Effect of High Concentration of Fe and Mn as Foliar Application on Growth and Yield of Sesame Grown in Calcareous Soil

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Abstract: ***A farmer field trial experiment was conducted at growth season of 2016 in Deraluk sub-district, Amadiya district, Dohuk province, Iraq to investigate the effect of foliar application of high level of Fe and Mn on growth and yield of sesame (Sesamum indicum L.) grown in calcareous soil. A concentration of 0.5% of the micronutrients Fe, Mn and Fe + Mn was used as a foliar application in two splits: The first split was just before anthesis (40DAS) and the second split was after full anthesis (65DAS). The results showed no significant reduction in all studied parameters which included plant highs, number of capsules, the weight of 1000 seeds, grain yield and Straw yield (except the treatments Fe and Fe+Mn they were significantly reduced from the control). No significant values of (HI) were found between the treatments despite the superiority of Mn and Fe+Mn over the control.***

Keywords: Foliar application, sesame, micronutrients, calcareous soil

1. Introduction

Sesame (*Sesamum indicum* L.) belongs to the family of Pedaliaceae and cultivated in the tropical and subtropical zone (Gupta et al., 1998; Iwo et al., 2002). Archeological records indicated that it has been known and used in India for more than 5,000 years and is recorded as a crop in Babylon and Assyria some 4,000 years ago (Were et al., 2006; Borchani et al., 2010). It's considered to have both nutritional and medicinal values for containing high ratio of oil (50-60 %), protein (19-25 %), carbohydrate (13-14%), ash (~5%), methionine, antioxidants lignans (such as sesamolin and sesamin), calcium and iron (Gupta et al., 1998; Ashakumary et al., 1999; Borchani et al., 2010). World total cultivation area under sesame was about 9.4 million hectares, producing 4.76 million tons (FAOSTAT, 2013). The sesame seed production in Iraq at 2015 (with the exception of Kurdistan region provinces) was about 1957 tons from cultivated area of 2090.5 hectares, with average production of 936.14 kg ha^{-1} (CSO, 2016); while in all over Iraq, the production at 2009 was 4559 tons from 7500 hectares, with average production of 607.87 kg ha^{-1} (Omer, 2011).

The major yield-limiting factors in soils of arid and semiarid regions are the deficiency of micronutrients. In such regions, soils are characterized by low organic matter, high pH and high $CaCO_3$ (El-Fouly, 1983; Amberger, 1991 and Malakouti, 2008). These properties of the soil reduce the availability of the mineral nutrients to crop plants (Sawan et al., 2008). Such kinds of soils are common in the northern part of Iraq and usually known as calcareous soils (Buringh, 1960; Al-Nuaimi, 1977).

The micronutrients play an important role in increasing crop yield. Brown et al. (1993) stated that micronutrients can contribute increasing of grain yield up to 50%, as well as increasing of macronutrients use efficiency. Iron Involves role in biological redox system, enzyme activation and oxygen carrier in nitrogen fixation (Romheld and Marschner, 1991); Mn utilized in enzyme activation, electron transport and in disease resistance (Burnell, 1988). In calcareous soils correction of Zn or Fe deficiency is not always easy through the use of Zn or Fe fertilizers because of their extremely poor solubility. Remediation of Zn and Fe deficiencies by fertilizers only is costly and time-consuming management (Al-Niemi et al., 2013).

Foliar feeding, a term referring to the application of essential plant nutrients to above-ground plant parts, has been documented as early as 1844 when an iron sulfate solution was sprayed as a possible remedy for “chlorosis sickness” (Gary, 1982). In addition to the roots, higher plants can also uptake the nutrients through the green parts, especially the leaves. Research showed that the nutrient passes through the cuticle, cell wall, the membranes (Middleton and Sanderson, 1965; Franke, 1967), leaves stomata’s (Eichert et al., 1998; Eichert and Burkhardt, 2001) and ectodesmata (Franke, 1961 and 1970; Pandey et al., 2013). It's more effective to control deficiency problem under certain circumstances than soil application (Grewal et al., 1997; Erdal et al., 2004; Babaeian et al., 2011; Fernandez et al., 2013). Foliar application of micronutrients has been widely used in many studies and had obvious effects on the growth and yield of crops. For example, Hamideldin and Hussein (2014) results showed that spraying sesame plants with boron (B) solutions improve their growth and yields. Shirazy et al. (2015) suggested that the combined doses of 60 kg N ha^{-1} with foliar application of 150 ppm micronutrients have produced the highest morphological growth of sesame. Also foliar application of micronutrients had many advantages with diverse crops e.g., with wheat crop (Khan et al., 2010; Zain et al., 2015; Stepien and Wojtkowiak, 2016), with rice (Ahmed et al., 2013; Boonchuay et al., 2013), with corn (Sayfan et al., 2012; El-Azab, 2015).

The purpose of the experiment was to investigate the effect of foliar application of high level of Fe and Mn on growth and yield of sesame (*Sesamum indicum* L.) grown in calcareous soil.

2. Materials and Methods

Field location and Soil characteristics

Farmer field trial experiment was conducted at growth season of 2016 in Deraluk sub-district (the field area was 1075 m^2 and located in: 38˚05''13'N; 41˚01''80' E; elevation: 639m), Amadiya district, Dohuk province, Iraq. The soil was clayey (21.85, 17.9 and 60.25% sand, silt and clay respectively) with a bulk density of 1.26 Mg t^{-1}, pH of 7.6, Ec of 0.35 Ds m^{-1}, organic matter of 10.32 g kg^{-1}, CEC of 25.43 $Cmole_c$ kg^{-1}. Available N and P were: 47 and 7 ppm respectively. Available dissolved ions (1:10 soil: water suspension) were: 0.17, 0.15, 2.1, 1.1, 0.1, 1.1 and 0.5 *meq* L^{-1} for K^+, Na^+, Ca^{++}, Mg^{++}, $CO_3^=$, $HCO_3^=$ and Cl^- respectively. Available micronutrients were: 8.84, 0.42, 4.99 and 3.44 ppm for Fe, Zn, Mn and Cu respectively.

