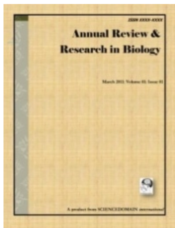

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Micronutrients Distribution in Soybean Plant with Zn, Fe, and Mn Application

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Authors' contributions

This work was carried out in collaboration between all authors. Author SK designed and conducted the experiment, performed the statistical analysis and wrote the first draft of the manuscript. Authors GNM and HHSA accommodate in designed the experiment and managed the literature searches. Authors FDK and BD managed the analyses of the study. All authors read and approved the final manuscript.

Research Article

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ABSTRACT

In order to investigate the effect of some of micronutrients application on micronutrient distribution, partitioning, and their ratio in different parts of soybean plant; we conducted an experiment in field conditions at Kermanshah, Iran, 2010 and 2011. Three levels of zinc (0, 20, 40 kg.ha^{-1} from $ZnSo_4$ source); iron (0, 25, 50 kg.ha^{-1} from $FeSo_4$ source) and manganese (0, 25, 40 kg.ha^{-1} from $MnSo_4$ source) were applied. Based on results, it was found that Zn and Mn concentrations increased within the plant with micronutrient fertilizers application. The highest Zn concentration was observed in pod, but Maximum Fe and Mn concentrations recorded in leaves. With increases in soybean old and reach to full maturity stage, the Zn, Fe, and Mn content in tissue plant were decreased. The results indicated that with Zn application [Zn]/[Fe] and [Zn]/[Mn] ratios in seed increased. With Fe fertilizer application [Zn]/[Fe] ratio was decreased, but had no effect on [Zn]/[Mn] ratio.

Keywords: Iron; manganese; partitioning; trace element; zinc.

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1. INTRODUCTION

Micronutrients are needful elements for normal growth of plants, that are needed at little amount [1]. If these elements are not available sufficiently, plants will suffer from physiological stresses cause by inefficiency of several enzymatic systems and other related metabolic functions [2]. Various responses were observed in growth and yield in crops species and in cultivars to trace elements deficiency [3]. Micronutrients concentration in different plant organs is related to plant growth stage, availability, and mobility of micronutrient. These are can be transferred from the root, stem, leaf and pod walls into developing seeds [4]. Micronutrients absorbed by the roots and transported via vascular systems to other plant organs. Many differences can be seen in mobile ability of micronutrients in soil [5]. Zinc, iron, and manganese are cations that need to be transported from the soil solution into the roots and partitioning in different parts of plant [6]. Distribution of micronutrients into different parts of plant affected by genotypic characteristic [7], In addition, this process affected by soil and plant conditions [8, 9]. Source and sink signals allow plants to achieve optimal metal homeostasis by a precise regulation mechanisms of the metal uptake, transport, distribution and remobilization. There are the interaction, antagonistic and synergistic effects among elements in soil and plant [10, 11, and 12]. Absence of micronutrients results in poor growth and quality and quantity of soybean yield. Soybean is most important source of calories, protein, and nutrition for human and one component of seed quality is chemical composition, such as the concentration of mineral elements, including micronutrients such as Zn, Fe, and Mn. Thus, the main objective of this study was to determine the effects of zinc, iron and manganese application on Zn, Fe, and Mn concentration, distribution, and partitioning in different parts of soybean plant.

