INTERACTIONS OF MACRO- AND MICRO-NUTRIENTS ON PLANT GROWTH AND NUTRIENTS UPTAKE

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1. INTRODUCTION

Most soils have abundant supplies of micro-nutrients. Their deficiencies are generally localized but become acute when large doses of macro-nutrients are applied as fertilizers to the soil for crop production. Some of the micro-nutrients show antagonistic effect to other nutrients but others conjointly act within, the plant system in the metabolic processes.

Of the macro-nutrients, calcium, magnesium and sulphur are secondary essential elements to nitrogen, phosphorus and potassium. These elements play an important role in correcting the reaction of the soil and regulating the uptake of cations and anions by the plants. As is known the soil of Egypt is formed of the Nile deposits. The Nile annually brings down enormous quantities of solid matter containing the macro- and the micro-nutrients. Here the interrelationship between macro- and micro-nutrients worth to be studied. Considerable attention has been devoted to the study of the influence of the macroelements on the absorption and uptake of microelements and vise-verse by plants.

2. [illegible]

Considerable attention has been given over the past few years to the relationship between macro- and micro-nutrients. Of the interactions between the essential elements, the interactions between Ca and Mg as macro-nutrients and Fe and Mn as micro-nutrients are studied in the undertaken work.

2.1 Iron in plants

As early as 1860, Sachs showed that iron was an essential trace element for plant growth. Iron was directly connected with the formation of chlorophyll although not actually a part of its molecule (Willstätter, 1913).

Since that time a number of investigations have conducted and considerable physiological information has been obtained. Some investigators (Rogers and Shive, 1932; Oserkowsky, 1933; Hliman, 1937; Thorne and Wallace, 1944; Jacobson, 1945; Bennet, 1945) indicated that iron in plant cells occurs chiefly in an undissolved form. Most of it was bond in chloroplasts or in the cytoplasm and mainly in the form of ferric iron. On the other hand, the fraction with a direct relation to chloroplasts [illegible] "active" [illegible] in its ferrous form. Yoshida and Kawasaki (1958) showed that iron content was higher in roots than in tops. Furthermore, Vlamis and Williams (1954) found that much iron located in rice and barley roots and was visible on the surface probably in the form of iron oxide.

It was stated that total iron content and concentration in the growing plants increased as the supply of iron increased (Fujiwara and Tsutsumi, 1957; Neaer, 1960; Hale and Wallace, 1960; El Kholi, 1961; Tayel, 1964; Sedik, 1965). Ishizuka et al (1961) noted that 0.1 ppm iron in the culture solution increased the yield; while up to 10 ppm iron had no influence; and concentrations above 10 ppm reduced the yield of rice. Similar results were obtained by Tocher (1965) on wheat.

At the same time the content of Fe in chlorotic leaves was usually either equal to the Fe content of green leaves or even somewhat higher. Thus it was evident that even under chlorosis inducing conditions the plant was still able to absorb from solution and to transport large amount of Fe and that chlorosis did not result in from a shortage in the supply (Kerschon, 1958).

Recently, the chelating agent, [illegible] related to [illegible], has drawn the attention of many investigators. Tiffin et al (1960) and Wallace and De Kock (1966) indicated that chelating agents delivered Fe to the root and increased its absorption. The chelating agents remaining for the most part in nutrient medium. Similar results were obtained by Jeffreys et al (1961), Riekels and Lingle (1966), Jeffrey and Wallace (1968). They added that this increase in Fe absorption was affected by low temperature, high pH, low Fe/chelating agents ratio and Fe content in the plant.

2.2 Inter-relation of Fe and other nutrients

There is abundant evidence that the absorption of Fe is influenced by the presence of a number of other substances in the medium. Prominent among these are calcium, magnesium, potassium, phosphate, manganese, bicarbonate and organic matter. Brown et al (1959), Wallace and Lunt (1960) and Elgala (1966) concluded that iron chlorosis in plants can be due, either, to limited supply of available iron or to the excess of certain heavy elements in the soil.

soil moisture, poor aeration and cool temperature were reported by Thorne et al, (1950) as possibly disturbing plant metabolism which may result in fixing plant iron in forms of low biological activity.

