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Some of Micronutrients Homeostasis in Soybean

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ABSTRACT

In order to investigation interaction effects of zinc, iron and manganese and their ratios in different organs at reproductive growth stages in soybean (*Glycine max* L.), two experiments were conducted as factorial based on randomized complete block design in three replications in Kermanshah, Iran at 2009-2010. For 2 years, three levels of zinc (Zn_0, Zn_{20} and zn_{40} as $ZnSO_4$), iron (Fe_0, Fe_{25} and Fe_{50} as $FeSO_4$) and manganese (Mn_0, Mn_{20} and Mn_{40} as $MnSO_4$) were applied. Zinc fertilization increased whole-plant [Zn]:[Fe] and [Zn]:[Mn] ratios in all of reproductive growth stages, but [fe]:[Mn] ratio in leaf at R_1, R_6, and R_8 was decreased. Iron application up to 25kgha^{-1} was caused that [Zn]:[Fe] ratio in leaf and stem decreased and with excess rate this ratio was not affected, significantly. Whole-plant [Zn]:[Fe] ratio was not affected by Manganese application. Also, manganese fertilization was decreased [Zn]:[Mn] ratio in whole-plant and all of reproductive growth stages. In addition, leaf, stem, pod and grain [Fe] affected by manganese application, significantly.
KEY WORDS: Homeostasis, interaction effects, soybean, micronutrient concentration, fertilization.

INTRODUCTION

Concerning of soybean, developed seeds are final destination for the micronutrients that absorbed by the roots and transported via vascular systems. Micronutrients concentration in different organs or tissues of plant is dissimilated and related to growth stage of plant, micronutrient mobility and availability of micronutrient in soil. One of the most important factors that determined micronutrient distribution in plant is mobility of micronutrient within phloem pathway and designated their remobilization from the vegetative tissues to reproductive organs [1]. [2] Stated that micronutrients can be transferred from the root, stem, leaf and pod walls into developing seeds or fruits. They also emphasized that future research should be focus on role of vegetative organs in supplying micronutrients and their translocation mechanisms during growth stages of plants. Previous study indicated that the role each of plant part in micronutrient remobilization is differs widely that depended to micronutrient application forms [3, 4, 5, 6, 7], environmental conditions [8, 9, 10, 11] and kind of crops [12, 13, 14, 15]. Bulk flow causes that phloem sap and soluble substances moves from the leaf, stem and pod walls as a source to seeds as a sink [16]. 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 is a little concentration of micronutrients in phloem. Therefore, their passing with other soluble substances such as macronutrients (K^+ and Cl^-) and/or carbohydrate [17]. The efficiency of redistribution differs greatly between micronutrients and for Zn, Fe and Mn about 59-90% ranged [18] that depended to the mobility of element. Micronutrients such as Zn, Fe and Mn are essential for plant growth and development, but excess amount of these metals can exert toxicity to plant cells. The ranges between deficient and toxic levels of micronutrients are narrow; in addition there are the interaction, antagonistic and synergistic effects among elements in soil and plant. In this experiment focused on the interaction effects of zinc, iron and manganese and their ratios in different organs at reproductive growth stages in soybean.

MATERIALS AND METHODS

Micronutrients concentration in plant organs affected by different levels of zinc, iron and manganese fertilization were tested by growing soybean (cv.Williams *Glycine max* MG III) in field conditions at the Islamic Azad University of Kermanshah, Iran ($34^0 23'$ N, $47^0 8'$ E; 1351 m elevation) for 2 years 2009 and 2010. Before planting, soil samples were collected from experimental area at 0-30 cm depth. The soil texture was silty clay with pH 7.3, electrical conductivity 0.57dSm^{-1}, total organic matter 2.5%, total nitrogen 0.21%, available phosphorus 10.2ppm, available potassium 534ppm, zinc, iron and manganese 0.82, 6.5 and 3.8mg.kg^{-1}, respectively for 2009; and pH 7.6, electrical conductivity 0.61dSm^{-1}, total organic matter 2.3%, total nitrogen 0.18%, available phosphorus 9.9ppm, available potassium 563ppm, zinc, iron and manganese 0.71, 6.2 and 4.3mg.kg^{-1}, respectively for 2010. The experimental design was a factorial experiment based on Randomized Complete Block with three replicates. Soybean seed was inoculated with *Bradyrhizobium japonicum*. Before planting, fertilizers were used as follows: 200kg P_2O_5/ha and 50kgN/ha and mixed with soil and land was ploughed once and harrowed twice. The plots consisted of six rows, 5 m in length spacing 60 cm apart. The distance between plants within a row was 5 cm and plant density achieved by

