Journal of Sugar Beet
http://jsb.areeo.ac.ir/

Journal of Sugar Beet 2014, 30(1)

Effect of micronutrients application on some morphological traits related to seed quantity and quality of sugar beet variety Shirin

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Farzaneh S, Sadeghzadeh Hemayati S, Taleghani DF, Chegini MA, Ghaderifar F, Azizi S. Effect of micronutrients application on some morphological traits related to seed quantity and quality of sugar beet variety Shirin. J. Sugar Beet. 2014; 30(1): 51-56. DOI: 10.22092/jsb.2014.5855

Received July 9, 2012; Accepted December 16, 2013

ABSTRACT

In order to study the effect of micronutrients application on some morphological traits associated with seed quantity and quality of sugar beet variety Shirin, an experiment was conducted in 2004-05 at Ardabil Agricultural Research Station, Ardabil, Iran. Based on soil test results, soil pH was 7.62-7.80 with 0.49- 0.53% organic matter content, and the quantities of absorbable P, total N, and K were found to be at optimum level. Eight treatments including: 1) control (no micronutrient), 2) Fe, 3) Mn, 4) B, 5) Fe and Mn, 6) Fe and B, 7) Mn and B, and 8) Mn, Fe and B were evaluated in randomized complete block design with three replications. Results indicated that the effect of different treatments on the number of lateral branches, main branch diameter, leaf dry weight, branch dry weight, and total dry weight was significant (P <0.01). Means comparison showed that the maximum number of lateral branches was obtained in Fe treatment and the highest rate of leaf dry weight, branch dry weight, and total dry weight was observed in the both Fe and Fe-B treatments. Results also showed that micronutrient application had a significant effect on seed yield, unfilled kernel percentage, vigour percentage, and standard seed size (round 3.5-4.5 mm) percentage. The Fe-B treatment resulted in the highest seed yield per hectare with the highest vigour and the lowest unfilled kernel percentage.

Keywords: Boron, dry matter, Fe, seed sugar beet, vigour

INTRODUCTION

Mineral elements are known to be important to plant's growth and production and mineral nutrition is one of the most important factors affecting the yield of field crops (Hashemi Dezfoli et al. 1997). Micronutrient deficiency in plants is a global problem. Continuous cultivation of a plant, excessive consumption of phosphate fertilizer, alkaline soil, and the lack of micronutrient fertilizer application are the main factors influencing micronutrient deficiency in the soil in Iran (Malakooti and Tehrani 2001). In general, a variety of factors such as soil texture, pH, electrical conductivity, organic matter content, etc., may influence element availability in the soil and in the case of poor soil condition, the aforesaid elements should be added. In Iran, factors such as soil salinity, poor soil texture and structure, nutritional imbalance, and improper soil use make fertilizer and supplemental nutrients application inevitable. The required element level for optimized production depends on the crop yield, fertilizer form and type of application (Grant and Bailey 1993). Compared with macronutrients which are applied in heavy quantities (50-500 kg ha^{-1}), micronutrients are applied in small quantities (only a few gram per ha) (Draycott and Christenson 2003). Essential micronutrients for plant growth are applied at concentrations equal to or less than 100 mg kg^{-1} plant dry weight (Anon 2001). Boron (B), chlor (Cl), copper

