Effects of micronutrient application on the absorption of macro- and micronutrients in soybean

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Abstract: An experiment using the completely randomized design with four treatments and four replications was conducted in Dasht-e-Naz in Sari (in the province of Mazandaran) in 2010 to study the effects of the application of the micronutrients zinc, manganese, and boron on the solubility and absorption of macro- and micronutrients in soybean. Results of this study showed that the application of the micronutrients zinc, manganese, and boron caused an increase in the concentration of these micronutrients in the leaves of soybean at full bloom and at seed maturity. Results of the comparison of the means indicated that the highest concentrations of nitrogen (4.614 %), phosphorous (0.116 %), potassium (1.637 %), zinc (88.5 ppm), manganese (116.4 ppm), and boron (79.08 ppm) in the leaves of soybean were obtained when manganese, boron, boron, zinc, manganese, and boron were applied, respectively. These results, regarding seeds, also showed that the greatest concentrations of nitrogen (6.57%), phosphorous (0.177%), potassium (0.926%), and zinc (52.5ppm) in the seeds of soybean were observed when manganese, boron, manganese (added to the soil), and zinc (added to the soil) were applied, respectively; they also indicated that the highest manganese and boron concentrations in soybean seeds, 23.08 and 46.58 ppm, respectively, were achieved when manganese was added to the soil and when boron was used. These results suggested that using micronutrients like zinc, manganese, and boron, caused an increase in the absorption and concentration of macronutrients such as nitrogen, phosphorous, and potassium in the leaves and seeds of soybean. The greatest mobility and absorption of nitrogen was observed when manganese was applied. Results also pointed out that application of boron increased the mobility and absorption of phosphorous and potassium.

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1. Introduction

The optimum application of plant nutrients has a significant role in increasing the yield and the quality of crop plants. Micronutrient deficiencies are of worldwide spread. Continuous cropping, excessive use of phosphorous fertilizers, calcareous soils, and the fact that micronutrient-containing and organic fertilizers are not applied, are among the factors bringing about micronutrient deficiencies in the soils of Iran (Malakouti and Tehrani, 1999). Iran, despite having the potential to produce oil crops, unfortunately, is still one of the main importers of edible oil crops, and about 85% of the edible oil consumed in the country is imported from abroad. Soybean is one of the important oil crops and enjoys a very prominent position in oil and protein production, because it produces a very high quality oil and a very good plant protein. The province of Mazandaran, because of its very suitable climate for soybean production, enjoys a special position among the provinces in Iran. One of the most important factors for increasing oil crop production, including soybean, is optimal fertilization and a balanced use of plant nutrients. However, Zinc deficiency is a problem in most calcareous soils, because clays and carbonates strongly absorb Zn^{2+} and/or $Zn(OH)^{+}$ (Haghparast Tanha, 1992). Many researchers (including Sadri and Malakouti, 1998; Balali et al., 1999; Majidi et al., 1999) have proved the beneficial effects of applying micronutrients on the quantitative and qualitative features of the crop plants in Iran. Zinc deficiency is one of the most important and widespread micronutrient deficiencies in the world, and it causes a reduction in crop yield (Graham et al., 1992; Cakmak, 2000). Zinc deficiency is common in soils high in pH and rich in calcium carbonate. Zinc application, besides increasing the growth of roots and shoots and seed yield, increases the transfer of zinc to the seeds of the oil crop (Nasseri, 1991). Grewel et al.,(1999) acknowledged that incorporating zinc in the subsoil increased zinc content in seeds, roots, and stubble. Boron deficiency is observed in sandy and strongly calcareous soils, because there is a mutual influence between the calcium ion and the boron found in the soil and, therefore, if there is a lot of calcium in a soil which has a high pH, boron absorption will be reduced (Malakouti and Nafissi, 1992). Boron is one of the necessary micronutrients for plants, and its deficiency rapidly decreases and stops growth (Hu and Brown, 1997). Soybean is sensitive to boron deficiency, and boron is very effective in increasing soybean oil content (Mekki et al., 2005). Boron has a very important role in vital plant functions, including cell division of meristem tissues, flower and leaf bud formation, repair of vascular tissues, sugar and carbohydrate metabolism and their transport, seed germination, and seed formation (Manshcner, 1995).

