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Plant Nutrition Newsletter

A Series of Technical Information and Essential Plant Research

IRON NUTRITION AND METALOSATE® IRON

Iron in the Soil, Its Characteristics and Availability to Plants

The content of iron in the earth's crust by weight is approximately 5 percent. Iron is invariably present in all soils, with the majority of it being held within the crystal lattices of numerous minerals, rendering the majority of it unavailable to plants for nutritional usage. As most of the minerals which contain iron weather, iron oxides are formed. The solubilities of these Fe3^{+} oxides are extremely low.

Generally, the concentration of soluble iron in soils is extremely low when compared to the total iron concentration. The soluble inorganic forms include Fe3^{+}, Fe(OH)2^{+}, Fe(OH)2^{+} and Fe2^{+}. In the case of well-aerated soils, Fe2^{+} contributes very little to the total soluble inorganic iron except under high pH conditions. When considering Fe3^{+}, "the solubility level reaches a minimum in the pH range between 7.4 - 8.5."[1] The result is that acid soils are relatively higher in soluble inorganic iron than calcareous soils where levels can be extremely low.

Iron Utilization by Plants

Much experimental evidence[2] suggests that the transport of iron across the plasma membrane is closely linked to Fe3^{+} reduction. The iron which is taken up by plants is Fe2^{+}. Iron has the ability to diffuse into the cellular walls and intercellular regions of plants. When the iron moves into these regions, it quickly oxidizes to Fe3^{+} due to an increase in pH. The ability of the plant to reduce Fe3^{+} becomes severely retarded due to generally higher than optimal pH levels. Oftentimes, what this indicates is that due to the higher pH in the plant's apoplastic regions, iron found in these areas is in a state that is not metabolically active (Fe3^{+}). This indicates that "the chlorosis frequently appearing on calcareous and saline soils with a high pH is not a consequence of low Fe solubility in the soil due to high pH but results from the high pH in the soil which permeates the root apoplast to retard [Fe3^{+}] reduction."[3]

Iron has a strong tendency to form chelates and is characterized by the relative ease in which it can change valency. This makes it extremely valuable in catalyzing many physiological reactions within plants. It has been shown "that in Fe deficient leaves the rate of photosynthesis decreased per unit area but not per unit chlorophyll indicating that the photosynthetic apparatus remains intact but the number of photosynthetic units was decreased. Results show that as the intensity of Fe deficiency was increased and the chlorophyll per unit leaf area fell, protein content per leaf area, leaf cell volume, and chloroplast number were all unaffected, but that chloroplast volume and the amount of protein per chloroplast fell dramatically."[4] This indicates that iron is involved in protein metabolism as well as DNA and RNA synthesis.

"As a rule, iron deficiency has much less effect on leaf growth, cell number per unit area, or number of chloroplasts per cell than on the size of the chloroplasts and protein content per chloroplast. Only with severe iron deficiency is cell division also inhibited and, thus, leaf growth reduced. Iron is required for protein synthesis, and the number of ribosomes—the sites of protein synthesis - decrease in iron-deficient leaf cells."[5]

Iron Deficiency in Citrus

photos courtesy of the Potash & Phosphate Institute

Iron Deficiency in Corn

photos courtesy of the Potash & Phosphate Institute

Iron in Crop Nutrition

The concentration of iron in green plant tissues is in the range of 50 to 150 ppm. The total iron in the soil is always in excess of crop requirements, illustrating that when iron deficiency in a crop occurs, it always has to do with the availability of the iron in the soil.

Work done by Clarkson and Sanderson[6] indicates that only root tips and not the basal parts of roots are capable of absorbing iron. Some crops which commonly experience iron deficiency include: citrus, deciduous fruit trees, vines, soybeans, maize, grain sorghum, legumes, rice, and tomatoes.

Oftentimes, iron chlorosis is not caused by an absolute iron deficiency. In contrast to most other plant nutrients where there is an inverse relationship between the intensity of the deficiency and the concentration of the nutrient in the plant tissue, this does not apply to iron. Frequently, the iron concentration in the chlorotic leaves can be higher than in the green leaves.[7,8,9]