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(Cu), iron (Fe), manganese (Mn), molybdenum (Mo), and zinc (Zn) are necessary micronutrients for sugar beet growth (Draycott and Christenson 2003). Plant response to micronutrient deficiency depends on micronutrient type. For example, sugar beet response to B, Fe, and Mn deficiency is high, to Cu, Mo, and Zn is medium and to Cl is low (Draycott and Christenson 2003). Fe is a necessary element for plant growth and its deficiency results in the reduction of chlorophyll content, number of photosynthesis pigments, CO_2 fixation, and starch and sugar storage in leaves (Malakooti and Tehrani 2001; Sharma and Sanwal 1992). Boron has important effect on cell wall formation and its deficiency leads to the growth inhibition and yield reduction (Ha and Broun 1997). Although boron deficiency influences vegetative growth but in most cases, yield reduction occurs without any clear symptoms which highlights boron influence on pollination and seed formation (Shorrocks et al. 1991). Since there is interplay between calcium and boron, boron deficiency usually occurs in light sandy and highly alkaline soil, and a high calcium concentration in high pH soil leads to the reduction in boron absorption (Malakooti and Nafisi 1994; Rani and Reddy 1993). Manganese deficiency in alkaline soil with optimum ventilation can be overcome by spraying and topdressing on soil (Malakooti and Nafisi 1994). Manganese has important effect on enzyme systems involved in auxin synthesis, nitrogen metabolism, and CO_2 assimilation (Tisdale et al. 1990). In most experiments, especially on tuber crops, it was approved that micronutrients such as Mn and Fe have an important role in increasing tuber dry weight. However, Taleghani (1999) showed that micronutrients application had no significant effect on sugar and root yield. Sugar beet root has more susceptibility to B and Mn deficiency than Zn, Fe, and Cu (Draycott and Christenson 2003). Sroller and Pulkrabek (1979) showed that micronutrients (B, Mn, Zn, and Ca) application alone or with phosphate fertilizer resulted in the increase of seed yield, spikelet number, and 1000-seed weight. Sadeghzadeh Hemayati (2001) reported that micronutrient application led to the increase in raw yield (10.75%), optimum seed (15.5%), and 1000-seed weight, but had no influence on seed vigour of sugar beet. Several studies reported increase in quantitative and qualitative yield of sugar beet through micronutrients absorption by leaves and branches (Jassem and Sadouski 1990). The present study aimed to evaluate the effect of micronutrients application on quantity and quality of monogerm sugar beet seed cv. Shirin.

Table 1. Some important meteorological parameters including temperature and rainfall of Ardabil area during the growing season (2004-05)

Climatic factors	Year	April	May	June	July	August	September	October	November	December	January	February	March
Rainfall (mm)	2004	14.6	19	21.7	24	26.2	23	22.6	10.3	3.3	3.8	0.7	11
	2005	12	19.8	22.4	24.2	27.9	23.2	-	-	-	-	-	-
Min. monthly temp. (°C)	2004	-2	7.1	8	12.2	12.6	10	6	4	0	-6.8	-8.1	0.6
	2005	0.2	7.4	8.6	12	12.9	10.3	-	-	-	-	-	-
Max.Monthly temp. (°C)	2004	14.6	19	21.7	24	26.2	23	22.6	10.3	3.3	3.8	0.7	11
	2005	12	19.8	22.4	24.2	27.9	23.2	-	-	-	-	-	-

MATERIALS AND METHODS

This study was conducted over two years (2004-05) at Ardabil Agricultural Research Station (12 km east of Ardabil, Iran, Latitude of 48°12´N and Longitude of 48°28´E at 1350 m above sea level). The monogerm, diploid hybrid variety Shirin used in the current study was developed by Sugar Beet Seed Institute, Karaj, Iran and registered in OECD (Organization for Economic Cooperation and Development) in 1999. The climate was semi-arid with cold and a long dry season, especially in summer. The average temperature and rainfall during the growing season are summarized in Table 1.

Randomized complete block design with three replications and eight treatments including control (no micronutrient fertilizer), Fe, Mn, B, Fe-Mn, Fe-B, B-Mn, and Fe-B-Mn was used. To provide Fe, iron chelate fertilizer (Fe-EDTA) containing 7.7% pure iron was used. Boric acid (15%) and Mn-EDTA (13%) were used as B and Mn, respectively. Micronutrients (2:1000 of stock solution per ha sprayed at a rate of 200 l solution per ha) were sprayed three times including shooting stage, and 15 and 30 days after shooting. Since the total amount of N, P, and K was at optimal level, therefore these fertilizers were not applied (Table 2). Each plot consisted of 6 rows of 6m length with the rootlets sown in a 65×60 cm pattern at a density of3.08 plants per m^2. Between-row spacing was 65 cm.

Table 2. Physicochemical properties of the soil in the experimental site in 2004-05.

