Evaluation of the effects of basal and foliar application of Zn, Mn and B on seed yield, yield components of soybean

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Abstract: In order to study the effects of application of zinc, boron, and manganese through spraying them on the crop or by incorporating them in the soil on soybean seed yield and on yield components, an experiment was carried out in Dasht-e-Naz in Sari using the factorial design with 16 treatments and 4 replications in the cropping seasons 2009 to 2010. The treatments were as follows: T1=control; T2= Zns; T3=Mns; T4=Bs; T5=Zns; T6=Zns+Bf; T7=Zns+Mnf; T8=Zns+Znf; T9=Mns; T10=Mns+Bf; T11=Mns+Mnf; T12=Mns+Znf; T13=Bs; T14=Bs+Bf; T15=Bs+Mns; T16=Bs+Znf. Results of means comparison showed that the highest number of pods on the main stem (41.31) was obtained when manganese was incorporated in the soil. Moreover, the maximum number of seeds per pod (2.96) was achieved when zinc was incorporated in the soil. Furthermore, the biggest 1000 seed weight (150.5 g) belonged to the treatment in which zinc was sprayed on the crop. These results also showed that, among the treatments in which the micronutrients were incorporated in the soil, the highest seed yield (152.9 $g.m^{-2}$) was harvested when manganese was incorporated in the soil; and among the treatments in which the micronutrients were sprayed on the crop, the highest seed yield (146.3 $g.m^{-2}$) was obtained when zinc was sprayed on the crop. Results of the mutual effects of the data also showed that the highest seed yield among all the treatments (170.7 $g.m^{-2}$) belonged to the one in which manganese was incorporated in the soil and zinc was sprayed on the crop. Next to this treatment, manganese incorporation in the soil and sprayed on the crop (153 $g.m^{-2}$), and in third place was the treatment in which manganese was incorporated in the soil and boron was sprayed on the crop (149 $g.m^{-2}$). The lowest seed yield was harvested in the control treatment (88 $g.m^{-2}$).

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1. Introduction

Despite the fact that Iran has the potential to produce oil crops, we, unfortunately, are still one of the main importers of oil and oil crops and about 85 percent of our edible oil consumption is imported from abroad. Soybean is a very important oil crop which enjoys a very prominent position in oil and protein production due to the high quality of its oil and because of its very suitable protein. One of the most important factors in increasing the production of oil crops, including soybean, is to provide these crops with optimum and balanced amounts of plant nutrients. Undoubtedly, the optimum use of plant nutrients has a great role in increasing the yield and the quality of soybean and its oil. Micronutrient deficiency is a worldwide phenomenon. Zinc deficiency is one of the most important and widespread micronutrient deficiencies in the world, and it causes reduction in yields of crop plants (Graham et al., 1992; Grewel et al., 1997; Cakmak, 2000). Boron is one of the essential elements for plants and its deficiency rapidly reduces and stops growth (Hu and Brown, 1997). Soybean is sensitive to boron deficiency (Victor et a., 1990) and this micronutrient is very effective in soybean seed formation and in increasing its oil yield (Grant and Baily, 1990; Mekki et al., 2005). Soybean is also very sensitive to manganese deficiency, a condition which often exists in soils with neutral pH and in alkali soils having high pH; and if manganese is deficient, soybean plants become short and their leaves turn yellow. Manganese deficiency has a negative effect on soybean oil yield.

Since soybean is very important in the province of Mazandaran as a main crop or as a second crop planted after wheat and other fall crops are harvested, and because the importance of the use of micronutrients in increasing yield is recognized and we lack comprehensive and thorough information on the effect of the use of micronutrients on the seed and oil yield of common varieties of soybean planted in the province, this study was carried out with the purpose of investigating how soybean seed yield and its components of yield are influenced by the use of the micronutrients zinc, boron, and manganese, and by the way these micronutrients are used (incorporated in the soil or sprayed on the crop).