Soybean is very sensitive to manganese deficiency, which is common in neutral or alkali soils having a high pH; and in soils deficient in manganese, soybean plants become short and their leaves turn yellow. Manganese deficiency has a negative effect on the oil content of soybean seeds. Manganese deficiency becomes more pronounced in well-aerated calcareous soils; and to modify it, spraying manganese on the crop and its strip application can be effective (Malakouti and Nafissi, 1992). Manganese has an important role in the enzyme systems involved in auxin synthesis, nitrogen metabolism, CO_2 assimilation, etc (Tisdale, 1990). This research was conducted in Dasht-e-Naz in Sari with the purpose of studying the effects of applying the micronutrients zinc, boron, and manganese on the absorption of plant nutrients in the leaves and seeds of soybean.

2. Material and Methods

To carry out this research, a piece of land was selected and its physico-chemical features were determined. A soil test was conducted to find out the plant nutrients required for planting the crop, and NPK were incorporated in the soil before seeding. An experiment was conducted using the completely randomized design with four treatments and four replications (i.e., a total of 16 treatments) in the agro-complex of Dasht-e-Naz in 2010. The treatments included the application of the micronutrients zinc, manganese, and boron, which were applied to the soil before seeding in the form of zinc sulphate, manganese sulphate, and boric acid, respectively. In order to investigate the amount of micronutrients absorbed by the crop, leaf samples were taken from all the experimental plots at the flowering stage, and seed samples were taken at the stage of seed maturity. The samples were sent to the soil and water laboratory of the Mazandaran Agriculture and Natural Resources Research Center for analysis and determination of the concentration of the elements.

3. Results

Effects of the Treatments on the Concentration of the Elements in Soybean Leaves

Concentration of Nitrogen in the Leaves

Results of the analysis of the variance of the data showed that the effects of the different levels of the elements added to the soil on the concentration of nitrogen were significant at the 5 percent probability level (Table 1). Results of the comparison of the means indicated that the highest concentration of leaf nitrogen (4.614%) was achieved when manganese was added to the soil, the second highest leaf nitrogen concentration (4.463%) was obtained by adding boron to the soil, and that the lowest leaf nitrogen concentration (4.307%) was that of the control (Table 2 and Diagram1).

Concentration of Phosphorous in the Leaves

Results of the analysis of the variance of the data showed that the effects of different levels of the elements added to the soil on the concentration of phosphorous in the leaves were not significant (Table 1). Results of the comparison of the means indicated that the highest concentration of leaf phosphorous (0.116%) was obtained when boron was added to the soil, the second highest leaf phosphorous (0.113%) was achieved by adding manganese to the soil, and that the lowest leaf phosphorous concentration (0.109%) belonged to the control (Table 2 and Diagram2).

Concentration of Potassium in the Leaves

Results of the analysis of the variance of the data showed that the effects of the different levels of the elements added to the soil on the concentration of potassium were not significant (Table 1). Results of the comparison of the means of the data indicated that the highest leaf potassium concentration (1.637%) was achieved when boron was added to the soil, and that the addition of manganese and zinc came second and third with leaf potassium concentration of 0.89% and 0.805%, respectively. The lowest leaf potassium concentration (0.570%) was that of the control (Table 2 and Diagram 3).

Concentration of Zinc in the Leaves

Results of the analysis of the variance of the data indicated that the effects of the different levels of the elements added to the soil on leaf zinc concentration were significant at the one percent probability level (Table 1). Results of the comparison of the means indicated that the highest leaf zinc concentration (88.5ppm) was obtained when zinc was added to the soil, and that this treatment was statistically different from the others. The treatment of adding manganese to the soil and the control came second and third with 81.67 and 79.67 ppm, respectively. The lowest leaf zinc concentration (75.67ppm) was achieved by adding boron to the soil (Table 2 and Diagram 4).

Concentration of Manganese in the Leaves

Results of the analysis of the variance of the data indicated that the effects of the different levels of the elements added to the soil on leaf manganese concentration were not significant (Table 1). Results of the comparison of the means showed that the highest leaf manganese concentration (116.4%) was achieved by adding manganese to the soil, and that this treatment did not have a statistically significant difference with the others. The treatments of adding boron and zinc to the soil came second and third with 103.7 and 99.25 ppm, respectively. The lowest leaf manganese concentration (71.17ppm) was that of the control (Table 2 and Diagram 5).