2. MATERIALS AND METHODS

Williams (*Glycine max*, supplied by the oilseed company of the Kermanshah agricultural administration, Iran), a soybean variety widely planted in Kermanshah Province, Iran was selected as the experimental material. These studies were conducted at 2010 and 2011 in the research field of the Islamic Azad University of Kermanshah, Iran (34º23' N, 47º8' E; 1351 m elevation). Soil samples were collected from experimental area at 0-30 cm depth. The soil texture was silty clay with pH 7.6, electrical conductivity 0.61dSm^{-1}, total organic matter 2.3%, total nitrogen 0.16%, available phosphorus 8.6ppm, available potassium 563 ppm, zinc, iron and manganese 0.71, 2.6 and 6.3 mg.kg^{-1}, respectively for 2010; and pH 7.3, electrical conductivity 0.52dSm^{-1}, total organic matter 2.5%, total nitrogen 0.18%, available phosphorus 8.5ppm, available potassium 525 ppm, zinc, iron and manganese 0.76, 2.2 and 5.7 mg.kg^{-1}, respectively for 2011. The experimental design was a factorial experiment based on Randomized Complete Block with three replicates. Before planting of soybean, fertilizers were used as follows: 27kg P_2O_5 and 7 kg N (based on 200kg P_2O_5/ha and 50kg NH_4NO_3/ha) and mixed with soil and land was ploughed once and harrowed twice. Inoculation of seeds with appropriate strain of *Bradyrhizobium japonicum* was carried out. Usage amounts of fertilizers zinc (0, 20, 40 kg.ha^{-1} from $ZnSo_4$ source); iron (0, 25, 50 kg.ha^{-1} from $FeSo_4$ source) and manganese (0, 25, 40 kg.ha^{-1} from $MnSo_4$ source) were calculated based on plots area surface; next, fertilizers were mixed with soft soil at the ratio of 1:5 and placed on furrows made manually next to the stacks. Phonological stages were defined according to [13]. The plots were irrigated when necessary to avoid water deficits. During the growing season, at R1, R3, R6, and R8 growth stages, five plants were selected from each plot, randomly. (R1: early of flowering, R3: early of pod set, R6: effective filling period, and R8: full maturity). At these stages, plants were cut from soil surface with shears and different parts of plant were separated. To measure concentration of elements in stem, leaf (leaves on the most top trifoliate of the plants were used), pod and seed, Samples were dried in the oven at 70ºC for 48 hours, weighed, and incinerated at 550ºC. Dry ash samples were soluble in concentrated HNO_3 and $HCLO_4$. Zinc, iron, and manganese contents were determined by Atomic Absorption Spectrometry (AAS) according to [14]. Then ratios of these elements in soybean organs at reproductive growth stages were measured.

3. RESULTS AND DISCUSSION

In this study, impact of different levels of zinc, iron, and manganese fertilizers application on Zn, Fe, and Mn concentration in leaf, stem, pod, and seed at during growth stages were analyzed. The concentration of zinc, iron, and manganese in leaves and stem of soybean plant at reproductive growth stages (R1 to R8) are shown in Figs. 1 and 2. Based on results, Zinc and Manganese concentrations increased with micronutrient fertilizers application. Zn and Mn content in leaf and stem at reproductive growth stages were lower in the check treatment and with application of these elements up to 40 $kg.ha^{-1}$, [Zn] and [Mn] were increased. These results are agreed with previous studies emphasized tissue micronutrient content; significantly increase with soil fertilizer application [15, 16]. [17] stated that mineral concentration in soybean plant increased when that fertilizer were applied. But the results were quite different from the iron. In Fe study, Fe concentration in leaves (Fig. 1) and stem (Fig. 2) of plant increased up to 25 $kg.ha^{-1}$ iron fertilizer applications and decreased when higher doses were used. Element translocation and distribution in plant is related to plant growth stages and element function during growing period [18, 19, and 20]. [4] Concluded that root uptake capacity and homeostasis mechanism in shoots affected by micronutrient transfer from the roots to shoots. It is important to note that the highest zinc concentration was observed in pod and seed with 40 $kg.ha^{-1}$ Zn fertilizer applications (Figs. 3 and 4). Based on [21] study elements transfer to the seeds from the other organs, and this is normally that zinc concentration in pod and seed more than the zinc concentration in stem and leaves. Transpiration from the leaves and in continuance water uptake from the roots creates the hydrostatic pressure that causes the micronutrients to be transferred from the roots to leaves and other developing organs such as pods and seeds. Thus, it seems that the leaves and pods are the temporary sink for zinc [22]. Source and sink signals allow plants to achieve optimal metal homeostasis by precise regulation mechanisms of the metal uptake, transport, distribution and remobilization. Since, there is differing widely in mobile ability between micronutrients, therefore, we observed dissimilar results for iron and manganese distribution and partitioning. Maximum iron and manganese concentrations were observed in leaves (Fig. 1). While, the lowest iron concentration measured in pod and manganese concentrations was observed in stem. With increases in soybean old and reach to full maturity stage, the zinc, iron, and manganese content in tissue plant were decreased Fig. 1, 2, and 3. This finding agrees with previous study [20]. Admittedly, there is a negative correlation between plant age and trace element concentration in tissue plant, and the lowest element content were obtained at harvest time. Therefore, in our experiment the highest and lowest element concentration in different parts of plant was achieved in R1 and R8 growth stages, respectively. The results of this study shown that using iron fertilizer up to 25 $kg.ha^{-1}$ had major effect on seed Fe concentration (Fig. 4). Moderate fertilizers application has not antagonistic effects on micronutrients distribution in plant organs. Hence, Zinc, iron, and manganese fertilizers application in the moderated ratio had not negative impact on absorption, transfer, and distribution of the metals. But, in excess amount and high soil concentration of these elements could significantly reduce concentration of other elements in seed (Fig. 5). Seed [Fe] and [Mn] were not affected by 20 $kg.ha^{-1}$ zinc application, but these values were reduced by excess amount up to 40 $kg.ha^{-1}$ zinc. In addition, seed [Zn] reduced by iron application, slightly. Previous studies indicated that iron used in little amount, amended absorption and transfer of manganese in soybean seed [23]. The results of zinc, iron and manganese fertilizers application on [Zn]/[Fe], [Zn]/[Mn], and [Fe]/[Mn] ratios in soybean seed are shown in Fig. 6. The results indicated that with zinc application, [Zn]/[Fe] and [Zn]/[Mn] ratios in seed increased, severely. While, Fe fertilizer application was caused that [Zn]/[Fe] ratio reduced, but [Zn]/[Mn] ratio unaffected by iron application. Also, the similar results were obtained in [Fe]/[Mn] ratio with zinc used and [Zn]/[Fe] ratio with manganese application. [Fe]/[Mn] ratio less than 0.4 in soybean shoot is index for imbalance and considered as a genotype tolerant to Fe chlorosis [11]. As could be expected, manganese fertilizer application reduce [Zn]/[Mn] and [Fe]/[Mn] ratios in seed (Fig. 6). In this study, the highest [Zn]/[Mn] ratio was observed in check treatment (0 kg.ha^{-1} Mn).