2. Material and Methods

This study was conducted in Dasht-e-Naz in Sari with the purpose of investigating the effects of using the micronutrients zinc, boron, and manganese, and of comparing how the way they are used (incorporated in the soil or sprayed on the crop) influences the seed yield and the components of yield of soybean. The study was carried out using a factorial experimental design, with the two factors of incorporating the micronutrients zinc, boron, and manganese in the soil and spraying them on the crop, and a total of 16 treatments with 4 replications. The treatments in the experiment were as follows: T1= control; T2= Zns; T3= Mns; T4= Bs; T5= Zns; T6= Zns + Bf; T7= Zns + Mnf; T8= Zns = Znf; T9= Mns; T10= Mns + Bf; T11= Mns + Mnf; T12= Mns + Znf; T13= Bs; T14= Bs = Bf; T15= Bs = Mns; T16= Bs = Znf. First, the physicochemical features of the soils under study were determined. Based on the soil test which had been carried out, the required amounts of nutrients were calculated. The macronutrients NPK were incorporated in the soil before seeding. The amounts of the micronutrients needed were determined in the soil test, and the calculated amounts of zinc (in the form of zinc sulphate) and manganese (in the form of manganese sulphate), and boron (in the form of boric acid) were added to the soil before seeding. In the spray treatments, zinc, manganese, and boron were sprayed in two stages: at the start of stem elongation and again at flower bud formation.

3. Results

The number of pods on the main stem

Results of the analysis of the variance of the data showed that the effects of the different levels of the micronutrients added to the soil (Factor A), the effects of the different levels of the micronutrients sprayed on the crop (Factor B), and the mutual effects of these two factors (AB) on the feature of the number of pods on the main stem were significant at the probability level of one percent (Table 1). Results of the comparison of the means indicated that, among the treatments in which the micronutrients were added to the soil, the highest number of pods on the main stem (41.31) was obtained when manganese was added to the soil. Adding zinc and boron to the soil came second and third with 37.33 and 34.28 pods on the main stem, respectively. These results also suggested that the number of pods on the main stem was lowest (30.72) in the control (Table 2). As for the treatments in which the micronutrients were sprayed on the crop, the results obtained showed that the highest number of pods on the main stem (39.03) belonged to treatment in which zinc was sprayed on the crop, and spraying manganese and boron, with 37.62 and 34.58 pods on the main stem, came second and third, respectively. The lowest number of pods on the main stem (32.4) was obtained in the control (Table 3). Results of the mutual effects of the data also indicated that the highest number of pods on the main stem (45.33) among all the treatments was observed when manganese was added to the soil and zinc was sprayed on the crop. This treatment could not be placed in the same group with any of the other treatments. The treatment in which manganese was added to the soil and it was also sprayed on the crop came second with 42.07 pods on the main stem. The lowest numbers of pods on the main stem (25.73 and 23.3) were observed in the treatments of adding boron to the soil and spraying it on the crop and in the control, respectively (Table 4).

Total Number of Pods per Plant

Results of the analysis of the variance of the data showed that the effects of adding different levels of the micronutrients to the soil (Factor A), and of spraying different levels of them on the crop (Factor B), were significant at the one percent probability level for the feature of the total number of pods per plant, and at five percent for the mutual effects of the two factors (AB) (Table1). Results of the comparison of the means indicated that, among the treatments of adding the micronutrients to the soil, the highest total number of pods per plant (71.05) was obtained when manganese was added to the soil, and that this treatment was statistically in one group with the treatment of adding zinc to the soil (in which treatment the total number of pods per plant was 66.79). After these two, came the treatment of adding boron to the soil and the control, which were statistically in one group, with 57.04 and 55.14 pods per plant, respectively (Table 2). The results obtained also showed that, among the treatments of spraying the micronutrients on the crop, the highest number of pods per plant (68.33) belonged to the treatment of spraying zinc on the crop, with that of spraying manganese on the crop coming second with 65.81 pods per plant. Statistically, these two could be placed in one group. The lowest number of pods per plant (56.64) was observed in the control (Table 3). Results of the mutual effects of the data also indicated that the highest number of pods per plant (77.87) among all the treatments belonged to that of adding manganese to the soil and spraying zinc on the crop. This treatment could statistically be placed in one group with the treatment of adding manganese to the soil and spraying it on the crop (in which the number of pods per plant was 77.87). As with the number of pods on the main stem, the lowest number of pods per plant was obtained in the treatments of adding boron to the soil plus spraying it on the crop and in the control, with 42.77 pods per plant for the boron treatments and 44.43 pods per plant for the control (Table 4).

