Influence of nano-iron oxide and zinc sulfate on physiological characteristics of peppermint

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ABSTRACT
To evaluate the impact of nano-iron oxide and zinc sulfate fertilizers on peppermint in field conditions, a factorial split experiment with two micronutrient fertilizers [Zinc (Zn) and Iron (Fe)] in RCBD with three replicates was conducted at University of Tehran, during 2014 and 2015. Fe at four levels (0, 0.25, 0.5, and 0.75 g L⁻¹) and Zn at three levels (0, 2.5, and 5 g L⁻¹) were applied. Fe and Zn fertilizer application significantly improved photosynthetic pigments, mineral nutrient content, essential oil concentration, and dry matter yield in peppermint. The highest iron content (1578.00 mg kg⁻¹) was achieved when 5 g L⁻¹ of Zn was applied along with 0.75 g L⁻¹ Fe. According to our results, the application of 2.5 g L⁻¹ of Zn plus 0.5 g L⁻¹ Fe fertilizers could be recommended to achieve the highest plant dry matter and essential oil yield.

Introduction
Medicinal plants like peppermint are widely used in the traditional and modern pharmaceutical industries (Abou-Arab and Abou 2000). The extent of medicinal plant cultivation has been significantly improved in agricultural systems within the last decade. Peppermint (Mentha piperita L.) is cultivated for medicinal and food purposes (Tiwari 2016; Zheljazkov et al. 2010). Peppermint essential oil sales are in volume and menthol comprises the bulk component of peppermint essential oil cultivated for medicinal purposes. Menthol has significant amounts of antifungal and antibacterial components (Souza, Matos, and Matos 1991), and Menthol enhances cold receptors in the respiratory tract and improves nasal airflow (Shah and Mello 2005).

Iron (Fe) and zinc (Zn) mineral elements, as micronutrients, play different roles in the structure of various enzymes as well as a regulating role of cofactors in the metabolism of carbohydrates, proteins, and cellular photosynthesis (Marschner 1995). Also, Fe plays a special role in many physiological processes such as chlorophyll biosynthesis and cellular respiration (Ye et al. 2015; Zargar et al. 2015). In alkaline soils, Fe is mostly found in insoluble Fe³⁺ form, therefore, these soils are usually Fe deficient (Ye et al. 2015). Kobayashi and Nishizawa (2012) stated that the available Fe in Fe²⁺ form is the only form usually absorbed by plants. Rui et al. (2016) demonstrated yield and chlorophyll increased by application of nano-iron oxide in peanut.

Fe-ethylendiaminetetraacetic acid (Fe-EDTA) has been introduced as a significant supplement to provide Fe to plants (Abadia et al. 2011). However, synthetic chemical fertilizers have harmful effects...