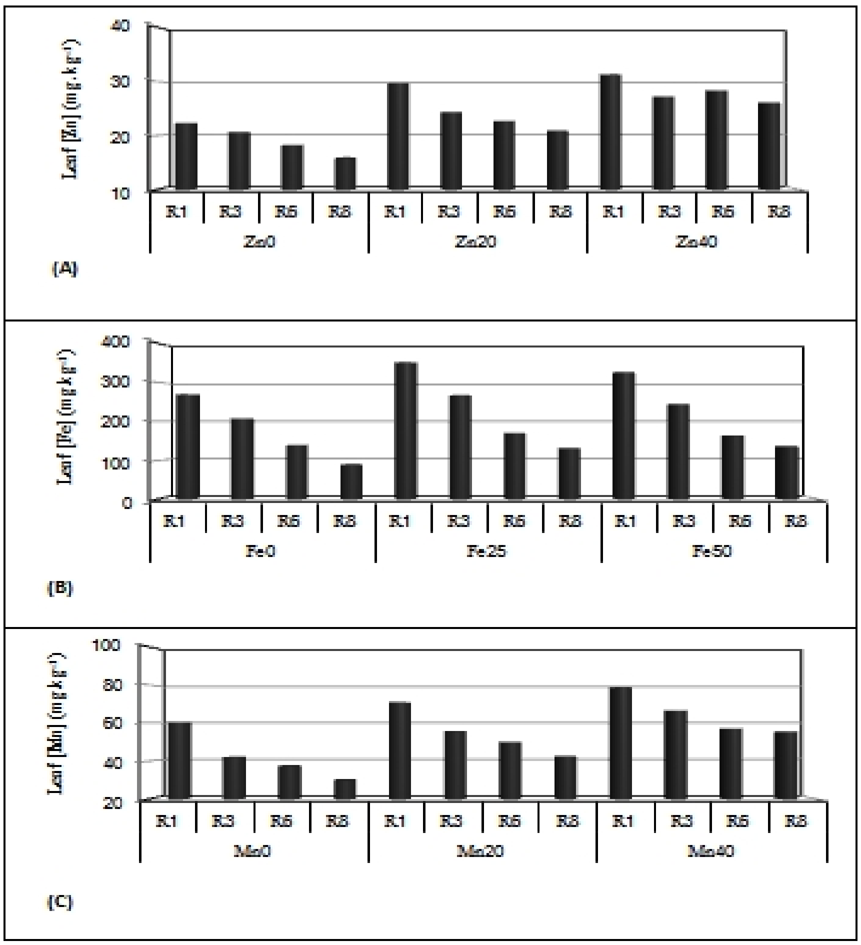

Fig. 1. The effects of Zinc, Iron, and Manganese fertilizers application on (A) [Zn], (B) [Fe], and (C) [Mn] in leaf at R1-R8 growth stages of soybean

- R1: early of flowering, R3: early of pod set, R6: effective filling period, and R8: full maturity.

