INTERNATIONAL JOURNAL OF PLANT, ANIMAL AND ENVIRONMENTAL SCIENCES
IJPAES
VOLUME-2, ISSUE-4, OCT-DEC-2012 ISSN 2231-4490

Coden : IJPAES www.ijpaes.com

Received: 22nd August-2012 *Revised: 25th August -2012* *Accepted: 28th August -2012*

Research article

ALLOCATION RATIO OF PHOTOSYNTHATE TO DIFFERENT PARTS OF SUGAR BEET PLANT AFFECTED BY NANO-IRON FOLIAR APPLICATION AT VARYING GROWTH STAGES

Mahmood Mazlomi Mamyandi[1], Alireza Pirzad[2*], Mohammad Reza Zardoshti[2]

[1]MSc. Student of Department of Agronomy and Plant Breeding, Faculty of Agriculture, Urmia University, Urmia-Iran.
[2]Assistant Professor, Department of Agronomy and Plant Breeding, Faculty of Agriculture, Urmia University, Urmia-Iran

**Corresponding Author: alirezapirzad@yahoo.com*

ABSTRACT: To evaluate effect of Nano-iron amounts spraying at varying phenological stages on allocation of photosynthate to different parts of sugar beet (*Beta vulgaris*) plant, a factorial experiment was carried out based on randomized complete block design with three replications in 2011. Treatments were foliar application of Nano-Iron (0, 1, 2 and 3 g/litter) and time of iron spraying at different growth stages (20, 40, 60, 80 and 100 % of ground cover). The highest increase in the weight of leaf, peduncle and total aerial parts were only observed at three of treatments included 1, 2 and 3 g/litter of Nano-iron at 80, 20 and 100 % of ground cover, respectively. The highest yield of fresh root (140571 kg/ha), total biomass (53576 kg/ha) and sugar (26994 kg/ha) were obtained from 2 g/l of iron spraying at 80 % of ground cover. Iron spraying of plants at 40 to 80 % of ground cover caused to beneficially produce the yield of dry root, biomass and sugar. In conclusion, effectiveness of leaf, peduncle and aerial parts from amounts and time of spraying were less than root, biomass and sugar yield. So, the foliar application of all iron concentration led to change the yield of root, biomass and sugar compared with control treatment. The ratio of weight (harvest index) of leaf, peduncle, aerial parts, root and sugar to biomass indicated the allocation of photosynthesis to each part of plant under experimental treatments. Harvest index of root (ratio of root yield/biomass) was raised up in all levels of Nano-iron applications compared to control.
Key Words: Allocation*,* *Beta vulgaris,* Nano-iron, Sugar, Yield

INTRODUCTION

Sugar beet (*Beta vulgaris* L) develops a sucrose-rich tap root composed of 90% root tissue and 10% hypocotyls tissue during the first year of its biennial life cycle. The root contains up to 20% sucrose per fresh weight at maturity. Sugar beet breeding aims towards increasing the extractable sucrose and to lower the concentration of nitrate, potassium, and sodium which inhibit sucrose purification, as well as to increase resistance to biotic and abiotic stress. After germination, dry biomass of sugar beet leaves exceeds that of roots [3]. But, at the 8–10 leaf stage, leaves and roots start growing simultaneously and, later on, roots take up the major part of dry weight. Sucrose accumulates during growth in the absence of a ripening phenomenon [11].Micronutrient elements are relatively needed in very small quantities for adequate plant growth and production, their deficiency may cause great disturbance in the physiological and metabolic processes involved in the plant. Thus, the application of micronutrients fertilizer in the cultivation zone may not be meeting the crop requirement for root growth and nutrient use. The alternative approach is to apply these micronutrients as foliar sprays. Six micronutrients including Manganese (Mn), Iron (Fe), Copper (Cu), Zinc (Zn), Broom (B) and Molybdenum (Mo) are known to be required for all higher plants [13].