It had been shown by Jungk, (1967) that an increase in pH through liming increased the contents of inorganic cations and organic anions in the shoots.

2.2.1 Inter-relation of Fe and Ca

Ca^{2+} activity, as related to Fe chlorosis, had drawn the attention of many investigators (Thorne et al, 1950; Brown, 1956; Brown et al, 1959[a]; Brown et al, 1959[b]; Wallace and Lunt, 19[illegible]; Sadin, 1965; Mai-Thi My Nhung and Ponnamperuma, 1966; Brown, 1967). However, they added that the effect of Ca in the soil was difficult to separate from the effect of soil pH. Mc George and Breazeale (1956) stated that rye and barley seedlings absorbed iron as readily from calcareous as from non-calcareous ones, but there was a greater immobilization of iron in the plant tops in the case of the former. Maier and Cattani (1964) suggested that lime induced chlorosis, could be caused by iron inactivation or failure of iron metabolism within the plant itself. At the same time Howard [illegible]l ([illegible]) studied the relation between Ca and Fe and reported that high level of Fe was mainly associated with a decrease of Ca.

Taper and Leach (1957), Lingle et al (1963) using Fe-EDDHA, indicated that increasing Ca concentration in the culture solutions reduced the absorption and the total uptake of iron in the plants. Other results, in confirmation with the previously mentioned, were reported by Olsen (1958), Neher (1960), Taper & Leach (1961), and Khadre & Wallace (1965). Sabet and Abdel Salam (1966) also found that increasing Ca supply decreased Fe content of the roots.

However, Ruth Neumun and Yoav Weiset (1966) indicated that the presence of Ca in the absorption medium had only a slight effect on the uptake of Fe and on its translocation.

On the other hand, Estra and Weir (1964) did not find any significant correlation between Fe content in the plant and the exchangeable Ca. Twyman (1959), ElKholi (1961) showed that the uptake of Ca was decreased by applying high levels of iron. Bolle-Jones (1955) indicated that Ca carbonate addition increased the Ca concentration of young and old lemna particularly those of low Fe-plants.

Brown et al (1960) concluded that where Fe was held from the plant root by the chelate, Zn , Ca and Mg continue to be absorbed. They suggested that some of these ions could act competitively against the proper functioning of Fe if their concentrations were allowed to increase.

Another explanation for the effect of Ca on Fe content in plant was introduced by Van Steveninck (1965) who concluded that Ca mainly associated with the cell surface, i.e., outer protoplasmic surface and cell wall. He suggested that Ca^{2+} plays an important role in bonding negative charges of the plasma surface and cell wall respectively. Mg^{2+}, Fe^{2+} and Mn^{2+} ions were predominantly associated with the proplasmic phase. He also added that non-specific effect of divalent cations on the colloid chemical behaviour of the protoplasm were of importance only when Ca^{2+} was absent.

Recently, several plant species grown at low levels of Ca in solution culture did not develop symptoms of Ca deficiency provided that Mg and heavy metals (Fe, Cu, Zn, Sr) were in relatively low supply. There was evidence that Cu also compensates for the toxic effects of metals (Fe , Mg) and in this respect, could be substituted by chelating agents (Wallace et al, 1968).

2.2.2 The inter-relation of Fe and Mg

Mg has been found by some investigators to be an important factor in reducing the absorption and content of iron in plants. Holmes et al (1944) indicated that the use of $MgSO_4$ as a supplementary fertilizer increased Mg content but reduced Fe content. Similar results were reported by Neher (1960), Lingle et al (1963). In a more recent work, Guha and Mitchell (1966) concluded that Fe showed a decrease in concentrations with the height of plants, which could only partly be explained by dilution effect due to an increase in dry weight with height, while Mg , Ca , Mn were relatively constant at all heights.

In a study on tomato, Twyman (1959) investigated the effect of Fe supply in the nutrient solution on the yield and composition of leaves. He reported that increasing the supply of Fe in the nutrient solution from 0.047 to 0.375 mg/liter increased the dry weight and Fe content of the leaves, but reduced their Mg content.

Brown et al (1960) showed that if Fe was held from the plant root by the chelate (EDDHA) Mg continued to be absorbed. Mg could act competitively against the proper functioning of Fe if Mg concentrations were allowed to increase.