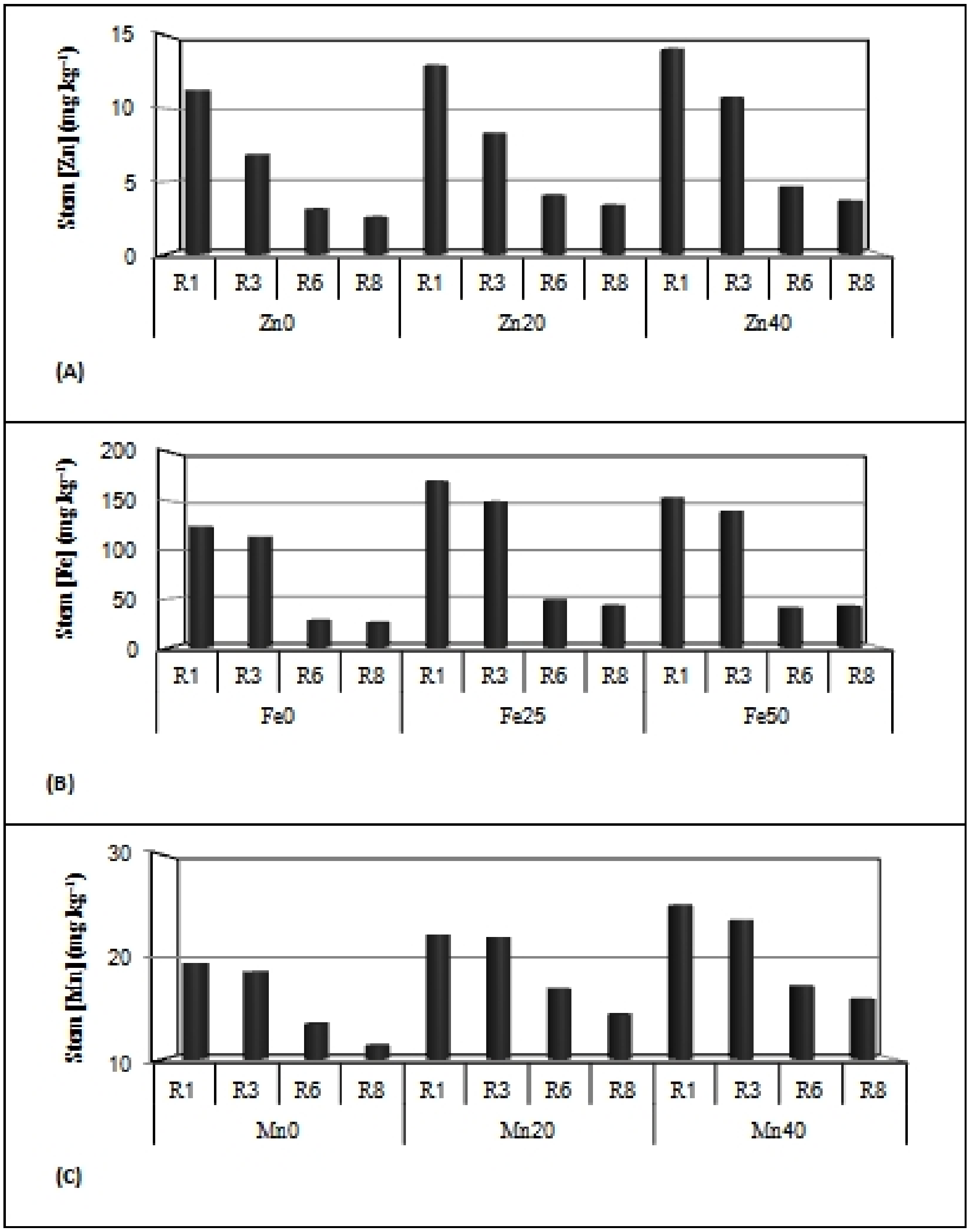

Fig. 2. The effects of Zinc, Iron, and Manganese fertilizers application on (A) [Zn], (B) [Fe], and (C) [Mn] in stem at R1-R8 growth stages of soybean

- R1: early of flowering, R3: early of pod set, R6: effective filling period, and R8: full maturity.