Iron is the sixth most abundant element in the Universe, and the most common refractory element, [10] it makes up about 5% of the earth's crust, both the Earth's inner and outer core are believed to consist largely of an Iron-Nickel alloy constituting 35% of the mass of the Earth as a whole. Iron is consequently the most abundant element on Earth, but only the fourth most abundant element in the Earth's crust [12]. The most of the iron in the crust is found combined with oxygen as Iron Oxide minerals such as Hematite and Magnetite. Traditionally, iron (II) compounds are called Ferrous, and iron (III) compounds Ferric. Iron also occurs in higher oxidation states, an example being the purple potassium ferrate (K_2FeO_4) which contains iron in its +6 oxidation state. Iron (IV) is a common intermediate in many in biochemical oxidation reactions [14; 6]. Iron is a necessary trace element found in nearly all living organisms. Iron-containing enzymes and proteins, often containing Heme Prosthetic groups, participate in many biological oxidations and in transport. Examples of proteins found in higher organisms include Hemoglobin, Cytochrome and Catalase [8]. Iron deficiency is a widespread agricultural problem in many crops, especially in calcareous soils. In these soils, total Fe is high but occurs in chemical forms not available to plant roots. The high rate of Bi-Carbonates in the solution of clay is the general factor in chlorosis led from lack of iron in the plants grown in the lime clay [7].

Iron (applied to the soil as ferrous sulphate) was found to significantly increase the number ear heads per tiller, length of ear heads, number of grains per year, grain yield per plant and the 1000 seeds weight in proportion to its concentration used both in pot and field experiments. This was coupled with the increase in total carbohydrate, starch and crude protein contents of wheat grains. This causes a reduction in the synthesis of chlorophyll and Indole-3-Acetic Acid (IAA), leading to an inhibition of photosynthesis at grain filling stage and ultimately reduced total carbohydrate, starch and protein contents of grains, which might be a good reason for the production of inferior quality of wheat grains [5]. The amount of phosphoenolpyruvate carboxylase protein determined by immuno-blotting was, on a protein basis, 35-fold larger in the yellow zone of Fe-deficient root tips than in the Fe-sufficient root tips. The possibility that post-translational regulation of phosphoenolpyruvate carboxylase may occur mediated through phosphorylation was studied by immunological detection of phosphoserine residues in root tip extracts [1].

Given the importance of allocation to the economic value of organic matter, evaluate effect of Nano-Fe particles sprayed at varying growth stage on each components of biomass and ratio of them, and probable increasing of harvest index is the main objective of this research.

MATERIALS AND METHODS

To evaluate the effect of Nano-iron spraying at different amount and time on the Allocation ratio of photosynthate to different parts of sugar beet (*Beta vulgaris cv.*(AZARE), a field experiment was carried out as factorial arrangement based on randomized complete block design with three replications. Experiment was conducted at the Research Farm of Azar Ghand Naqadeh Factory with latitude of 27°.450' N, 22°.370' E and 1286 m above sea level in 2011. Experimental units in each replication comprised of 5 line of 5 meters long. Inter- and intra- row spacing was 0.6 and 0.15 meters, respectively. Treatments were amount of iron including (0, 1, 2 and 3 g per litter of Nano-Iron Chelate obtained from Khazra Company) and spraying time included (foliar spray at 20, 40, 60, 80 and 100 of ground cover by plant canopy).

The flowing measurements were recorded at the harvest stage on 10 repetitive plants in each treatment per replication: leaf weight (g), peduncle weight (g), weight of aerial parts (g) dried at 72º C for 72 hours. The yield of biomass (kg/ha), yield of root (kg/ha) and sugar (kg/ha) were obtained from plants harvested of 5 m^2 in each experimental unit. Harvesting was done manually 6 months after planting. The tubers were weighed to determine the yield and samples taken for quality analysis of sucrose content (sugar %). Sugar content was determined using a sacharimeter model (Shmid + Haensch) of Germany, after making a pulp and clarification using lead acetate. Analysis of variance (ANOVA) on data was performed using the general linear model (GLM) procedure in the SAS 9.1 software. The Student-Neuman Keul's test (SNK) was applied to compare treatment means using the MSTATC software package.

RESULTS

Result of ANOVA showed the significant interaction effect between iron concentration and spraying stage on the weight of leaf, peduncle, aerial part of the single plant, the yield of root and sugar, and also on the harvest index of leaf, peduncle, total aerial parts and root to total biomass of sugar beet ($P \leq 0.01$) and also sugar ($P \leq 0.05$). (Harvest index= ratio of weight of each part to total biomass).

Table 1. Analysis of variance the effect of Nano-iron concentration and spraying time (growth stage) on the yield of different parts in sugar beet (*Beta vulgaris cv.* AZARE) plant.