Concentration of Boron in the Leaves

Results of the analysis of the variance of the data indicated that the effects of the different levels of elements added to the soil on leaf boron concentration were significant at the one percent probability level (Table 1). Results of the comparison of the means showed that the highest leaf boron concentration was obtained when boron was added to the soil, and that this treatment had a statistically significant difference with the others. In the treatment of adding zinc or manganese to the soil also, the concentration of leaf boron (71.17ppm for zinc and 69.75 ppm for manganese, respectively) was higher than that of the control, which was 53.57 ppm (Table 2 and Diagram 6).

Effects of the Treatments on the Concentration of the Elements in Soybean Seeds

Seed Nitrogen Concentration

Results of the analysis of the variance of the data indicated that the effects of adding the different levels of the elements to the soil on the concentration of seed nitrogen were significant at the 5 percent probability level (Table 3). Results of the comparison of the means showed that the highest seed nitrogen concentration (6.574%) was obtained when manganese was added to the soil, and that this treatment had a statistically significant difference with the others. The treatment of adding boron to the soil came second (with 6.331%), and the lowest seed nitrogen concentration (6.298%) belonged to the control (Table 4).

Seed Phosphorous Concentration

Results of the analysis of the variance of the data showed that the effects of the different levels of the elements added to the soil on seed phosphorous were not significant (Table 3). Results of the comparison of the means indicated that the highest concentration of seed phosphorous (0.177%) was achieved when boron was added to the soil, and that this treatment did not have a statistically significant difference with the others. The treatments of adding zinc and manganese to the soil came second and third, respectively. The lowest seed phosphorous (0.156%) belonged to the control (Table 4).

Seed Potassium Concentration

Results of the analysis of the variance of the data indicated that the effects of the different levels of the elements added to the soil on seed potassium concentration were significant at the level of five percent probability (Table 3). Results of the comparison of the means showed that the highest concentration of seed potassium (0.926 %) was obtained when manganese was added to the soil, and that this treatment did not have a statistically significant difference with the treatment of adding zinc to the soil (in which seed potassium concentration was 0.913%). The lowest seed potassium concentration (0.839%) was observed in the control (Table 4).

Seed Zinc Concentration

Results of the analysis of the variance of the data showed that the effects of adding the different levels of the elements to the soil on the concentration of seed zinc were significant at the level of one percent probability (Table 3). Results of the comparison of the means indicated that the highest concentration of seed zinc (52.5ppm) was obtained when zinc was added to the soil, and that this treatment had a statistically significant difference with the others. The treatments of adding manganese and boron to the soil came second and third with 45.92 and 45.58ppm, respectively. The lowest seed zinc concentration (42.5ppm) was observed in the control (Table 4). Grewel et al. (1999) showed that application of zinc in the subsoil increased the zinc content of the seeds, the roots, and the stubble.

Seed Manganese Concentration

Results of the analysis of the variance of the data indicated that the effects of adding the different levels of the elements to the soil on seed manganese concentration were significant at the level of five percent probability (Table 3). Results of the comparison of the means showed that the highest seed manganese concentration (23.08 ppm) was achieved when manganese was added to the soil, and that this treatment had a statistically significant difference with the others. The treatments of adding boron and zinc to the soil came second and third with 22.5 and 21.75 ppm, respectively. The lowest seed manganese concentration (20.17 ppm) belonged to the control (Table 4). Alley et al. (2008) reported that applying manganese sulphate to the soil and spraying it on the crop increased the absorption of manganese and the seed and oil yield of soybean.

Seed Boron Concentration

Results of the analysis of the variance of the data showed that the effects of adding the different levels of the elements to the soil on seed boron concentration were significant at the level of five percent probability (Table 3). Results of the comparison of the means indicated that the highest seed boron concentration was achieved when boron was added to the soil, and that this treatment had a statistically significant difference with the others. In the treatments of adding zinc and manganese to the soil also, seed boron concentration (36.67 and 36.83 ppm, respectively), showed an increase compared to the control (in which seed boron concentration, 36.5 ppm, was the lowest) (Table 4). This finding was in agreement with the findings of Marschner (1995).