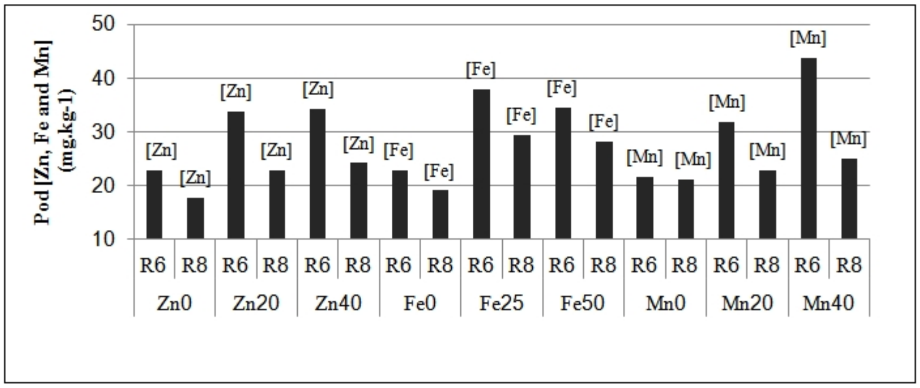

Fig. 3. Zn, Fe, and Mn concentration in pod affected by zinc, iron and manganese fertilizer application at R6 and R8 growth stages of soybean - R6: effective filling period and R8: full maturity

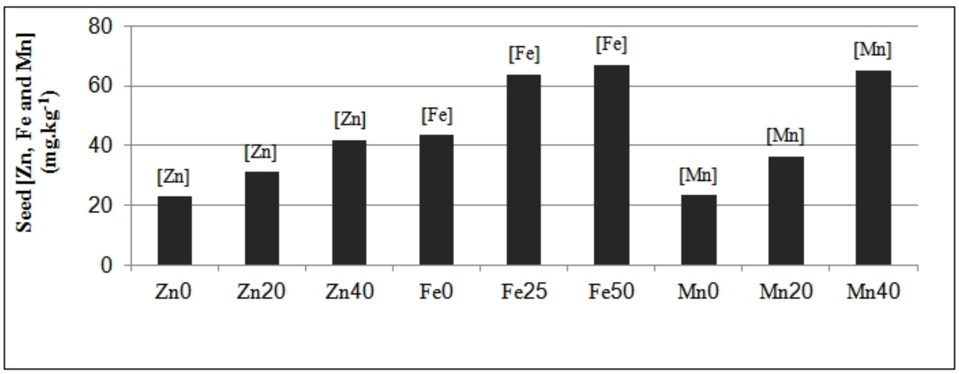

Fig. 4. The effects of Zinc, iron, and manganese fertilizer applications on concentration of these elements in soybean seed

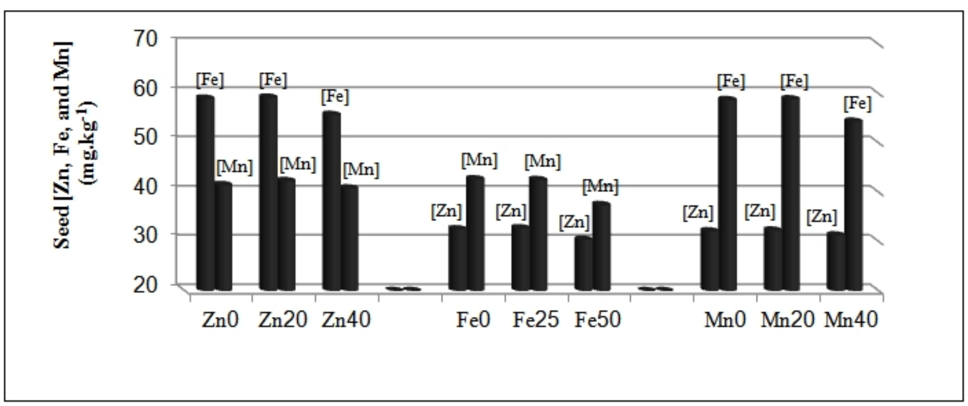

Fig. 5. Interaction effects of zinc, iron and manganese fertilizer applications on Zn, Fe, and Mn concentration in soybean seed