Source of variation	df	Mean square				
		Leaf weight	Peduncle weight	Aerial part weight	Dry root yield	Sugar yield
Replication	2	7.52	6.93	36.91*	5376635	16831853.2*
Iron concentration (A)	3	59.21**	64.85**	213.32**	339132402**	764772018.0**
Growth stage (B)	4	15.52*	86.06**	53.74**	123141451**	86020171.4**
A×B	12	41.49**	38.00**	108.63**	40921207**	24654483.5**
Error	38	5.22	3.34	8.78	9246111	5173079.0
Coefficient of variation (%)		12.69	8.81	7.64	20.37	12.16

* and ** significant at $P \leq 0.05$ and $P \leq 0.05$, respectively. df, degree of freedom

Table 1 (continued). Analysis of variance the effect of Nano-iron concentration and spraying time (growth stage) on the yield of different parts of sugar beet (*Beta vulgaris cv.* AZARE) plant.

Source of variation	df	Mean square				
		Harvest index of				
		Leaf	Peduncle	Aerial parts	Root	Sugar
Replication	2	0.097	0.15	0.46	9.24	2.30
Iron concentration (A)	3	2.19*	8.01**	16.40*	500.13**	63.53**
Growth stage (B)	4	3.61**	0.64	3.81	368.85**	69.21**
A×B	12	2.02**	3.07**	7.52**	80.08**	12.05*
Error	38	0.54	0.49	1.66	13.23	2.25
Source of variation (%)		17.94	14.97	14.59	9.29	4.41

* and ** significant at $P \leq 0.05$ and $P \leq 0.05$, respectively. df, degree of freedom

The maximum weight of leaf (24.70 g/plant) was obtained from spraying 1 g/litter Nano-iron at 40% of ground covered with sugar beet followed by 2 g/litter at 60% (24.80 g/plant) and 3 g/litter iron at 100 % of ground cover (25.40 g/plant). Other treatments produced the plants with the leaf weight as well as control (without iron spraying) (Figure 1).

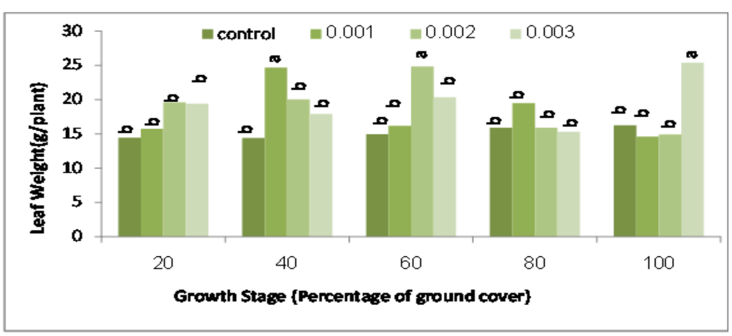

Figure 1. Means comparison of leaf weight of sugar beet (*Beta vulgaris cv.* AZARE) plants affected by foliar spraying at different concentration and growth stages. The similar letters show non significant difference at $P \leq 0.05$.

The maximum weight of peduncle (28.10 g/plant) belonged to plants sprayed by 1 g/litter Nano-iron at 80%, of ground cover. Among treatments, spraying at 80% ground cover by very concentrations and application of 3 g/litter at 60% ground coverage produced heavier peduncle than control (Figure 2).

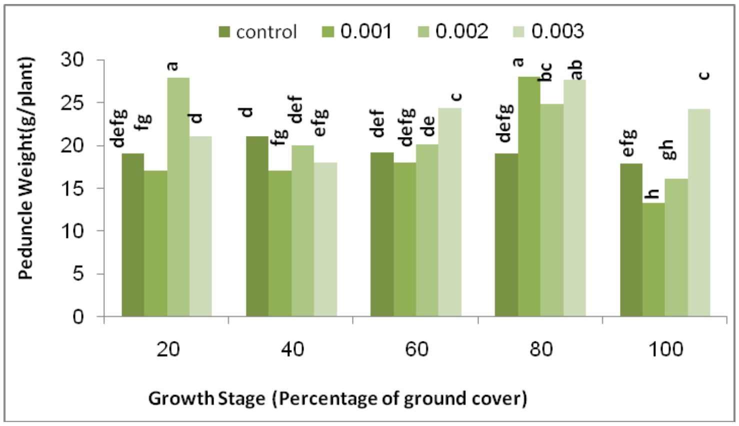

Figure 2. Means comparison of peduncle weight of sugar beet (*Beta vulgaris cv.* AZARE) plants affected by foliar spraying at different concentration and growth stages. The similar letters show non significant difference at *P*≤0.05.