Trait	2004	2005
Sand	17	17
Silt	55	55
Clay	28	28
Soil texture	Loam silt	Loam silt
Absorbable potassium (mg Kg^{-1})	584	450
Absorbable phosphorus (mg Kg^{-1})	26.6	20.6
Total N (%)	0.05	0.04
Organic carbon (%)	0.53	0.49
TNV (%)	1.25	1.7
Saturation percentage of soil	54.9	45.0
Soil pH	7.62	7.8
Electrical conductivity (dS m^{-1})	0.41	0.45
Zn (mg Kg^{-1})	0.54	0.92
Fe (mg Kg^{-1})	2.00	1.98
Mn (mg Kg^{-1})	9.60	9.42
B (mg Kg^{-1})	0.89	0.8

The two border rows in each plot were assigned to the pollinator parent and the four middle rows to the male sterile parent. Before land disking and levelling, it was ploughed by mouldboard plough. Then, the furrows were built by furrower (with 65 cm distance). Healthy rootlets weighing 100-150 g were planted late winter (second half of March) and immediately irrigated to help rootlets establishment. Weeding was carried out manually and chemical pesticides were used to control agrotis (*Agrotis segetum*) and black aphid. Before harvest, pollinator parents were removed and at harvest, plants were cut from 10 cm above ground (after removing two plants from the beginning and end of the rows). Collected seeds were then dried, threshed, and cleaned. For morphological traits evaluation, five plants per plot were selected randomly and in laboratory, main stems (those that come directly out of crown) and lateral stems (originated from main shoot) were counted. Main stem diameter was measured from 10 cm above the crown in the tallest stem. To measure stem, leaf, and seed dry weight, after separating them, they were weighed and placed in separate bags into oven for 48 h at 75 ^{o}C. Dried samples were weighed with a balance with an accuracy of 0.001 g. To calculate quantitative and qualitative traits such as raw seed yield, percentage of round seeds with 3.5-4.5 mm diameter, percentage of round seeds with <3.5 mm diameter, percentage of round seeds with >4.5 mm diameter, unfilled seeds, 1000-seedseed weight, and mechanical viability, samples were taken from the extracted seeds of each plot and were transferred to the Seed Laboratory of Sugar Beet Seed Department of Ardabil. Samples were separated by twig separator and cleaning machines. For 1000-seedseed weight and seed viability measurement, only round seeds with 3.5-4.5 mm diameter were sampled. Data were analyzed using SAS software and means were compared by LSD test at 5% level.

RESULTS AND DISCUSSION

Soil chemical analysis results for two years are shown in Table 2. The electrical conductivity was 0.41-0.45 dS/m which had no limitation for crop planting. Soil pH was 7.62-7.80 which is classified as alkaline soil. Soil organic carbon was considered low (0.49-0.53). The total amount of N, P, and K were in optimal condition.

Results of combined analysis showed that the effect of different treatments on lateral branch number, main branch diameter, leaf and branch dry weight, and total dry weight was significant ($p<0.01$) (Table 3). Mean comparison of the morphological traits is shown in Table 4. Fe application resulted in the highest number of lateral branches. The highest leaf, root and total dry weight was obtained in Fe and Fe-B treatments. Although micronutrients application had no significant effect on seed dry weight but by Fe application, the highest seed weight was obtained. Previous studies reported the effect of Fe on sugar beet seed (Shaikhzadeh Mosadegh 2002), sugar beet root (Ahmadi 2004), wheat (Ohki 2001), and potato (Malakooti and Taheri 2001). In different studies, micronutrients application resulted in increase of above-ground weight (Taleghani 1999) and main branch diameter (Hanousek 1973).

Table 3. Results of combined analysis for quantitative traits of sugar beet seed and plant based on two years experiment (2004-05).

S.O.V.	df.	Main branch number	Lateral branch number	Plant height	Main branch diameter	Leaf dry weight	Branch dry weight	Seed dry weight	Total plant dry weight
Year (Y)	1	3.05**	22.27^{ns}	9371.63**	190**	19564.9**	25438.94**	42440.17**	255409.62**
Replication/Y	4	0.39	16.2	19.3	12.48	177.3	10977.52	1195.62	74426.13
Micronutrients (A)	7	0.35^{ns}	47**	139.64^{ns}	26.2**	703.2**	5729.58**	1142.18^{ns}	17681.23**
Y x A	7	0.15^{ns}	10.94^{ns}	119.45^{ns}	14.19^{ns}	249.7^{ns}	1789.72^{ns}	727.56^{ns}	4837.57^{ns}
Error	28	0.18	10.4	64.08	6.8	206.94	1413.02	540.92	3700.45
C.V.		13.17	9.37	6.48	10.67	27.28	15.23	19.37	14.5

Ns=non significant, *,** significant at 5% and %1 probability levels, respectively.

