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A General Overview On Manganese (Mn) Importance For Crops Production

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Abstract: Plants quantitative and qualitative yield is strongly dependent on plant nutrition. In addition, in plant nutrition each element should be available in adequate amounts for plants, also balance and respect ratio between used nutrients is important. Manganese (Mn) plays an important role in oxidation and reduction processes in plants, such as the electron transport in photosynthesis. Manganese also has played a role in chlorophyll production, and its presence is essential in Photosystem II. Manganese acts as an activating factor which is causes the activation more than 35 different enzymes. Due to the metabolic role of manganese in the nitrate-reducing enzyme activity and activation of enzymes which play roles on carbohydrate metabolism, use of fertilizers containing manganese increases efficiency of photosynthesis and carbohydrates synthesis such as starch, thus photosynthesis efficiency decrease with manganese deficiency and therefore crop yield and quality will be reduced. Manganese is uptake and transfers the form of Mn^{2+} in plants, and transfer in the meristematic tissues gradual, thus the young organs of plants are rich of manganese. Calcareous soils, soils with high pH (mainly in arid and semi arid areas of the world), and especially in soils with poor ventilation are confronted with manganese deficiency. Magnesium (Mg) and lime have an antagonistic affect on manganese; therefore manganese uptake decreases by magnesium and lime.

Key words: Manganese, micronutrient, yield, quality

INTRODUCTION

Plant nutrition is one of the most important problems in crop production which have an important role in crop production and improve agricultural production quality. In most regions of the world the use of chemical fertilizers is very unbalanced and is not based on plants requirement. Each element in proper plant nutrition should be available enough for plants, and balance and respect the ratio between used nutrients is also important (Alloway, 2008). In developed countries 2 to 4 percent of fertilizer consumption is micronutrients, while in Iran, this amount is very small (2 grams per one ton production) (Malakouti and Tehrani, 1999). In agricultural development programs role of micronutrients is very important to increase crop yield and quality. So with balanced and efficient use of macro fertilizers (NPK) with micronutrients fertilizers such as manganese (Mn), zinc (Zn), and iron (Fe) the following objectives can be achieved (Mousavi *et al*., 2007; Malakouti and Tehrani, 1999):

1- High yield per unit area
2- Enrichment and increased concentrations of micronutrients in crop productions and promotion the health of community.
3- Reduction of environmental pollution
4- Produce seeds with higher viability and germination rate and seedling strength for next cultures.
5- Reduction of pollutants such as nitrate and cadmium concentrations in crop production and increase the quality of products.

In most of the Iran's soils pH is high and they are also calcareous, in this type of soils solvability of micronutrient is less and cause decline uptake these elements and finally requirement of plants to this elements is increasing (Alloway, 2008; Lalljee and Facknath, 2001; Uygur and Rimmer, 2000; Malakouti and Tehrani, 1999). Also irregular use of phosphate fertilizers in the poor soils of micronutrients such as manganese causes an imposed deficiency of these elements; therefore concentration of micronutrients will decline in crop products and its dry matter (Abdou *et al*., 2011; Ibrahim and Ali, 2009). Today in the world, policy of reduce utilization of chemical fertilizers, pesticides, and efficient use of inputs is considered to reduce environmental risk and provided human health.

Manganese is one of the main micronutrients, which has an important role in plant as a component of enzymes involved in photosynthesis and other processes. Manganese is part of an important antioxidant (superoxide dismutase) structure that protects plant cells by deactivating free radicals which can destroy plant tissue. Manganese plays vital roles in photosynthesis, as a structural component of the Photosystem II water-splitting protein. It also serves as electron storage and delivery to the chlorophyll reaction centers (Diedrick, 2010; Millaleo *et al*., 2010). Manganese is uptake by plant roots as the divalent ion Mn^{2+}. Also is needed in

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small amount and uptake usually is less than 1kg Mn/ha in cereals and around 2kg Mn/ha in sugar beet (Yang and Deng, 2008; Draycott and Christenson, 2003; Marcar and Graham, 1987; Gupta, 1986).

Manganese fertilizer increases the crop yield and quality, due to improved plant nutrition and increasing photosynthesis in plants, so crop yield and quality increases by increasing photosynthetic efficiency (Mousavi *et al*., 2007; Crosier *et al*., 2004; Kelling and Speth, 2001; Hiller, 1995).

Manganese in soil:

Manganese (Mn) is the eleventh abundant element forming the Earth's crust. In terms of abundance, manganese-containing compounds are after iron (Fe) in the earth's crust. Total amount of manganese in soil is between 20 to 3000 ppm and 600 ppm on average. Divalent manganese is absorbed by clay minerals and organic material, and In terms of nutrition plant, divalent manganese ions (Mn^{2+}) is most important (Malakouti and Tehrani, 1999). In soil manganese occurs as exchangeable manganese, manganese oxide, organic manganese and component of Ferro-manganese silicate minerals, the manganese ion (Mn^{2+}) is similar in size to magnesium (Mg^{2+}) and ferrous iron (Fe^{2+}) and can substitute for these elements in silicate minerals and iron oxides. Manganese reactions in soils are quite complex. The amount of available manganese is influenced by soil pH, organic matter, moisture, and soil aeration (Schulte and Kelling, 1999).