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over planting and thinning at V_3 stage. 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, 20, 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. During the growing season, at R_1, R_3, R_6 and R_8 growth stages [19], five plants were selected from each plot, randomly. To measure concentration of elements in leaf (leaves on the most top trifoliate of the plants were used), stem, pod and seed. For the micronutrients determination, Samples (leaves, stems, pods, and seeds) washed with distilled water and were dried in the oven at 70^{0c} for 48 hours, weighed, and incinerated at 550^{0C}. Dry ash samples were soluble in concentrated HNO_3 and $HCLO_4$. Zn, Fe and Mn contents were determined by Atomic Absorption Spectrometry (AAS) according to [20].

RESULTS AND DISCUSSION

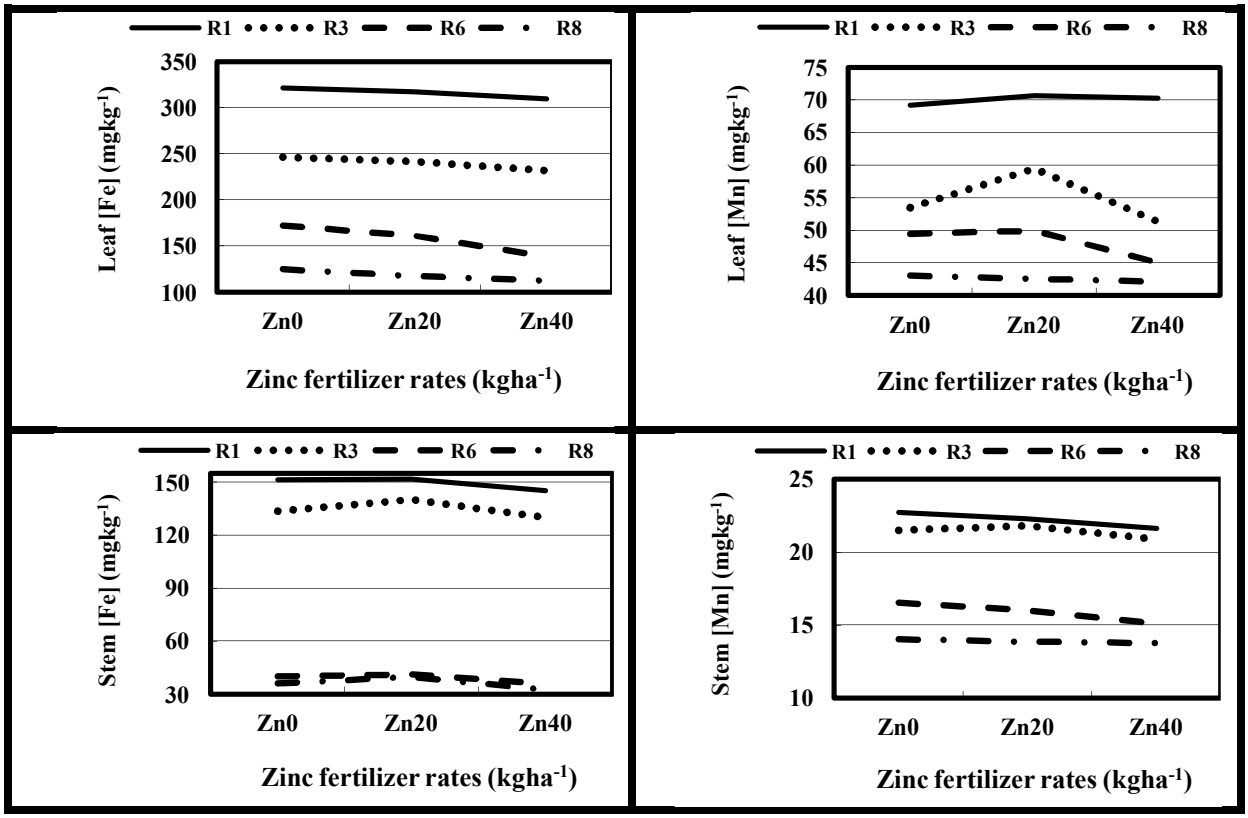
Table1. Zinc, Iron and Manganese ratios in different parts at reproductive growth stages