Table 4. Mean comparison of quantitative traits of sugar beet seed and plant for two years experiment (2004-05).

Trait	Main branch number	Lateral branch number	Plant height (cm)	Main branch diameter (mm)	Leaf dry weight (g per plant)	Branch dry weight (g per plant)	Seed dry weight (g per plant)	Total plant dry weight (g per plant)
Control	3.05 a	32.5 dc	113.67 a	23.63 bc	51.82 abc	224.06 b	103.6 c	379.48 bc
Fe	3.61 a	38.65 a	125.05 a	28.11 a	66.71 a	288.55 a	138.46 a	493.73 a
Mn	3.1 a	35.15 abc	120.93 a	24.93 bc	54.58 ab	240.33 b	118.9 a	413.82 bc
B	3.3 a	36.48 ab	127.7 a	24.17 bc	54.21 ab	250.25 ab	124.88 a	433.34 ab
Fe-Mn	2.85 a	29.1 d	123 a	23.6 bc	36.6 c	207.9 b	102.25 a	346.75 c
Fe-B	3.3 a	34.77 bc	125.93 a	26.6 ab	64.31 a	292.08 a	134.02 a	490.42 a
Mn-B	3.3 a	34.21 bc	129.15 a	22.33 c	38.02 bc	218.78 b	109.58 a	366.39 bc
Fe-Mn-B	3.45 a	34.38 bc	122.33 a	21.93 c	55.51 a	251.5 ab	124.75 a	431.76 ab
2004	3.5 a	35.08 a	109.5 b	22.42 b	32.53 b	223.66 b	90.32 b	346.51 b
2005	2.99 b	33.72 a	137.44 a	26.40 a	72.91 a	269.70 a	149.79 a	492.41 a

Means with the same letter in each column are not significantly different at p<0.05.

Table 5. Results of ANOVA for quantitative and qualitative traits of sugar beet seed based on two years experiment (2004-05)

S.O.V.	df.	Raw seed yield	Seed percentage (<3.5 mm)	Seed percentage (3.5-4.5 mm)	Seed percentage (>4.5 mm)	Unfilled seed percentage	Viability (%)
Year (Y)	1	5445894.4^{**}	1^{ns}	133.2^{**}	20.4^{ns}	1.3^{ns}	293.78^{**}
Replication	4	194381.5	35.7	77.3	114	7	4.7
Micronutrients (A)	7	528323^{ns}	81.3^{ns}	46.8^{**}	119.6^{ns}	44.9^{**}	12.17^{**}
Y x A	7	376528.2^{**}	30.6^{**}	17.8^{ns}	89.7^{ns}	14.5^{ns}	5.5^{ns}
Error	28	100495	7.2	12.2	108.9	5.8	61.05
C.V.		11.4	11.8	10.17	35.07	19.08	1.64

Ns=non significant, **,* significant at 1% and %5 probability level, respectively.

Table 6. Mean comparison of quantitative and qualitative traits of sugar beet seed for two years experiment (2004-05).

Treatment	Raw seed yield (kg ha^{-1})	Seed percentage (<3.5 mm)	Seed percentage (3.5-4.5 mm)	Seed percentage (>4.5 mm)	Unfilled seed percentage	Vigour (%)
Control	2362.8 a	27.15 a	31.45 c	22.62 a	15.93 a	87.87 c
Fe	2957.8 a	16.76 a	35.8 ab	34.76 a	11.65 b	89.96 b
Mn	3003.4 a	23.43 a	34.4 bc	25.93 a	12.73 b	90.23 b
B	2963.6 a	21.17 a	39.6 a	29.5 a	8.55 c	92.38 a
Fe-Mn	2551.2 a	26.7 a	31.65 c	35.03 a	16.85 a	87.9 c
Fe-B	3041.2 a	19.52 a	35.97 ab	33.08 a	10.18 bc	90.02 b
Mn-B	2651 a	25.73 a	31.87 bc	26.7 a	12.8 b	89.85 b
Fe-Mn-B	2835.3 a	21.48 a	33.62 bc	30.48 a	12.56 b	89.65 b
2004	2452.75 b	22.59 a	32.63 b	30.42 a	12.49 a	92.2 a
2005	3138.79 a	22.88 a	35.96 a	29.11 a	12.82 a	87.3 b

Means with the same letter in each column are not significantly different at p<0.05.