4. Discussion

The results obtained indicated that the application of micronutrients such as zinc, manganese, and boron increased the absorption and concentration of macronutrients, like nitrogen, phosphorous, and potassium in the leaves and seeds of soybean, and also that the greatest mobility and absorption of nitrogen was brought about in the treatment of the application of manganese to the soil, which was statistically different from all the other treatments except the treatment of adding boron to the soil. These results also indicated that the application of boron increased the mobility and absorption of phosphorous and potassium. It was also found out that the application of the micronutrients zinc, manganese, and boron caused an increase in their concentration in soybean leaves at full bloom and at seed maturity. As for seed micronutrient concentration, it was also observed that the highest seed nitrogen concentration (6.57%) was obtained when manganese was added to the soil, and that this treatment had a statistically significant difference with the others. It was also found out that the highest seed phosphorous absorption (0.177%) occurred when boron was applied to the soil, and that manganese application to the soil increased potassium absorption.

Table 1. Analysis of variation of the Nutrients

SOV	Mean Square					
	N	P	K	Zn	Mn	B
R	ns	ns	ns	ns	ns	ns
NBA	*	ns	ns	**	ns	**
CV	1.04	2.04	4.24	1.14	2.27	2.47

* and ** show the least differences at 1 and 5 level of probability respectively and ns shows none significant difference, SOV: Source of Variation, R: Replication, NBA: Nutrient Basal Application, CV: Coefficient Variation.

Table 2- Effects of application of nutrient on concentration of nutrients in soybean leaf.

Trmt	N (%)	P (%)	K (%)	Zn (ppm)	Mn (ppm)	B (ppm)
Control	4.30	0.10	0.57	79.67	71.17	53.75
Zn S	4.44	0.10	0.80	88.50	99.25	71.17
MnS	4.61	0.11	0.89	81.67	116.4	69.75
BS	4.46	0.11	1.63	75.67	103.7	79.08
LSD	0.07	0.54	2.17	1.54	117.7	2.81

ZnS: Zn Soil Application, MnS: Mn Soil Application, BS: Boron Soil Application, LSD: Least Significant Differences.

Table 3- Effects of application of nutrient on concentration of nutrients in soybean seed.

Trmt	N (%)	P (%)	K (%)	Zn (ppm)	Mn (ppm)	B (ppm)
Control	6.29	0.15	0.83	42.50	20.17	36.50
Zn F	6.24	0.16	0.91	52.50	21.75	36.67
MnF	6.57	0.17	0.92	45.92	23.08	36.83
BF	6.33	0.17	0.90	45.58	22.50	46.58
LSD	0.10	0.05	0.01	0.95	0.70	0.64

ZnF: Zn Foliar Application, MnF: Mn Foliar Application, BF: Boron Foliar Application, LSD: Least Significant Differences.