Land preparation and sowing

The land was well irrigated and after a week was plowed perpendicularly and horizontally then smoothed. Four strips from the middle of the land were selected and each strip was divided into three plots. Dry seeds of local cultivar were sown at a rate of 6 kg ha^{-1} via hand broadcasting method at June 5th, 2016. The weeds manually controlled 30 days after sowing (DAS). The crop irrigation has been done via flow irrigation method according to plant needs.

Fertilization

Basal nitrogen fertilizer was added at a rate of 80 kg N ha^{-1}, the fertilizer was divided to two equal amounts, the first dose was added with seeds and the second was after weed controlling (30 DAS). One time soil application of phosphorus fertilizer at a rate of 60 kg P_2O_5 ha^{-1} was added with seeds.

Treatments application

A concentration of 0.5% of the micronutrients Fe, Mn and Fe + Mn in addition to the control (water) was used as a foliar application in three replications and two splits: The first split was just before anthesis (40DAS) and the second split was after full anthesis (65DAS). The knapsack sprayer of 8 litter capacity was used and spraying time was at about two hours before sunset. The spraying was stopped just after the solution starting to flow over the shoots.

Harvesting

The crop was harvested on September 25th, 2016. One square meter was chosen for each treatment and the plants were removed with roots from the soil and made as bundles then kept in an upright state till to ensure full maturation of seeds. The capsules were accounted and removed from the plants, threshed and seeds were refined. The whole plant has been threshed and both straw and grain yields were calculated on a base of air-dry weight. The harvest index (HI) is the ratio of harvested grain to total shoot dry matter, and this can be used as a measure of reproductive efficiency. It has been calculated from the equation below:

$$HI = \text{Grain yield}/\text{biomass}.$$

Statistical analysis

A randomized complete block design (RCBD) was used for the statistical analysis of the data. The treatment means were compared by determining the least significant difference (LSD) at 5% level of probability (P=0.05) using statistical analysis software SAS (2002).

3. Results and Discussion

Concerning the plant highs, the number of capsules and the weight of 1000 seeds (table-1), there was no significant reduction of the treatments as compared with the control. The reduction ratio of the treatments as compared to the control respectively for Fe, Mn and Fe+Mn was as follow: For plant heights was 6.74, 9.22 and 7.8%; for number of capsules per plant was 16.98, 20.88 and 40.14%; and for weight of 1000 seeds was 2.86, 5.7 and 8.57%.

Table 1: Effect of Fe, Mn and Fe+ Mn as a foliar application on growth and yield of sesame

Treatment	Plant height (cm)	No. of capsules (plant)	1000 seeds weight (g)	Grain yield (Mg ha^{-1})	Straw yield (Mg ha^{-1})	Harvest index (HI)
Control	141.00	72.67	3.50	1.00	2.53	28.32
Fe	131.50	60.33	3.40	0.95	2.34	28.88
Mn	128.00	57.50	3.30	0.92	1.94	32.17
Fe+Mn	130.00	43.50	3.20	0.82	1.85	30.71
LSD	8.87	32.46	0.31	0.32	0.36	6.84

The grain yield was non-significantly reduced in all treatments as compared to the control with the ratios of 5.0, 8.0 and 18, 0% for Fe, Mn and Fe+Mn respectively. There was no significant reduction for the straw yield of Fe treatment as compared to the control, while the other treatments (Fe and Fe+Mn) were significantly reduced from the control. The reduction ratio of the treatment from the control was 7.51, 23.32 and 26.88% respectively for Fe, Mn and Fe+Mn. No significant values of (HI) were found between the treatments despite the superiority of Mn and Fe+Mn over the control.

The reduction of plant heights, number of capsules and the weight of 1000 seeds resulted in the reduction of both grain and straw yields. This reduction however it was not significant (except Mn and Fe+Mn treatments of the straw) may refer to the starting of the toxicity effects of surplus addition of Fe and Mn. The toxicity symptoms slightly appeared in the shoots (figures not shown). The plants were susceptible to Mn more than Fe, but they were most susceptible when Fe and Mn sprayed together than those when sprayed individually. The latter is more likely resulted from the interaction (antagonism effects) between these two elements in the plant during uptake and/or translocation. This phenomenon is frequently reported in the literature (Van Der Vorm and Van Diest, 1979; Roomizadeh and Karimian, 1996; Ghasemi-Fasaei et al., 2005; Moosavi and Ronaghi, 2010 and 2011). In chickpea, the foliar application of Fe decreased the dry matter and concentration and uptake of Mn due to the antagonistic effect of Fe on Mn translocation (Ghasemi-Fasaei et al., 2005). Moosavi and Ronaghi (2011) reported that the foliar application of Fe decreased shoot Mn concentration and uptake in soybean. In the same context, Shehu (2014) found the disadvantage of combined Mn and Zn on dry matter yield. He also reported that higher concentrations of Mn and Zn depressed seed yield and favored dry matter accumulation. The interaction of Fe and Mn might have suppressed the uptake of not only these two elements but some other nutrients which in turn altered their functions and subsequently depressed growth and yield.

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