Number of Seeds per Pod

Results of the analysis of variance of the data showed that the effects of adding different levels of the micronutrients to the soil (Factor A), and spraying them on the crop (Factor B), were significant at the one percent probability level for the feature of the number of seeds per pod, but the mutual effects of these two factors (AB) were not (Table 1). Results of the comparison of the means indicated that, among the treatments of adding the micronutrients to the soil, the highest number of seeds per pod (2.96) was obtained by adding zinc to the soil. Adding manganese to the soil came second with 2.86 seeds per pod. These results also showed the lowest number of seeds per pod was observed when boron was added to the soil, with 2.44 seeds per pod (Table 2). These results also showed that, among the treatments of spraying the micronutrients on the crop, the highest number of seeds per pod (2.91) was observed in spraying zinc on the crop, and spraying with manganese and boron, with 2.89 and 2.62 seeds per pod, respectively, came second and third, while the lowest number of seeds per pod (2.57) belonged to the control (Table3). Results of the mutual effects of the data showed that, among all the treatments, the highest number of seeds per pod (3.22) was seen in the treatment of adding zinc to the soil plus spraying manganese on the crop, and that this treatment, statistically, could be placed in one group with those of adding manganese to the soil plus spraying it on the crop, and adding zinc to the soil plus spraying it on the crop, which resulted in 3.20 and 2.97 seeds per pod, respectively. The lowest number of seeds per pod (2.06) belonged to the control (Table 4).

1000-Seed Weight

Results of the analysis of variance of the data indicated that the effects of the different levels of spraying the micronutrients on the crop (Factor B), and the mutual effects of adding them to the soil plus spraying them on the crop (AB) were significant at the one percent probability level for the feature of the 1000-seed weight, but that the effects of adding them to the soil were not (Table 1). Results of the comparison of the means showed that, among the treatments of adding the micronutrients to the soil, the greatest 1000- seed weight (146.6 g) belonged to the treatment of adding zinc to the soil, while the least 1000-seed weight (145.5 g) was obtained when manganese was applied to the soil (Table 2). Manchester (1995) showed that the use of zinc increases the dry weight, the 1000-seed weight, the seed yield, and the zinc content of seeds of the soybean crop. Among the treatments of spraying the micronutrients on the crop, the results obtained showed that the greatest 1000-seed weight belonged to spraying zinc on the crop (150.5 g), with manganese and the control coming second and third with 147.1 and 144.5 g, respectively, while the least 1000-seed weight (142.9 g) was obtained when boron was sprayed on the crop. Results of the mutual effects of the data also indicated that the greatest 1000-seed weight among the treatments (153 g) belonged to that of spraying zinc on the crop, while those of spraying manganese on the crop, adding zinc to the soil and the combination of adding boron to the soil and spraying it on the crop could bring about the biggest increase in the 1000-seed weight and raise it to above 150 g, and that the least 1000-seed weight was obtained when zinc was added to the soil and boron was sprayed on the crop (139.3 g), or when boron was incorporated in the soil and was also sprayed on the crop (138.3 g) (Table 4). Results of the mutual effects of the data also indicated that, among all the treatments, the greatest 1000-seed weight was obtained by spraying zinc on the crop, while those of spraying manganese on the crop, adding zinc to the soil, and the combination of spraying zinc on the crop and adding boron to the soil could cause the biggest increase in the 1000-seed weight and raise it above 150 g. The least 1000-seed weight was obtained with the combinations of adding zinc to the soil and spraying boron on the crop (139.3 g) and adding boron to the soil and spraying it on the crop (138.3 g) (Table 4).

Seed Yield

Results of the analysis of variance of the data indicated that the effects of the different levels of adding the micronutrients to the soil (Factor A), spraying them on the crop (Factor B), and the mutual effects of these two factors (AB) were significant at the one percent probability level for the feature of the seed yield (Table 1). Results of comparison of the means indicated that, among the treatments of adding the micronutrients to the soil, the highest seed yield (152.9 $g.m^{-2}$) belonged to manganese, with zinc (141.6 $g.m^{-2}$) and boron (122.3 $g.m^{-2}$) coming second and third, while the least seed yield (112.3 $g.m^{-2}$) was seen in the control (Table 2). These results also showed that, among the treatments of spraying the micronutrients on the crop, the highest seed yield belonged to zinc (146.3 $g.m^{-2}$), manganese and boron came second and third with 138.5 and 126.5 $g.m^{-2}$, respectively, and the least seed yield was that of the control (117.7 $g.m^{-2}$) (Table 3). Results of the mutual effects of the data also indicated that the highest seed yield among all the treatments belonged to that of adding manganese to the soil and spraying zinc on the crop (170.7 g.m^{-2}), and that this treatment could not be placed with any other treatment in one group. Similar results have also been reported by other researchers, such as Maftoun and Karimian (1998), Darjeh et al. (1991), and Malakouti (1992). The treatments of adding manganese to the soil and spraying it on the crop, and adding manganese to the soil and spraying boron on the crop, came second and third with 153 and 149 g.m^{-2}, respectively, while the least seed yield (88 g.m^{-2}) belonged to the control (Table 4).