Biochemical Role Of Manganese In Plants:

Divalent manganese ions (Mn^{2+}) is converted to Mn^{3+} or Mn^{4+} easily, therefore in the plant manganese plays an important role on oxidation and reduction processes, as electron transport in photosynthesis. Moreover manganese acts as an activator of many enzymes, (more than 35 different enzymes). Manganese has important role on activates several enzymes which involve to oxidation reactions, carboxylation, carbohydrates metabolism, phosphorus reactions and citric acid cycle. Of the most important these enzymes, protein-manganese in Photosystem II and superoxide dismutase can be pointed. There is more than 90% of superoxide dismutase in chloroplasts which about 4 to 5 percent of it is in mitochondria (Millaleo *et al*., 2010; Mukhopadhyay and Sharma, 1991; Jackson *et al*., 1978; Uehara *et al*., 1974).

Manganese (Mn^{2+}) In terms of biochemical functions is similar to magnesium (Mg^{2+}), both ions connects ATP with complexes enzymes (phosphotransferase·and phosphokinase). Dehydrogenase and Decarboxylase in the Krebs cycle (TCA) are also activated by Mn^{2+} (Marschner, 1995; Burnell, 1988). Manganese plays an important role in chlorophyll production and its presence is essential in Photosystem II, also involved in cell division and plant growth. RNA polymerase is activated by manganese. Manganese has an effective role in lipids metabolism, and due to effective role of manganese in the nitrate reduction enzymes, nitrate will accumulation in leaves which are facing with manganese deficiency. Moreover amount of lignin in the plant will decline due to manganese deficiency, that this reduction is more severe in the roots, this matter is very important especially to reduction resistance the roots of plants to fungi infecting (Anderson and Pyliotis, 1996; Marschner, 1995; Mukhopadhyay and Sharma, 1991; Ness and Woolhouse, 1980).

Manganese Interaction With Other Elements:

Manganese uptake considerably is different between various plant species, and generally its uptake is lower than other bivalent cations such as Ca^{2+} and Mg^{2+}. Manganese uptake decreases by magnesium and lime, that its main reasons are negative effect of increasing Ca^{2+} and pH. In terms of chemical behavior, manganese shows the same properties of the soil alkaline cations such as Ca and Mg and heavy metals such as Zn and Fe; thus these ions affect on the uptake and transport of manganese in plants (Aref, 2011; Marschner, 1995; Spiers, 1993; Hewitt, 1988).

Manganese and iron (Fe) has an interaction in plants, iron uptake by plants affects with high amounts of manganese in the soil; the same (Fe imposed deficiency by Mn) can exacerbate the problems caused by manganese toxicity in plants. Moreover, if the amount of iron in the soil is too much, causes manganese deposits and manganese uptake can be reduced for plant (Michael and Beckg, 2001; Malakouti and Tehrani, 1999).

Manganese Deficiency:

Manganese deficiency in terms of geographical distribution is widespread, but overall calcareous soils, soils with high pH (arid and semi arid regions of the world) and especially soils with poor aeration are mainly encountered with manganese deficiency. Also there is manganese deficiency on the soils surface erosion. Generally, the amount of dissolved manganese in the soil is influenced by soil organic matter. Manganese in some podzolic soils is poor inherently, due to excessive leaching. Manganese solubility will decline with increasing pH, as it is reduced 100 times by increases in one unit of pH. Chloroplasts is the most sensitive components in cells in manganese deficiency condition, so that the structure of chloroplasts significantly damaged by manganese deficiency. Net photosynthesis and chlorophyll amounts decreases with manganese deficiency (Ndakidemi *et al*., 2011; Ahangar *et al*., 1995; Polle *et al*., 1992; Ohki *et al*., 1981; Honann, 1967).

Manganese deficiency has very serious effects on non-structural carbohydrates, and roots carbohydrates especially. Crops quality and quantity decreased due to manganese deficiency, and this is due to low fertility of pollen and low in carbohydrates during grain filling. Manganese deficiency is similar to magnesium deficiency, because there comes yellow in both intercostals. Manganese deficiency symptoms first appear on younger leaves; because dynamics of these elements in different plant tissues is limited (manganese isn't a mobile element); but the magnesium deficiency symptoms is seen in older leaves primarily (Marschner, 1995; Longnecker *et al*., 1991; Sharma *et al*., 1991; Wilson *et al*., 1982). In dicot plants manganese deficiencies often are known with small yellow spots on leaves, also manganese deficiency symptoms in monocot plants appears as tape and gray-green spots on base of leaves. The major symptom of deficiency is a reduction in the efficiency of photosynthesis leading to a general decline in dry matter productivity and yield. Occurrence and intensity of manganese deficiency is depend to seasonal conditions, as manganese deficiency will be more severe in the cold and wet seasons, due to reduced roots metabolic activity in manganese uptake. Manganese concentrations in plant tissues have been determined 50 to 150 ppm. Manganese critical levels in plant tissues depending on the cultivar, species and environmental conditions and has been reported between 10 to 50 micrograms per gram for dry matter (Michael and Beckg, 2001; Marschner, 1995; Batey, 1971)