	Ratio	Leaf				Stem				Pod		Seed
Fertilizer		R_1	R_3	R_6	R_8	R_1	R_3	R_6	R_8	R_6	R_8	R_8
Zn_0	[Zn]/[Fe]	0.01	0.08	0.11	0.13	0.07	0.05	0.08	0.07	0.72	0.69	0.39
	[Zn]/[Mn]	0.32	0.39	0.37	0.37	0.50	0.32	0.19	0.18	0.72	0.76	0.55
	[Fe]/[Mn]	4.64	4.62	3.49	2.89	6.66	6.21	2.43	2.57	0.99	1.09	1.42
Zn_{20}	[Zn]/[Fe]	0.09	0.10	0.14	0.18	0.09	0.06	0.10	0.08	1.05	0.87	0.52
	[Zn]/[Mn]	0.42	0.41	0.45	0.49	0.58	0.38	0.25	0.24	1.02	1.00	0.73
	[Fe]/[Mn]	4.49	4.06	3.23	2.76	6.80	6.42	2.58	2.86	0.97	1.15	1.40
Zn_{40}	[Zn]/[Fe]	0.10	0.12	0.20	0.23	0.10	0.08	0.13	0.11	1.09	0.97	0.75
	[Zn]/[Mn]	0.45	0.53	0.63	0.62	0.65	0.52	0.31	0.27	1.05	1.06	1.02
	[Fe]/[Mn]	4.40	4.51	3.07	2.67	6.71	6.21	2.37	2.51	0.97	1.09	1.37
Fe_0	[Zn]/[Fe]	0.11	0.12	0.17	0.24	0.11	0.08	0.16	0.13	1.37	1.18	0.75
	[Zn]/[Mn]	0.38	0.42	0.46	0.48	0.54	0.40	0.27	0.24	0.93	1.09	0.76
	[Fe]/[Mn]	3.57	3.43	2.74	1.96	5.00	4.91	1.74	1.78	0.68	0.93	1.01
Fe_{25}	[Zn]/[Fe]	0.08	0.09	0.14	0.16	0.07	0.06	0.08	0.08	0.80	0.76	0.51
	[Zn]/[Mn]	0.41	0.44	0.46	0.50	0.59	0.40	0.25	0.23	0.92	0.86	0.77
	[Fe]/[Mn]	5.10	4.82	3.35	3.05	7.96	6.87	3.02	3.04	1.15	1.14	1.50
Fe_{50}	[Zn]/[Fe]	0.08	0.09	0.14	0.15	0.08	0.06	0.08	0.07	0.84	0.71	0.45
	[Zn]/[Mn]	0.40	0.46	0.51	0.50	0.61	0.42	0.22	0.22	0.95	0.89	0.77
	[Fe]/[Mn]	4.96	5.07	3.80	3.39	7.53	7.27	2.62	3.16	1.13	1.26	1.69
Mn_0	[Zn]/[Fe]	0.09	0.09	0.14	0.17	0.08	0.06	0.09	0.08	0.91	0.83	0.55
	[Zn]/[Mn]	0.48	0.57	0.62	0.69	0.65	0.48	0.29	0.27	1.41	1.03	1.38
	[Fe]/[Mn]	5.48	6.05	4.27	4.02	8.23	7.74	3.06	3.36	1.54	1.25	2.52
Mn_{20}	[Zn]/[Fe]	0.09	0.10	0.14	0.17	0.09	0.07	0.11	0.09	0.96	0.84	0.55
	[Zn]/[Mn]	0.40	0.44	0.47	0.50	0.59	0.41	0.24	0.23	0.97	0.95	0.89
	[Fe]/[Mn]	4.51	4.37	3.31	2.93	6.80	6.08	2.31	2.58	1.01	1.14	1.62
Mn_{40}	[Zn]/[Fe]	0.09	0.11	0.15	0.19	0.09	0.06	0.10	0.09	0.99	0.87	0.55
	[Zn]/[Mn]	0.33	0.35	0.39	0.37	0.51	0.34	0.22	0.19	0.68	0.84	0.48
	[Fe]/[Mn]	3.77	0.34	2.57	1.98	5.49	5.32	2.14	2.19	0.68	0.97	0.87

-R_1: early of flowering, R_3: early of pod set, R_6: effective filling period and R_8: full maturity