Changes of leaf and peduncle weight led to the minimum weight of aerial part in sugar beet (27.99 g/plant) sprayed with 1 g/litter Nano-iron at 100% ground cover. These values were less than aerial parts of control treatments. But, the maximum weight of aerial parts (49.73 g/plant) belonged to 1 g/litter foliar application of iron at 100% ground coverage (Figure 3).

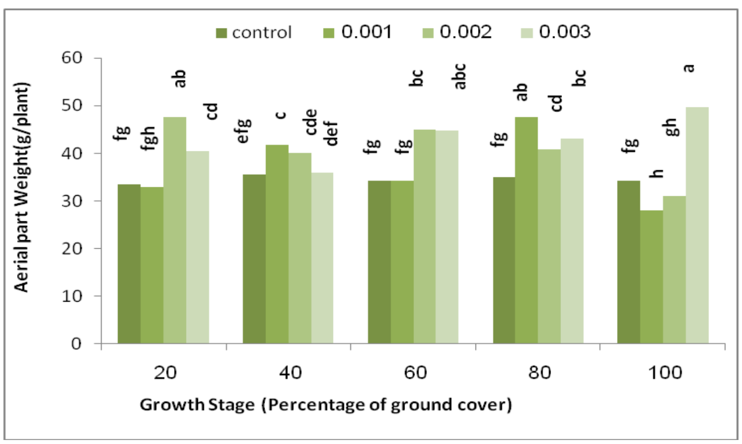

Figure3. Means comparison the weight of Aerial parts of sugar beet (*Beta vulgaris cv.* AZARE) plants affected by foliar spraying at different concentration and growth stages. The similar letters show non significant difference at *P*≤0.05.

The highest yield of root (Dry weight) (23323 kg/ha) was obtained from 2 g/litter Nano-iron application at 80% ground cover. This highest value was the same with root yield obtained from plants sprayed by 1 g/litter at 20%, all concentrations at 40, 60 and 80%, and however 3 g/litter iron at 100% ground cover. Iron spraying in 1 and 2 g/litter at early (20% ground cover) and late (100% ground cover) caused in the significant reduction of root yield (Figure 4).

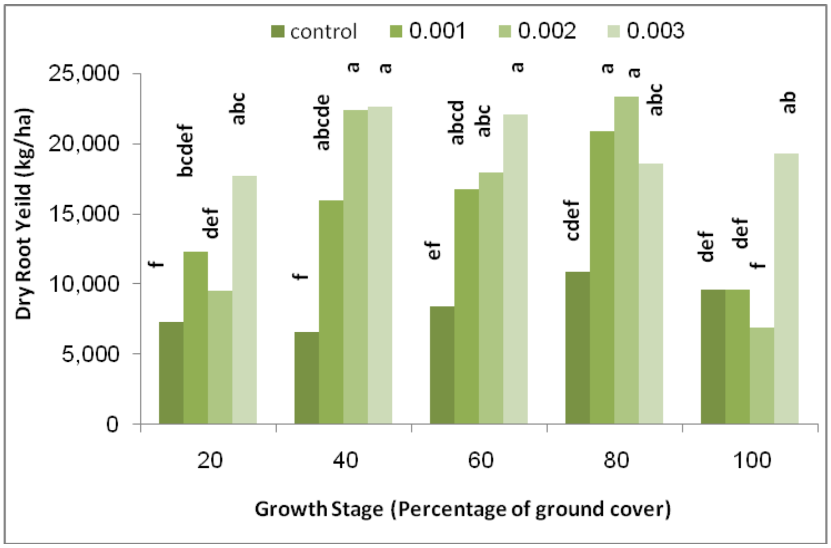

Figure 4. Means comparison of Dry Root yield of sugar beet (*Beta vulgaris cv.* AZARE) plants affected by foliar spraying at different concentration and growth stages. The similar letters show non significant difference at *P*≤0.05.