Table 1. Analysis of Variation of the studied traits

SOV	DOF	Mean Square				
		A	B	C	D	E
R	3	ns	ns	ns	ns	ns
F (A)	3	**	**	**	**	*
F (B)	3	**	**	**	**	**
AXB	9	**	**	*	**	**
Error	30	ns	**	ns	ns	ns
CV (%)		7.67	6.38	6.47	6.42	3.6

* and ** show the least differences at 1 and 5 level of probability respectively and ns shows none significant difference, SOV: Source of Variation, DOF: Degree of Freedom,* and ** show the least differences at 1 and 5 level of probability respectively and ns shows none significant difference

A: Seed Yield, B: Pod in main stem, C: Pods per Plant, D: Seed per Pod, E: 1000-seed weight,

F(A): Nutrient Basal Application,

F(B): Nutrient Spray.

Table 2- Comparison of the means of the data related to the addition of zinc, manganese, and boron to the soil on soybean yield and yield components.

Trmt	A (g.m^{-2})	B	C	D	E (g)
Control	112.3	30.72	55.14	2.72	146.3
Zn Soil	141.6	37.33	66.79	2.96	146.6
MnSoil	152.9	41.31	71.05	2.86	145.5
B Soil	122.3	34.28	57.04	2.44	146.3
LSD	5.91	3.31	6.68	0.26	8.76

A: Seed Yield, B: Pod in main stem, C: Pods per Plant, D: Seed per Pod, E: 1000-seed weight.

Table 3- Comparison of the means of the data related to spraying the micronutrients zinc, manganese, and boron on soybean yield and yield components.

Trmt	A (g.m^{-2})	B	C	D	E(g)
Control	117.7	32.40	56.64	2.57	144.5
Zn F	146.3	39.03	68.33	2.91	150.2
MnF	138.5	37.62	65.81	2.89	147.1
B F	126.5	34.58	9.24	2.62	142.9
LSD	5.91	3.31	6.68	0.26	8.76

A: Seed Yield, B: Pod in main stem, C: Pods per Plant, D: Seed per Pod, E: 1000-seed weight.

Table 4- Interaction effects of the addition of zinc, manganese, and boron to the soil to and spraying them on soybean plants.

Trmt	A (g.m^{-2})	B	C	D	E(g)
Control	88.00	23.33	44.43	2.52	134.3
ZnF	126.3	33.40	58.60	2.79	153.0
MnF	116.3	32.53	57.57	2.75	150.3
BF	118.3	33.60	59.97	2.82	147.7
ZnS	133.7	35.23	63.73	2.76	150.0
ZnS,ZnF	142.3	39.70	70.13	2.97	147.3
ZnS,MnF	148.3	37.97	69.50	3.22	149.7
ZnS,BF	142.0	36.40	63.80	2.90	139.3
MnS	138.9	37.03	63.53	2.69	144.7
MnS,ZnF	170.7	45.33	77.87	3.20	149.7
MnS,MnF	153.0	42.07	72.37	2.85	141.3
MnS,BF	149.0	40.80	70.43	2.70	146.3
BS	110.3	34.00	54.87	2.30	149.0
BS,ZnF	145.7	37.70	66.73	2.70	150.7
Bs,MnF	136.3	37.90	63.80	2.73	147.0
BS,BF	96.67	27.53	42.77	2.06	138.3
LSD	5.91	0.26	6.68	0.26	8.76

A: Seed Yield, B: Pod in main stem, C: Pods per Plant, D: Seed per Pod, E: 1000-seed weight.

4. Discussions

It was shown that the highest number of pods on the main stem (41.31) was obtained when manganese was incorporated in the soil. Moreover, the maximum number of seeds per pod (2.96) was achieved when zinc was incorporated in the soil. Furthermore, the biggest 1000 seed weight (150.5 g) belonged to the treatment in which zinc was sprayed on the crop. These results also showed that, among the treatments in which the micronutrients were incorporated in the soil, the highest seed yield (152.9 g.m^{-2}) was harvested when manganese was incorporated in the soil; and among the treatments in which the micronutrients were sprayed on the crop, the highest seed yield (146.3 g.m^{-2}) was obtained when zinc was sprayed on the crop. Results of the mutual effects of the data also showed that the highest seed yield among all the treatments (170.7 g.m^{-2}) belonged to the one in which manganese was incorporated in the soil and zinc was sprayed on the crop. Next to this treatment, manganese incorporation in the soil and sprayed on the crop (153 g.m^{-2}), and in third place was the treatment in which manganese was incorporated in the soil and boron was sprayed on the crop (149 g.m^{-2}). The lowest seed yield was harvested in the control treatment (88 g.m^{-2}).

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