Adequate supplies of Zinc, Iron and Manganese to plants have been shown to be crucial obtaining high yield, quality and growth [21, 22, 23, 24]. To investigate the interactive influence of Zn, Fe and Mn on micronutrient concentration in soybean organs we calculated the ratios of these elements in soybean. These ratios are considered as impression rates of fertilization on uptake, transfer and distribution of micronutrients in plant organs. The effects of different levels of zinc, iron and manganese on [Zn]:[Fe], [Zn]:[Mn] and [Fe]:[Mn] ratios in leaf, stem, pod and seed at reproductive growth stages in soybean are shown in Table 1. These ratios responses to micronutrients treatments, therefore, with zinc application, [Zn]:[Fe] and [Zn]:[Mn] ratios in leaf, stem, pod and seed at R_1 to R_8 increasing compared with check treatment. Zinc fertilization has resulted in increased whole-plant [Zn]: [Fe] and [Zn]: [Mn] ratios in all of reproductive growth stages. In contrast, with zinc fertilization [fe]: [Mn] ratio in leaf at R_1, R_6, and R_8 was decreased. In stem, pod and seed the results was difference and zinc application up to 20 kgha^{-1} was tended increased [Fe]: [Mn] ratio in these organs and with excessive application decreased, slightly. It is important to note that with increases soybean old and reach to maturity stage (R_8), [Zn]:[Fe] and [Zn]:[Mn] ratios in pod are more compared with leaf and stem. Indeed, zinc is transferred from the leaf and stem to pod when that coincidence to increase soybean old because finally destination of elements are grains. This finding agrees with previous study [25, 26]. In contrast, means of [Fe]:[Mn] ratio in leaf and stem more than pod and grain. May be, increasing Fe and Mn in pod occurred commensurately. Based on results obtained, iron application up to 25kgha^{-1} was caused that [Zn]:[Fe] ratio in leaf and stem decreased and with excess rate this ratio was not affected, significantly. In this study, the highest [Zn]:[Fe] ratio in pod was observed in check treatment (1.37) at R_6 stage compared 25 and 50 kgha^{-1} Fe with (0.80 and 0.84), respectively. Also, the similar results were observed at R8 and soybean seed. The highest amd lowest [Zn]:[Mn] ratio belonged to pod and stem, respectively. In soybean [Fe]: [Mn] ratio less than 0.4 in shoot is index for imbalance and considered as a genotype tolerant to

Fe chlorosis [27]. According to results, [Fe]:[Mn] ratio ranged between 0.68 in pod at R_6 and 8.23 in stem at R_1 stage. In the other hand, the highest and lowest of this ratio was observed in stem and pod, respectively (Table 1). Whole-plant [Zn]:[Fe] ratio was not affected by Manganese application, significantly. Also, manganese fertilization was caused that [Zn]:[Mn] ratio decreased sharply in whole-plant at all of reproductive stages. The similar results was observed concerning [Fe]:[Mn] ratio. In previous study we shown that in soybean with reach to maturity stage (R_8), the tissues micronutrients concentration were decreased [28]. The effects of zinc fertilization on iron and manganese concentration in soybean organs at reproductive stages were presented in Figure 1. Zinc application was tended decreases leaf [Fe] at reproductive stages. Indeed, the highest leaf Fe levels were in the check zinc treatment. Stem and pod [Fe] at R_6 stage and stem [Fe] at R_6 and R_8 stages were affected by zinc fertilization, slightly (Fig 1). At R_3 stage stem [Fe] elevated up to 59.49 mg. kg^{-1} (data not shown). Grain [Fe] and [Mn] was not affected by 20 $kgha^{-1}$ zinc application, but these values were significantly reduced by excess amount up to 40 $kgha^{-1}$ zinc. [29] Reported that zinc application might be prevented from the uptake and transfer Fe in shoots and fruit. The results was shown that R_3 and R_6 growth stages of soybean more sensitive to zinc application and 20$kgha^{-1}$ zinc was caused leaf [Mn] increased and with excess expending remarkably reduced (Fig 1). The other growth stages having little or no changes [Mn] by zinc application. Influences of iron application on zinc and manganese concentration were observed in Figure 2. Leaf, stem, pod and grain [Zn] reduced by iron application at different growth stages. High concentration of iron is a preventer for absorbs and transfers of zinc [30]. In addition, iron fertilizer reduces leaf, stem and grain [Mn] at reproductive growth stages, but iron application up to 25 $kgha^{-1}$ tended that pod [Mn] increases and then with excess amount was reduces. Indeed, elevating pod [Mn] achieved at less iron concentrations. Iron used in little amount, amended absorption and transfer of manganese in plant [31]. Except of leaf [Zn] at R_1 stage, manganese fertilization had a little effect on [Zn] in different parts of soybean (Fig 3). Nevertheless, leaf, stem, pod and grain [Fe] affected by manganese application, significantly. Concentration of iron reduces with manganese application (Fig 3). Antagonistic effects of iron and manganese that emphasized on in previous studies [32, 33] was observed in this experiment, clearly.