The highest biomass, Leaf + Peduncle + Root, (83576 kg/ha) was obtained from foliar application of 2 g/litter Nano-iron at 80% ground cover. Like root yield, this highest biomass was statistically the same with biomass of 1 g/litter Nano-iron at 20% ground cover, 2 and 3 g/litter at 40 and 60%, and however 1, 2and 3 g/litter at 80% of ground cover as well as 3 g/litter Nano-iron spraying at 100% ground cover stage by sugar beet canopy. The all of other treatments produced the lowest biomass like control treatment. So, the minimum yield of biomass (23635 kg/ha) belonged to treatment without Fe foliar application (Figure 5).

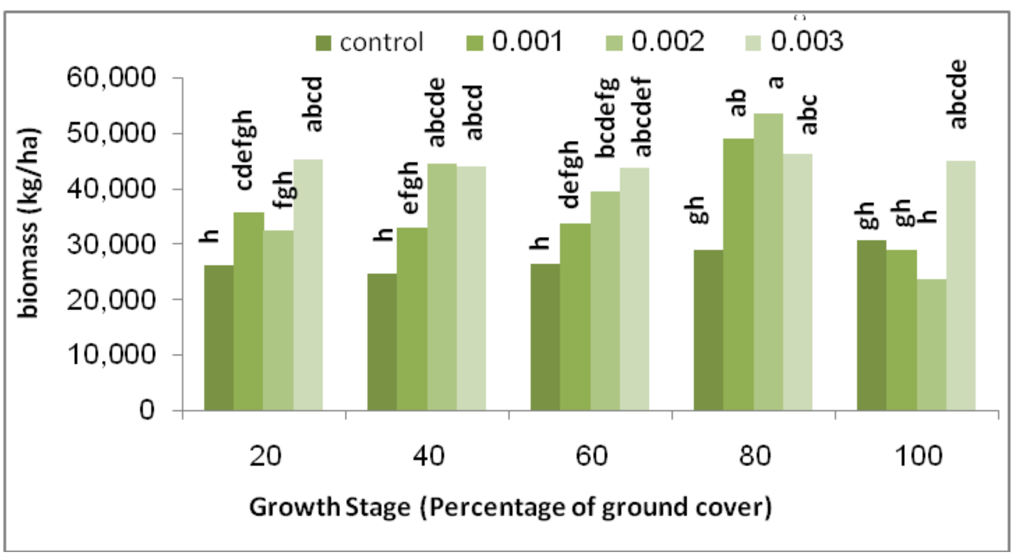

Figure 5. Means comparison of Biomass of sugar beet (*Beta vulgaris cv.* AZARE) plants affected by foliar spraying at different concentration and growth stages. The similar letters show non significant difference at *P*≤0.05.

The highest yield of sugar (26995 kg/ha) was obtained from foliar application of 2 g/litter Nano-iron at 80% ground cover. The statistically reductions were observed at early spraying (20, 40 and 60 % ground cover) of 1 g/litter Nano-iron, and late spraying of 2 g/litter compared with control treatment. The all of other treatments produced the same or higher yield of sugar than control (Figure 6).

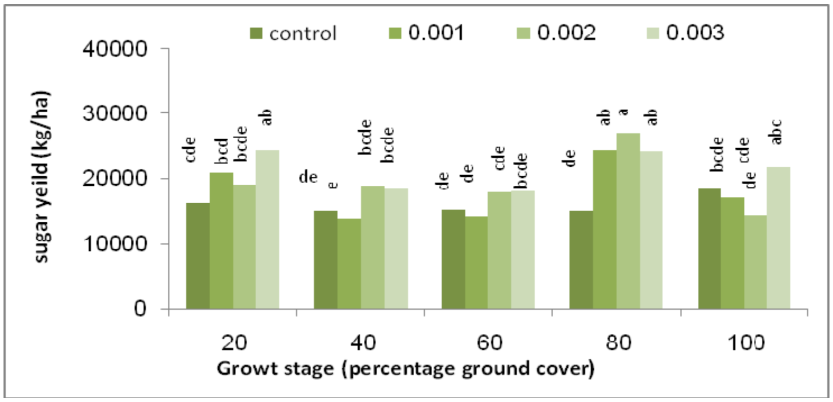

Figure 6. Means comparison of sugar yield of sugar beet (*Beta vulgaris cv.* AZARE) plants affected by foliar spraying at different concentration and growth stages. The similar letters show non significant difference at *P*≤0.05.

