Sharma and Singh, 2002; Maji *et al.*, 2012). Although acid soils cover significant area of the country, scanty information regarding the status of Mn and Fe in acid soils of India is available.

Availability of Mn and Fe to plant is dependent on soil properties and plant types (Fageria *et al.*, 2002). Of various soil properties, soil pH and soil organic carbon (SOC) content are important factors. By each unit increase of soil pH in the range of 4 to 9, the solubility of Fe in soil decreases by 1 000 fold as compared to a 100-fold decrease for Mn, Cu and Zn (Lindsay, 1979). Soil organic matter (SOM) enhances Mn availability to the crop plants (Reisenauer, 1988), whereas Fe availability is improved with addition of organic matter in drained and waterlogged soils (Tisdale *et al.*, 1985). Moreover, intensive cropping coupled with imbalanced fertilizer

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application often leads to nutritional imbalances in soils (Kabata-Pendias, 2001). It has been reported that continuous cropping with maize and wheat in an Inceptisol at New Delhi for more than three decades resulted in the decline of available Mn and Fe in soil from their respective initial levels (Behera *et al.*, 2009a).

Information regarding the spatial distribution pattern of Mn and Fe in cultivated soils is very important for the adoption of effective Mn and Fe management practices (White and Zasoski, 1999). Spatial distribution pattern of Mn and Fe can be assessed by geostatistical methods which estimate Mn and Fe contents in non-sampled points using spatial autocorrelation models obtained from sampled points with the minimization of estimation error variance (Mueller *et al.*, 2003; Saito *et al.*, 2005).

Out of several extractants used for extracting plant-available metals including Mn and Fe from different types of agricultural soils, the diethylene triamine penta-acetic acid (DTPA) extractant is used predominantly worldwide including India, although the method was originally developed for neutral and calcareous soils (Lindsay and Norvell, 1978). Information regarding the extractability of different extractants for extracting plant-available Mn and Fe from acid soils of India is lacking. Therefore, the aim of this study was to measure the contents of total and extractable Mn and Fe, to establish the relationship among total and extractable Mn and Fe and soil properties, and to characterize the spatial distribution pattern of Mn and Fe in some cultivated acid soils of India.

MATERIALS AND METHODS

Location and procedure of soil sampling

A total of 400 (100 from each area) soil samples were collected from the cultivated areas of Orissa (Hariharapur series), Jharkhand (Debatoli series), Himachal Pradesh (Rajpora series) and Kerala (Neeleswaram series) states of India (Fig. 1). The detailed description of sampling sites can be found in Behera *et al.* (2011). During soil sampling, surface soil samples from 0 to 15 cm depth were collected randomly using stainless steel soil augers and taken to the laboratory for analysis. The latitude, longitude and mean sea level of the sampling sites were recorded using a handheld global positioning system (GPS). Collected soil samples were air dried, ground to pass a 2-mm sieve after stone and debris were removed, and then stored in plastic bottles for analysis in laboratory.

Soil analysis

Soil pH, electrical conductivity (EC), SOC content, and exchangeable potassium (K), calcium (Ca) and magnesium (Mg) of soil samples were determined by the standard procedures (Behera *et al.*, 2011). Total contents of Mn and Fe in soil samples were determined by digesting soils with the mixture of H_2SO_4, HF and

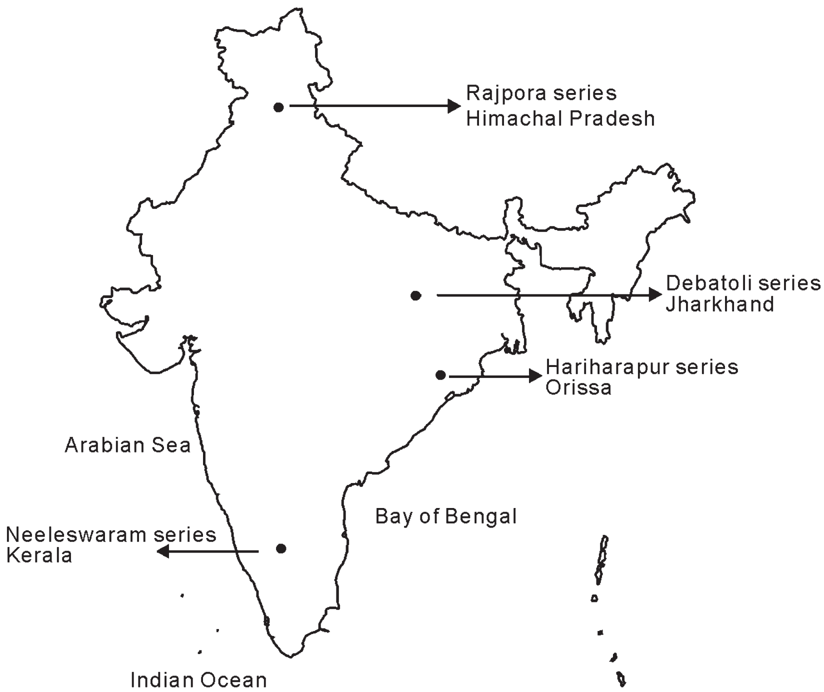

Fig. 1 Sample location of the soil series studied.