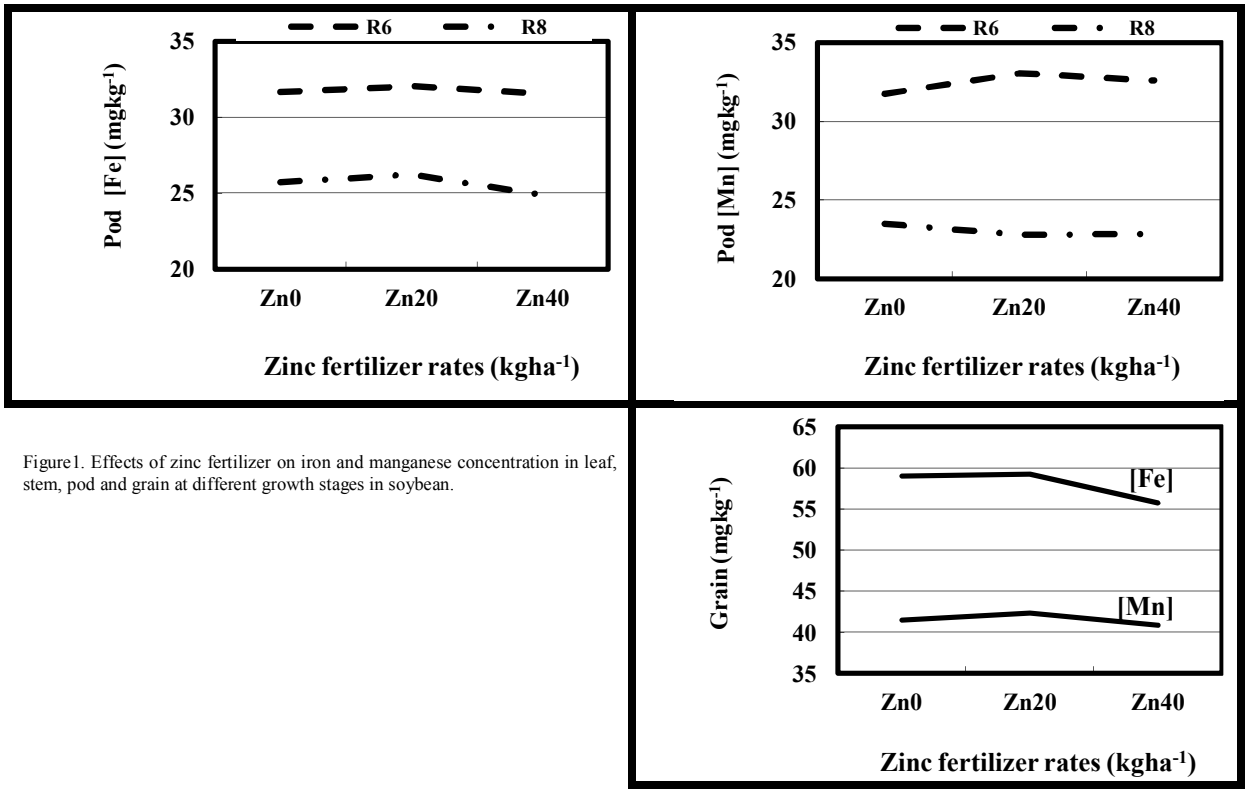
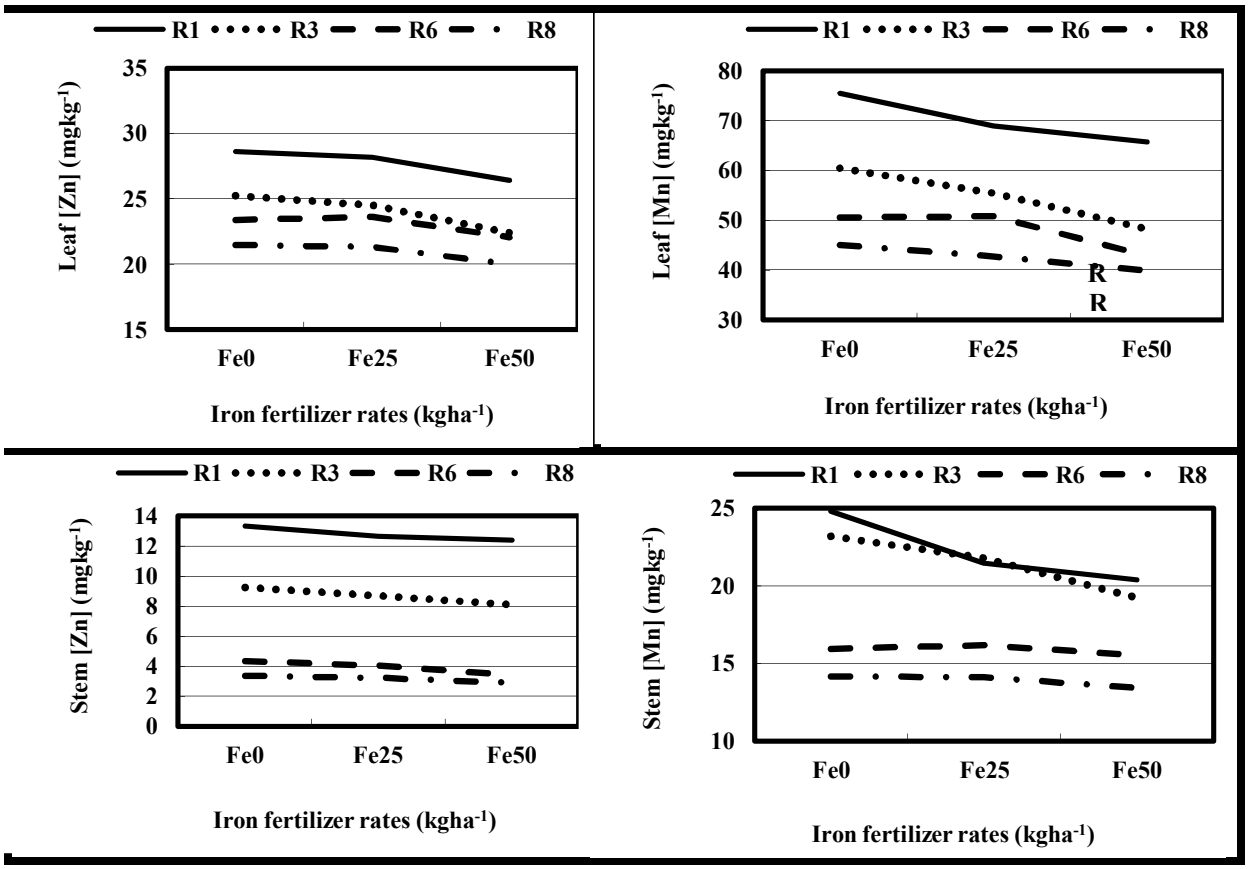