The ratio of each part of plant as harvest index (Allocation ratio of photosynthesis to different parts of sugar beet plant), were affected by interaction effects of tow factor (concentration and time of iron spray). So, the highest ratio of leaf to total biomass (6.031 %) was occurred in spraying 1 g/litter at 40% ground cover. And the minimum leaf ratio (2.37 %) was obtained by 2 g/litter Nano-iron at 80% ground cover as well as control treatment (Figure 7).

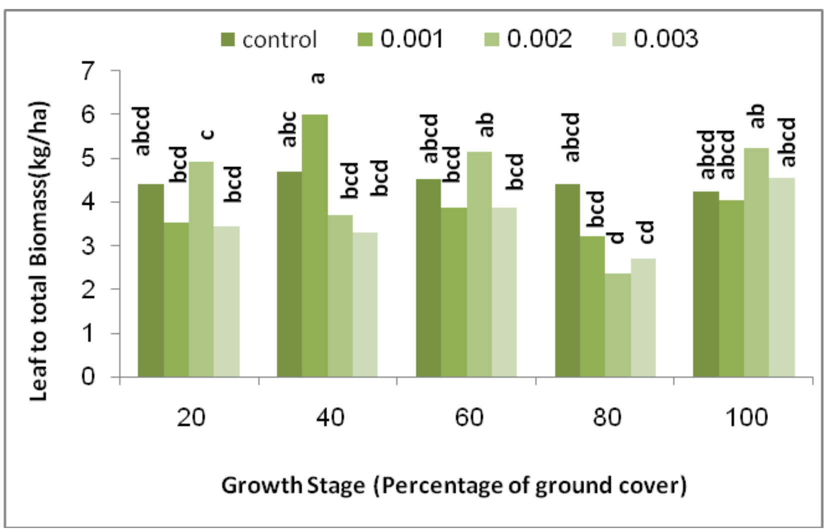

Figure 7. Means comparison harvest index of Leaf (leaf weight to total biomass ratio) of sugar beet (*Beta vulgaris cv.* AZARE) plants affected by foliar spraying at different concentration and growth stages. The similar letters show non significant difference at *P*≤0.05.

Harvest index of peduncle, the ratio of peduncle to total biomass, had the reducing trend by application of Nano-iron, except 2 g/litter at 20% ground cover, in that produced the highest ratio of peduncle to biomass (6.98%). Other Fe spraying caused to lower peduncle ratio than control (Figure 8).

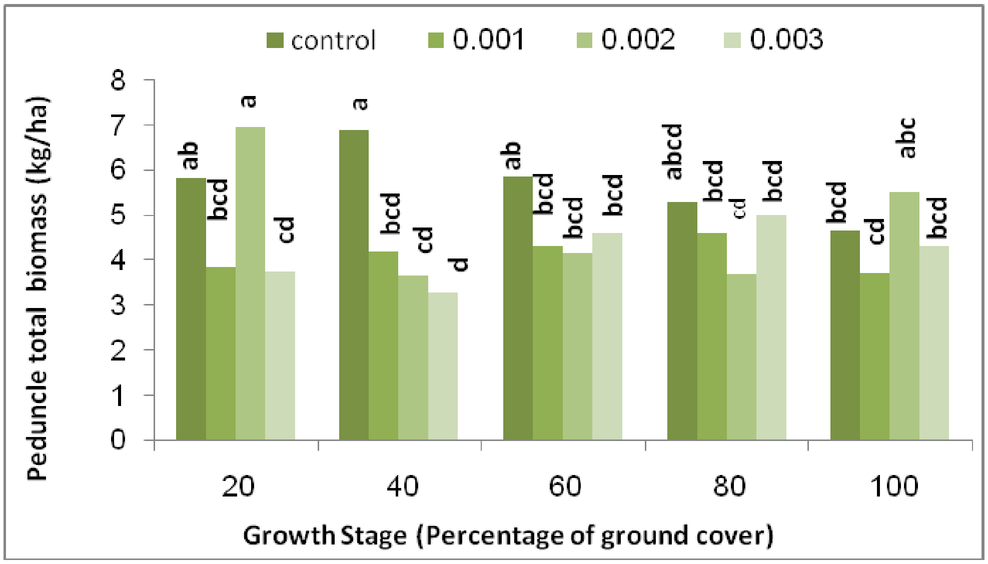

Figure 8. Means comparison harvest index of peduncle (peduncle weight to total biomass ratio) of sugar beet (*Beta vulgaris cv.* AZARE) plants affected by foliar spraying at different concentration and growth stages. The similar letters show non significant difference at *P*≤0.05.

