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Iron deficiency chlorosis in plants as related to Fe sources in soil

I. Díaz (1), A. Delgado (1), A. de Santiago (2), M.C. del Campillo (3), and J. Torrent (3)

(1) University of Seville, Sevilla, Spain (adelgado@us.es, +34954486436), (2) Instituto de Investigación La Orden-Valdesequera, Badajoz, Spain, , (3) Universidad de Córdoba, Córdoba, Spain,

Iron deficiency chlorosis (IDC) is a relevant agricultural problem in many areas of the World where calcareous soils are dominant. Although this problem has been traditionally ascribed to the pH-buffering effect of soil carbonates, the content and type of Fe oxides in soil contribute to explain Fe uptake by plants and the incidence of this problem. During the last two decades, it has been demonstrated Fe extraction with oxalate, related to the content of poorly crystalline Fe oxides, was well-correlated with the chlorophyll content of plants and thus with the incidence of IDC. This reveals the contribution of poorly crystalline Fe oxides in soil to Fe availability to plants in calcareous soils, previously shown in microcosm experiments using ferrihydrite as Fe source in the growing media. In order to supply additional information about the contribution of Fe sources in soil to explain the incidence of IDC and to perform accurate methods to predict it, a set of experiments involving different methods to extract soil Fe and plant cultivation in pots to correlate amounts of extracted Fe with the chlorophyll content of plants (measured using the SPAD chlorophyll meter) were performed. The first experiment involved 21 soils and white lupin cultivation, sequential Fe extraction in soil to study Fe forms, and single extractions (DTPA, rapid oxalate and non-buffered hydroxylamine). After that, a set of experiments in pot involving growing of grapevine rootstocks, chickpea, and sunflower were performed, although in this case only single extractions in soil were done. The Fe fraction more closely related to chlorophyll content in plants ($r = 0.5$, $p < 0.05$) was the citrate + ascorbate (CA) extraction, which was the fraction that releases most of the Fe related to poorly crystalline Fe oxides, thus revealing the key role of these compounds in Fe supply to plants. Fe extracted with CA was more correlated with chlorophyll content in plants that oxalate extractable Fe, probably due to a more selective dissolution of poorly crystalline oxides by the former extractant. In general terms, the best correlation between extractable Fe and chlorophyll content in plants was observed with hydroxylamine, which explained from 21 to 72 % of the variance observed in chlorophyll content in plants, greater than the variance explained by the rapid oxalate (11 to 60 %, not always significant) or the classical active calcium carbonate content determination (6 to 56 %, not always significant). Extraction with DTPA provided the worse results, explaining from 18 to 36 % of the variance in chlorophyll content in plants. The good predictive value of the hydroxylamine extraction was explained by its correlation with Fe in poorly crystalline Fe oxides (estimated as CA-extractable Fe) and by its negative correlation with the active calcium carbonate content of soils.