Figure1. Effects of zinc fertilizer on iron and manganese concentration in leaf, stem, pod and grain at different growth stages in soybean.



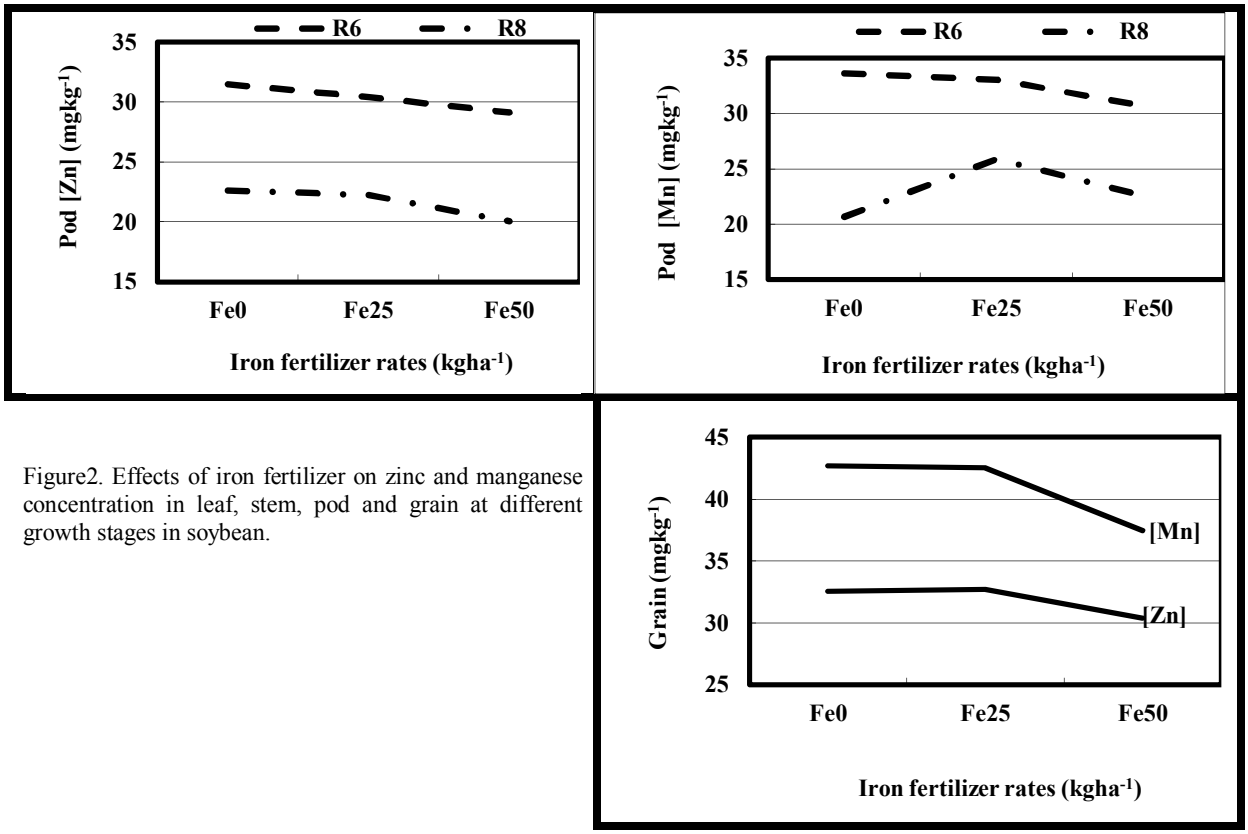
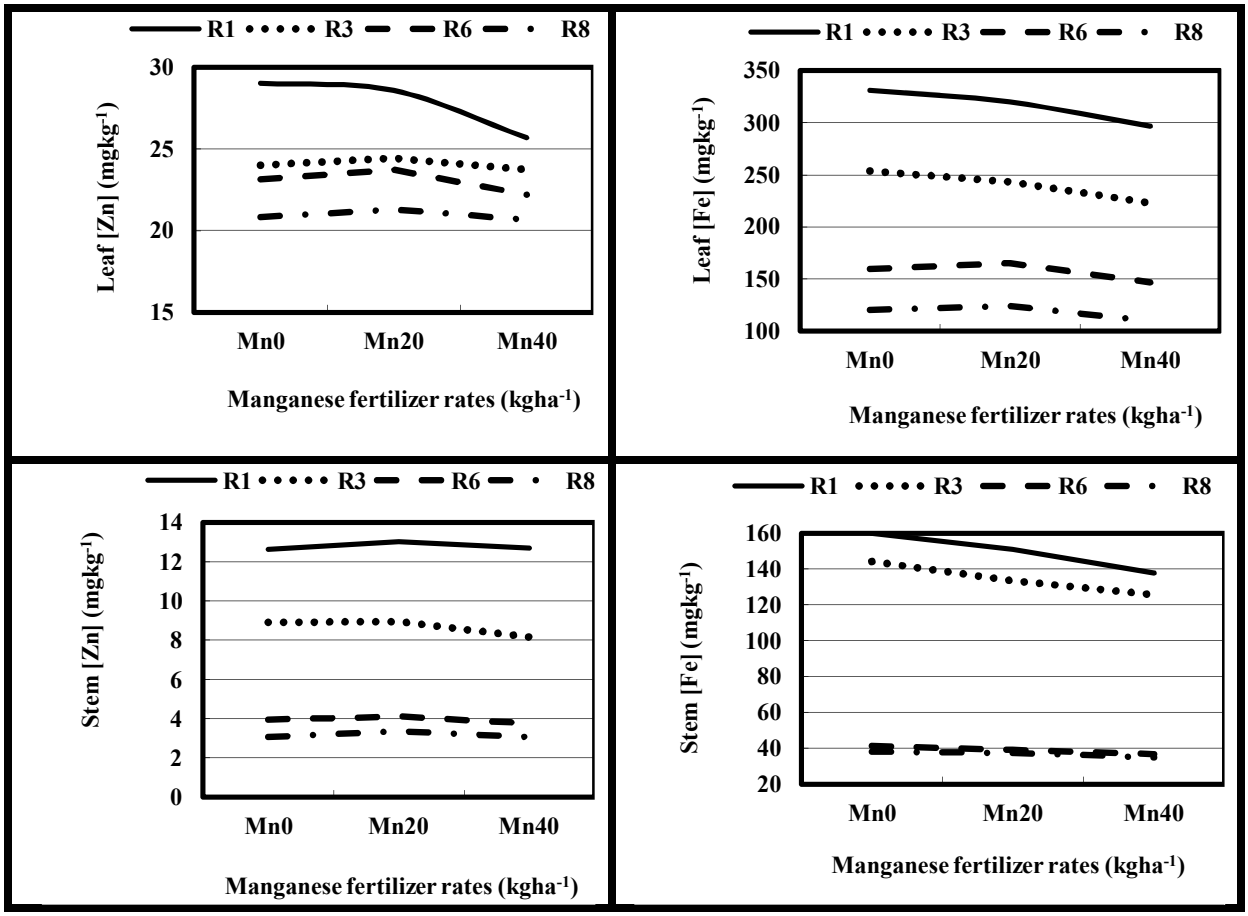