Aerial parts of sugar beet as photosynthetic organ, was changed differentially by varying amounts of iron at growth stages of plant. So, the highest ratio of aerial parts to biomass 11.91%) was obtained from 2 g/litter iron application at 20% ground cover by sugar beet canopy. This highest value was the statistically same with harvest index of control, as well as most treatments. Few treatments, like 1 and 3 g/litter at 20%, and however 2 and 3 g/litter at 40 and 80% caused to reduce the ratio of aerial parts to biomass (Figure 9).

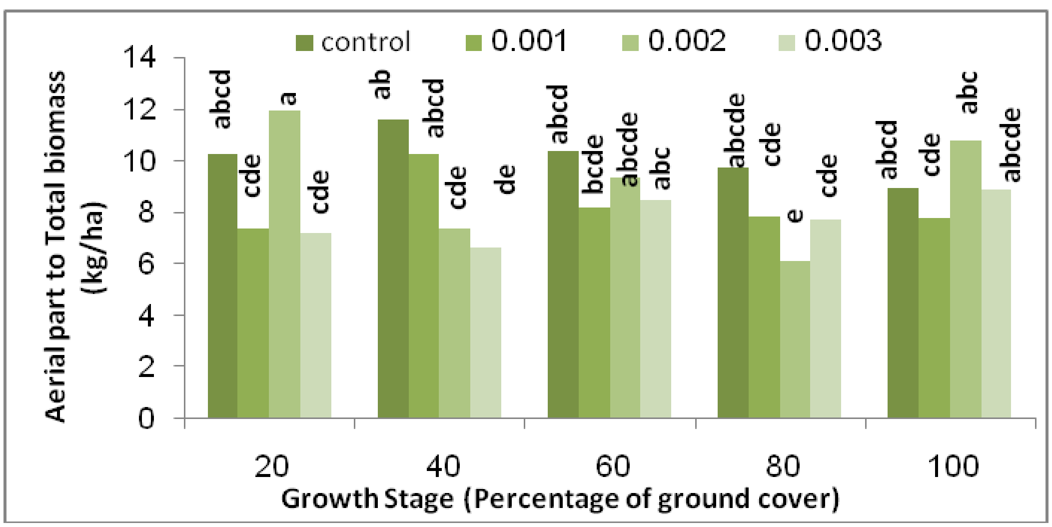

Figure 9. Means comparison harvest index of aerial parts (the weight of aerial parts to total biomass ratio) of sugar beet (*Beta vulgaris cv.* AZARE) plants affected by foliar spraying at different concentration and growth stages. The similar letters show non significant difference at *P*≤0.05.

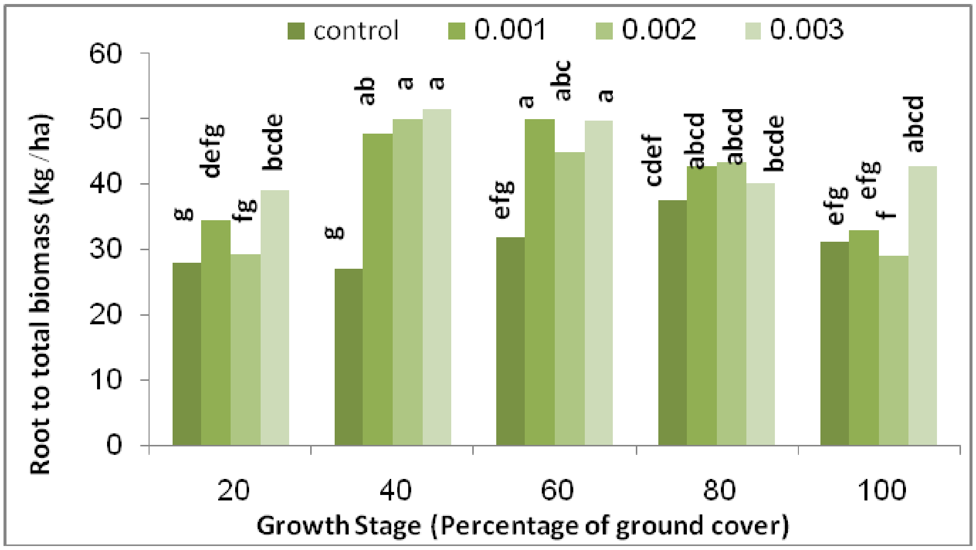

Figure 10. Means comparison harvest index of root (root weight to total biomass ratio) of sugar beet (*Beta vulgaris cv.* AZARE) plants affected by foliar spraying at different concentration and growth stages. The similar letters show non significant difference at *P*≤0.05.