Van Steveninck (1965) indicated that Fe^{2+} followed the same distribution as Mg^{2+} i.e. became predominantly associated with the protoplasmic phase. However, a shift of Mg^{2+} towards the cell wall fraction would occur when Ca^{2+} was removed and no divalent ions were added in the external solution. Fe^{2+} was relatively in effective in preventing the Mg shift, while Ca^{2+} and Mn^{2+} did.

2.3 Mn in plants

Mazé (1914) showed, by the use of water culture experiments, that Mn was necessary for the growth of maize. Later some investigators called attention to the importance of Mn for a considerable number of plants (Miller, 1928; Mc Hargue and Calfee, 1932; Lyon and Beeson, 1943). Recently Rasheed (1965) found that Mn application affected Mn content of the plant.

On the other hand, Hewitt (1951), Mc Ebroy and Mason (1954), Karim and Deraz (1961), Mer and Dixon (1962), Mc Gregor and Wilson (1964), stated that the growth of plants was not changed when Mn was applied. Different species appear to very in sensitivity to Mn (Collander, 1941; Morris and Pierre, 1949).
According to Vlamis and Williams (1964) the optimum growth of barley and rice in culture solution occurred when the concentration was 0.1 and 0.2 ppm; below this level yields dropped rapidly for both species; at higher Mn supply barley yield fell, but rice yield was not significantly reduced.

2.3.1 Inter-relation of Mn and Ca

Studies of cation absorption showed an antagonism between Ca and Mn (Rich, 1956: Löhnis, 1960). Results obtained by Williams and Vlamis, (1957[a]); Taper and Leach (1957); Ouellette and Dessureaux (1958) reported that reduction through Mn toxicity occurred by increasing Ca concentration in culture solution. These results were in conformity with the findings of Hunter and Mc Gregor (1946), Mc Gregor et al (1960), Graven et al (1965) and Rothwell (1966) using sols instead water culture.

[illegible] (1946), Sutton and [illegible] ([illegible]), Page (19[illegible]2) and Dukshoorn (1962) pointed out that a high Mn supply varied in its toxicity to plants owing to the different levels of Ca and pH of the medium. Morris and Pierre (1947), Walker et al (1956) failed to show Mn toxicity by increasing Ca levels.

The effect of Ca on Mn was further emphasized by the findings of Diest and Schuffelen (1966) as they found that both oats and sunflower absorbed Mn via two carriers. Ca and Mn competed for one carrier. Mn uptake on the other carrier was unaffected by Ca. In oats only, Ca in the nutrient medium enhance the net uptake of Mn. However, wider Ca/Mn ratio than those used appeared to be needed to reach the level where Mn was absorbed by a specific carrier only.

According to Collender (1941) Mn^{2+} had an ionic radii of 0.80 A°, which was relatively close to that of Ca^{2+} 0.99 A°. He found a negative correlation between the content of Ca in soils and plant Mn. He suggested that ionic size might determine, in part, the depressing effect of Ca on the uptake of Mn by plant.

Van Steveninck (19[illegible]) reported that [illegible]$^{2+}$ and [illegible]$^{2+}$ added to the solution were effective because they render the Ca^{2+} in solution available to the tissue.

2.3.2 The combined effect of Mg and Mn in plant

There is abundant evidence that the absorption of Mn is influenced by the presence or absence of Mg in the medium.

Farberry (1943) showed that Mg deficiency caused an increased absorption of Mn. Löhnis (1954) found that the application of $MgSO_4$ to Mg-deficient soil increased the symptoms caused by excess of Mn. The Mg/Mn antagonism had been reported for beans, potatoes, cereals and soybeans, but not for flax, senedella or lupin. Williams and Vlamis (1957[a]) stated that Ca reduced Mn content of the old leaves of barley, from water solution by 45 % compared with the control, while with Mg the reduction is 25 %.

El Khory (1961) showed that Mn and Fe interaction significantly affected the uptake of Mg in lucerne and tomato plants.

On the other hand, Fr[illegible] (195[illegible]) found that Mg showed no effect on Mn content of the plants in lime soil.