Figure2. Effects of iron fertilizer on zinc and manganese concentration in leaf, stem, pod and grain at different growth stages in soybean.



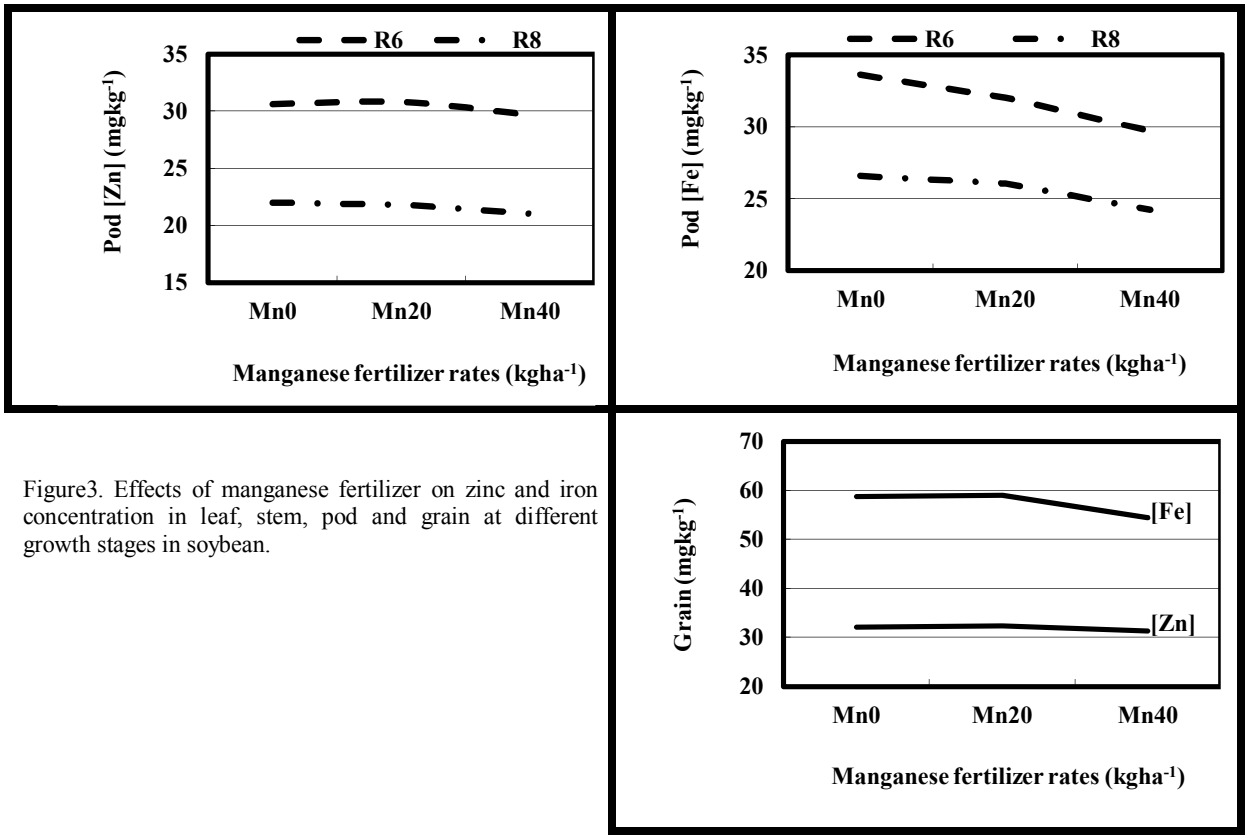


Figure3. Effects of manganese fertilizer on zinc and iron concentration in leaf, stem, pod and grain at different growth stages in soybean.

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