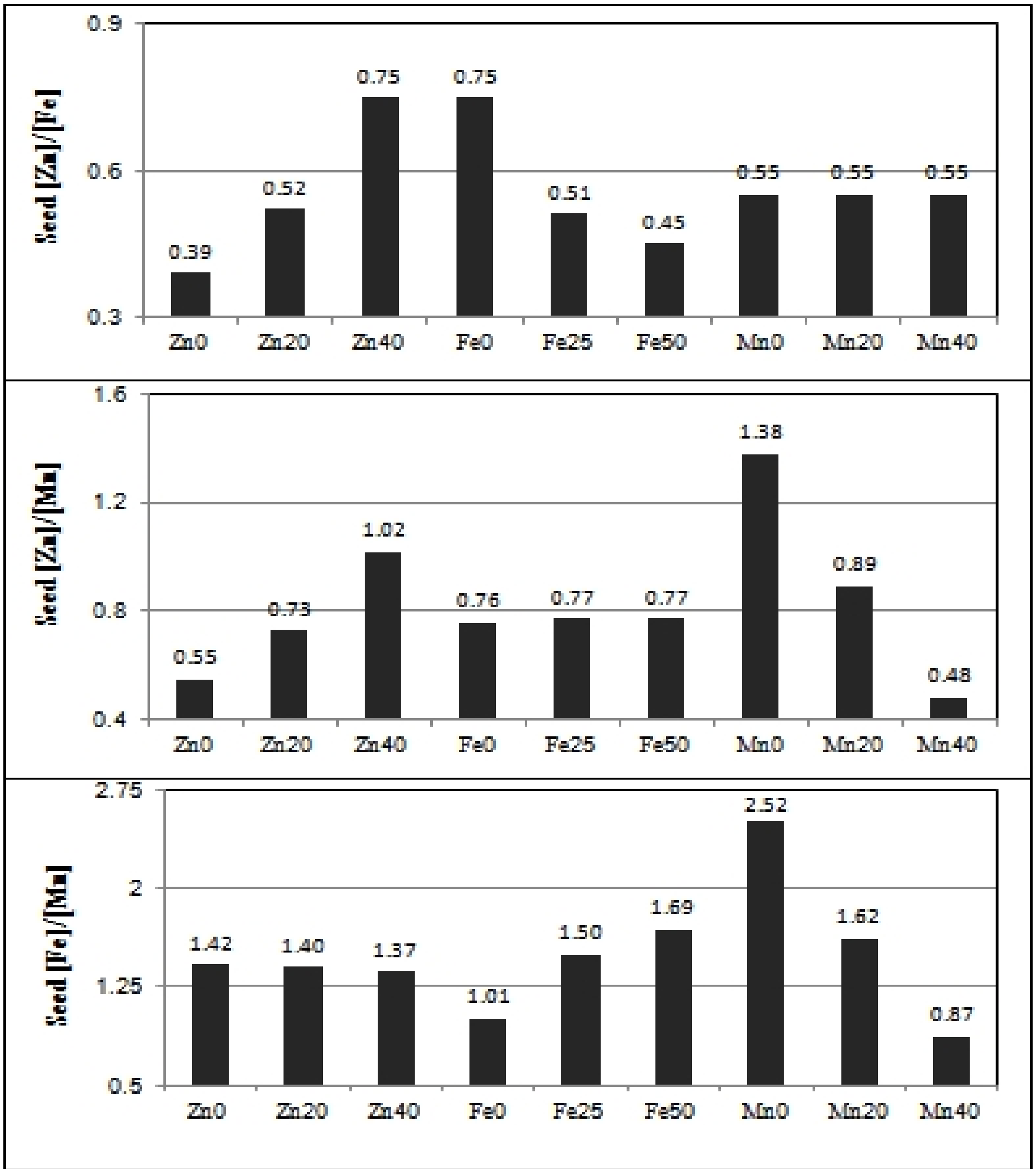

Fig. 6. Effects of Zinc, Iron, and Manganese fertilizer applications on [Zn], [Fe], and [Mn] ratios in soybean seed

4. CONCLUSION

Ratios of Zn, Fe, and Mn are considered as impression rates of fertilization on uptake, transfer and distribution of micronutrients in plant organs. In this experiment, these ratios were responding to micronutrient treatments. Also, some Antagonistic effects between zinc, iron and manganese were observed, clearly. Finally, adequate supplies of the micronutrients will have favorable effects on soybean quality and growth.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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