Manganese toxicity:

Manganese toxicity is different in plants and depends on plant species and environmental conditions. Manganese toxicity is a major factor on limiting growth in acidic soils, in these soils high concentrations of manganese in the leaves reduces photosynthesis and thus growth is reduced. Brown spots on mature leaves and chlorotic dots at the tips of young leave appear with toxicity caused by manganese. These symptoms are appearing less in up light intensity compared with less light intensity. Manganese toxicity started with chlorotic in the elderly leaves and make progress to young leaves (Millaleo *et al*., 2010; Reichman, 2002; Bachman and Miller, 1995; Wu, 1994; Wissemeier and Horst, 1992; Brown *et al*., 1972; Edwards and Asher, 1982). Symptom of manganese toxicity started from the border of leave and makes progress toward areas between leaves, and leaves necrosis spreads with increased toxicity. Necrosis in the leaves extending with increased toxicity. Cells size is influenced by manganese toxicity more than cells number. Uneven distribution of chlorophyll and accumulation of granules starch in chloroplasts is the effects of manganese toxicity. Manganese toxicity can be eliminated with use of high amount of magnesium (Rezai and Farbodnia, 2008; Bachman and Miller, 1995; Wu, 1994; Terry *et al*., 1975).

Method, Timing And Amount Of Manganese Fertilizers:

Prevention of deficiencies is the best way to deal with micronutrients deficiencies, choose of resistant plant varieties and cultivars and appropriate management practices can be used to prevent of manganese deficiency occurrence. The most fertilizer containing manganese is manganese sulfate, which is contains 26-28% manganese and is used in acidic and alkaline soils. Manganese sulfate is used as to band or broadcast is roots depth. Manganese reacts with soil particle and will become inaccessible forms quickly, so it looks much better to use of band method. Manganese oxide with about 70% pure manganese is usable only in acidic soils, due to the limited solubility. Manganese kalat (Mn-EDTA) with 12% Mn can cite of organic sources fertilizer. In calcareous soils, foliar applications of manganese kalat are recommended only. Generally, the use of manganese as foliar applications is recommended in calcareous soils. Manganese sulfate ($MnSO_4$) is effective inorganic fertilizer for foliar applications. The main sources of manganese fertilizer are in table 1 (Malakouti and Tehrani, 1999; Schulte and Kelling, 1999).

Table 1: The main sources of manganese fertilizer

Sources of manganese fertilizer	Chemical formula	Mn%
Manganese Sulfate	$MnSO_4.3H_2O$	26-28
Manganese Oxide	MnO	41-68
Manganese Carbonate	$MnCO_3$	31
Manganese Kalat	Mn-EDTA	12
Manganese Chloride	$MnCl_2$	17
Manganese Dioxide	MnO_2	63

The role of manganese on crop yield:

Manganese deficiencies in crop production are most prevalent in the alkaline to acid soils imposing limitations to crop production and yield. Soil, foliar application or seed treatment of manganese is essential for better crop yield and quality. Manganese facilitates the production of carbohydrates and is required for optimum utilization of macro nutrients in plants. Manganese promotes the activity of various enzymes that helps in the photosynthetic light reactions, respiration and protein synthetic processes leading to better utilization of NPK to convert into functional seed carbohydrates. Crops yield increases with manganese foliar applications due to increasing photosynthesis efficiency and synthesis of carbohydrates such as starch. Manganese has an important metabolic role in nitrate-reducing enzyme activity and activation of enzymes involved in carbohydrate metabolism, thus its deficiencies decrease photosynthesis efficiency and thereby reducing crops yield and quality (Diedrick, 2010; Malakouti and Tehrani, 1999). Mousavi *et al*., (2007) in their study reported that potato yield increased and storage dry matter improved by use of manganese and zinc. Hiller (1995) and Walworth (1998) in separate investigation reported that yield and quality of potato increased with foliar applications of micronutrients such as manganese. Bansal and Nayyar (1994) investigated the effect of manganese foliar applications on 10 cultivars of soybean and observed a significant increase in the economic and biological yield of soybeans. Mahler *et al*., (1992) examined the effects of manganese sulfate on irrigated wheat yield and quality, and concluded wheat yield increased significantly with use of manganese sulfate.

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