Year had significant effect (p<0.01) on raw seed yield, standard seed percentage (round seed with 3.5-4.5 mm diameter), and seed viability (Table 5). Raw seed yield and standard seed percentage were 3138.79 kg ha^{-1} and 35.96% in 2005 and 2452.75 kg ha^{-1} and 32.63% in 2004, respectively. Therefore, raw seed yield and standard seed percentage in 2005 were 21.85 and 9.26% higher than 2004, respectively (Table 6). Micronutrients had also significant effect (p<0.01) on round seed (with 3.5-4.5 mm diameter) percentage, unfilled seeds, and seed viability.

Although micronutrients application had no significant effect on raw seed yield and round seed (<3.5 mm) percentage but it increased raw seed yield and decreased round seed (<3.5 mm) percentage so that the raw seed yield of Fe, Mn, B, Fe-Mn, Fe-b, Mn-B, Fe-Mn-B treatments were 2362.8, 2957.8, 3003.4, 2963.6, 2551.2, 3041.2, 2651, and 2835.3 Kg ha^{-1}, respectively. Therefore, by Fe-B application, the highest raw seed yield was obtained (Table 6). Considering the random effect of year and significant year×micronutrients interaction (Tables 5 and 7), occurrence of type I error (Yazdi Samadi et al. 1998) prevented the effect of micronutrients from being significant on raw seed yield and under-size seed percent.

Mean comparison of round seed (<3.5 mm) percentage (Table 6) showed that the highest percentage (27.15) of round seed (<3.5 mm) was obtained in control treatment. The highest standard seed percentage was obtained in B and Fe-B treatments. Unfilled seed percentage was 15.9, 11.7, 12.7, 8.6, 16.9, 10.2, 12.8, and 12.6% for

Table 7. Effect of year × treatment interaction on raw seed yield and round seed (>3.5 mm) percentage

Year	Treatment	Raw seed yield (kg ha^{-1})	Round seed percentage (>3.5 mm)
2004	Control	2210.6 b	25.13 b
	Fe	2536.9 a	19.28 a
	Mn	2904.0 a	22.10 ab
	B	2482.5 a	20.83 ab
	Fe-Mn	1952.5 b	25.11 b
	Fe-B	2390.8 ab	22.66 ab
	Mn-B	2677.9 a	22.73 ab
	Fe-Mn-B	2466.7 a	22.93 ab
2005	Control	2514.9 d	29.16 e
	Fe	3378.6 ab	14.23 a
	Mn	3102.8 bc	24.76 de
	B	3444.6 ab	21.50 cd
	Fe-Mn	3149.8 b	28.30 e
	Fe-B	3691.6 a	16.36 ab
	Mn-B	2624.0 cd	28.73 e
	Fe-Mn-B	3202.7 ab	20.03 bc

Means with the same letter are not significantly different at $p<0.05$

control, Fe, Mn, B, Fe-Mn, Fe-B, Mn-B, Fe-Mn-B treatments, respectively, which decreased to 45.9 and 31.4% by B and Fe-B application compared with control treatment. The highest seed viability was obtained in B treatment (Table 6).

Results of this study showed that micronutrients application, especially B and Fe, increased sugar beet seed quality. Increases in yield and qualitative traits are promising results (Jassem and Sadowski 1990). In a study by Vik and Ruzikova (1997), a combination of P fertilizer, B, Mn, Zn, and Cu micronutrients improved seed quality but decreased seed viability, seedling growth and number of seeds per spikelets. Alba (1979) reported 1.78, 5.34, 8.31, and 18.10% increase in sugar beet seed yield by application of 15, 30, 45, and 60 Kg borax ha^{-1}, respectively, compared with control (3.37 t ha^{-1}). In another study, N and K application with superphosphate enriched by calcium borate, increased seed yield, viability and vigour (Kharchenko 1983). Wang (1994) reported 9.1 and 10.4% increase in monogerm seed viability by foliar application of B . Wisniewski and Sadowski (1991) reported seed viability and yield reduction with decreased B application. Sroller and Pulkrabek (1979) showed that micronutrients (B, Mn, Zn, and Ca) application alone or in combination with P increased seed yield, number of spikelets per ha^{-1}, and 1000-seed weight.

Suggestions

It is recommended to use Fe and B micronutrients during growth stages, especially at bolting stage, to increase seed yield.

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