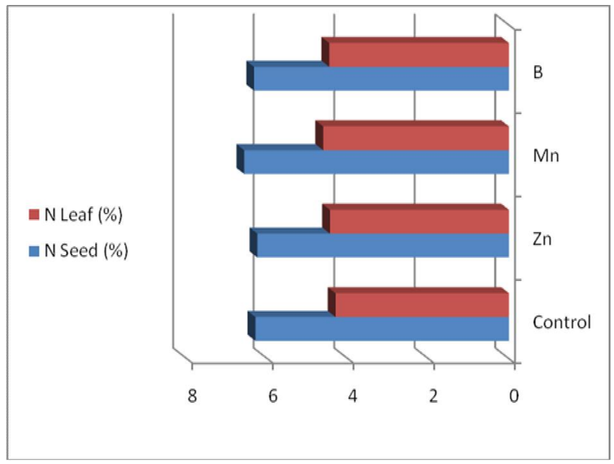

Fig 1-N concentration in leaf and seed

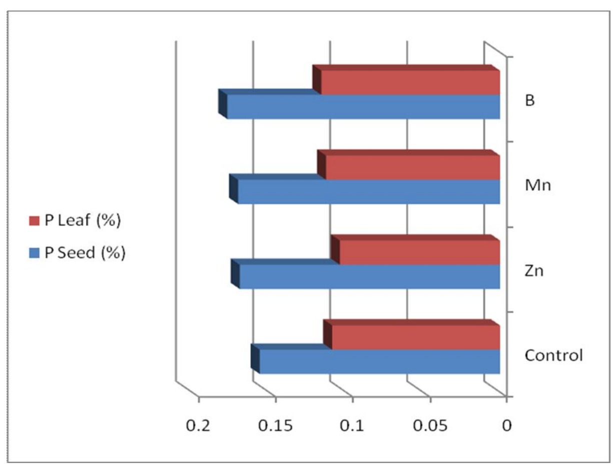

Fig 2-P concentration in leaf and seed

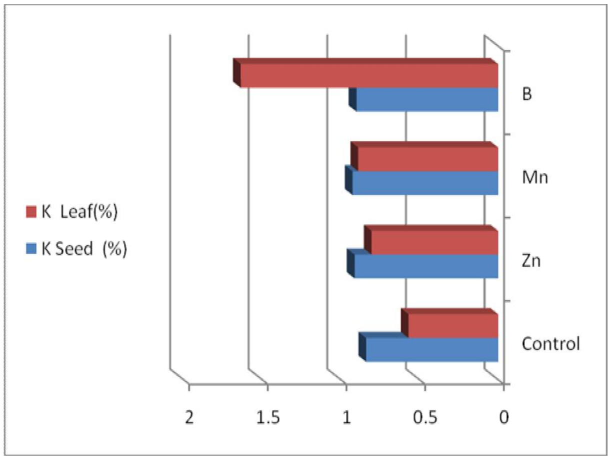

Fig 3-K concentration in leaf and seed

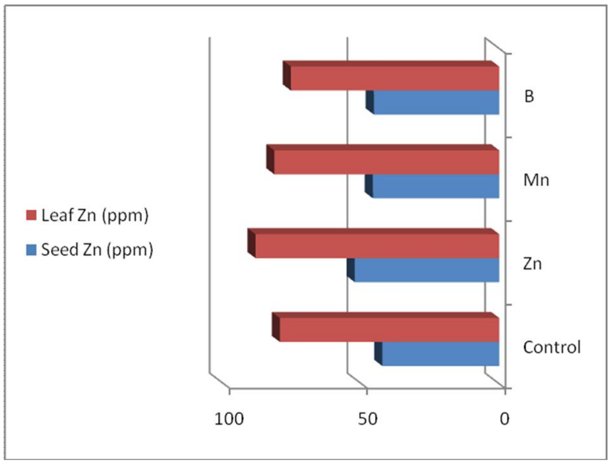

Fig 4-Zn concentration in leaf and seed

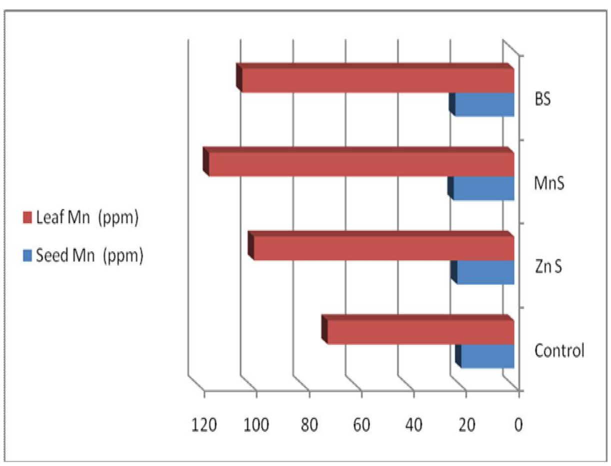

Fig 5-Mn concentration in leaf and seed

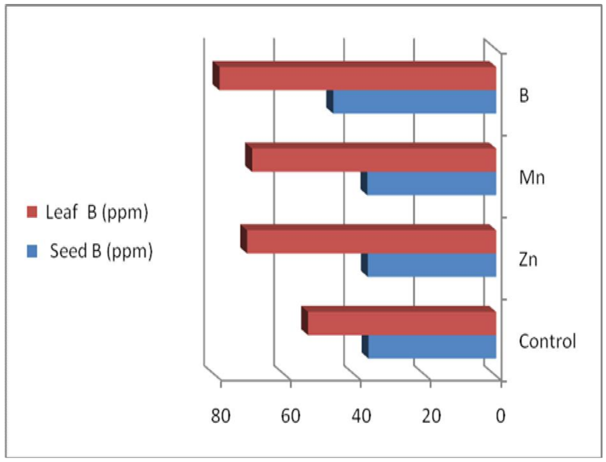

Fig 6-B concentration in leaf and seed

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