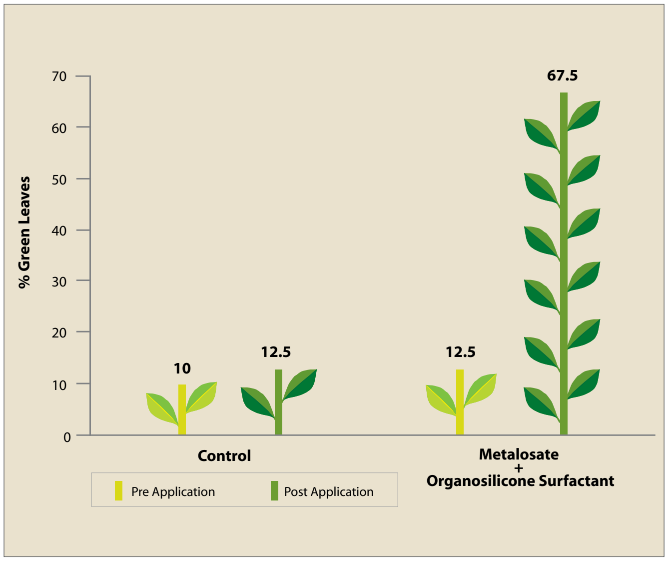
Nitrogen fertility on crops or trees grown in calcareous soils can have a significant influence on iron availability within the plant. "Nitrogen nutrition in calcareous soils is predominantly that of nitrate even if N is applied as ammonium."[10] The pH of the leaf apoplast receiving nitrate fertilizer increased while that receiving ammonium nitrogen decreased in pH. From this finding it was discovered "that at high apoplastic leaf pH [Fe3$^+$] reduction in the leaf apoplast is restricted and hence the uptake of Fe from the apoplast into the cytosol impared."[11] These findings have been confirmed by spraying chlorotic leaves with a diluted acid such as citric or sulfuric. Within two days temporary regreening of the leaves can be observed while measuring no increase of iron in the tissue.

Iron Deficiency Symptoms and Correction with Metalosate® Iron

In the leaves of most plant species, chlorosis is the most commonly seen symptom. This results from the plant's inability to manufacture chlorophyll. Iron chlorosis is always associated with the youngest or newest tissue growth. The lack of iron also has negative effects on the roots of plants. In both dicots and monocots, with the exception of the grasses, iron deficiency is associated with inhibition of root elongation, increase in the diameter of apical root zones, and abundant root hair formation.[12] The critical deficiency content of iron in leaves is in the range of 50 to 150 ppm.

The application of Metalosate® Iron in a foliar spray has been proven very effective in solving iron deficiencies. In work done by Eric Holmden and Rene Carlson of Ocean Agriculture (Pty) Ltd. on Midknight citrus trees (Valencia type) in South Africa, they were able to decrease iron chlorosis by 55 percent. Three applications of Metalosate® Iron combined with an organosilicone surfactant were applied at a rate of 54 oz per acre (4 liters per hectare). Visual observations were made pre- and post- application and a determination was made with respect to the percentage of green vs. chlorotic leaves present at each instance. Figure 1 summarizes the findings.

Figure 1. Percent green-leaf increase on citrus in South Africa following applications of Metalosate® Iron + organosilicone surfactant



The results of some radioactive isotope studies done using Metalosate® Iron compared to iron sulfate indicate a significantly greater level of absorption when applying the the amino-acid chelated form of iron. Corn plants grown to a

Table 1. Distribution of ^{59}Fe in Corn Plants

Plant Part	Radioactivity (cc/min/mg)**	
	Metalosate® Iron	$FeSO_4$
Point of application	227 a	68 b
Opposite leaf	0.20	0.13
Root	0.13	0.03
Stem*	1.28 a	0.40 b
Average except point of application*	0.83 a	0.30 b

* Values differ significantly at P 0.10
** Corrected counts per minute per milligram

height of 60 cm in a greenhouse were dosed on one leaf with 20 microliters of ^{59}Fe solution containing 4.5 micrograms of iron. Iron sulfate and Metalosate® Iron were used. Five days following the single application, the treated area, the treated leaf, the opposite leaf, the stem, and the roots were sampled and assayed for ^{59}Fe. Table 1 is a summary of the results.[13]

In another experiment tomato plants grown in a greenhouse were used. A single dose of 0.00004 gm of ^{59}Fe was applied on one leaf in the manner described in the previous experiment. Three forms of iron were used: $FeSO_4$, Fe EDTA, and Metalosate® Iron. On the fourth day following dosing the plants were sampled, cleaned, and measured for ^{59}Fe by liquid scintillation counter. The results are shown in Table 2.[14]

Table 2. Distribution of ^{59}Fe in Tomatoes from Three Forms of Iron

Plant Part	Radioactivity (cc/min/mg)**		
	Metalosate® Iron	EDTA	$FeSO_4$
Leaf dosed	43.09	23.23	29.24
Adjacent leaves	0.15	0.11	0.20
Dosed leaf stem	0.34	0.03	0.12
Total	**43.58**	**23.37**	**29.56**

As can be seen from these radioactive isotope studies, the Metalosate® Iron was absorbed and translocated 62.8 percent better than the iron EDTA and 46.5 percent better than the iron sulfate. This is due to the fact that the iron supplied by the Metalosate® Iron is in the amino-acid chelated form, a molecular form which is compatible with plant cells. It easily and readily passes through the plant cuticle and is then fully utilized by the plant.

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Iron Deficiency in Tomato

photos courtesy of the Potash & Phosphate Institute

Iron Deficiency in Beans

photos courtesy of the Potash & Phosphate Institute

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