Fe application at 40, 60 and 80% ground cover led to increasing of root harvest index (root yield to biomass ratio), so the highest harvest index of root (51.47%) was obtained from 1, 2 and 3 g/litter Nano-iron at 40 and 60% ground cover by sugar beet canopy. While iron spraying at 80% of ground cover caused in higher value of harvest index than control. But these increase of root ratio to total biomass obtained from plant sprayed at early (20% ground cover) and late (100% ground cover) was more less than 40, 60 and 80% of cover stage by canopy. Although, all iron treatments rose up allocation of dry matter to roots compared to control (Figure 10).

Unlike root harvest index, ratio of sugar to biomass was lower in Nano-iron application than control treatment. And it is the same to control only in spraying at early (20% ground cover) and late (100% ground cover). This reduction of sugar ratio to biomass did not mean the lower yield of sugar (Figure 11).

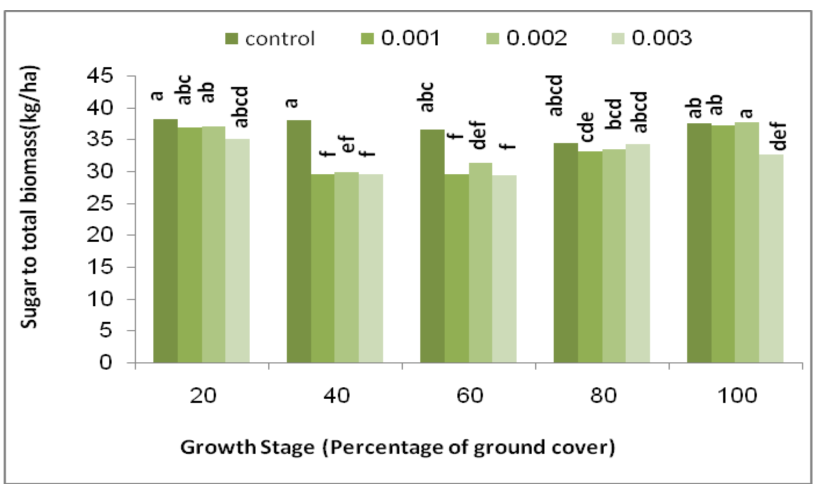

Figure 11. Means comparison harvest index of sugar (sugar weight to total biomass ratio) of sugar beet (*Beta vulgaris cv.* AZARE) plants affected by foliar spraying at different concentration and growth stages. The similar letters show non significant difference at *P*≤0.05.

Finally, the leaf and peduncle weight per plant undergoing the effects of the iron concentration and the usage time (the different stages of growth on the basis of the land coverage by plants) were very low. So, the increase of the leaf weight and the weight of peduncle in comparison to the control treatment was seen just in 3 of treatments. The changes in the reaction of the plant from the aerial part weight (total weight of the leaf and the peduncle) are very much. Just three treatments (1, 2 and 3 g/litter iron levels at 80, 20 and 100% ground cover, respectively) increased the weight of aerial part in sugar beet in comparison to the conditions, in which there was no use of iron. But, the root yield response to the iron spraying was very delicate. Spraying of all Nano-iron concentration at 40, 60 and 80 % ground cover stage, and the concentrations more than 3 g/litter at 20 and 100 % ground cover of sugar beet canopy, could increase the root yield. Just the 1 and 2 g/litter iron did not show differences at the early (20% ground cover) and the latest time (100% ground cover). As the root forms the big part of the biomass yield, the changes in biomass is similar to the total yield of the root along with treatments of the experiment. The sugar yield in all iron concentrations of 80 % ground cover, and the highest concentration (3 g/litter) of 20 and 100% ground cover were increased as well as following the root yield. The ratio of leaf, peduncle, aerial parts, root and sugar weight to the biomass (the harvest index of leaf, peduncle, aerial part, root and sugar) is the total of the changes of each adjective in contrary to biomass.

As the increase of nutrients in soil does not always lead to raise the yield, content of leaf nutriens and enhancement of the quality of the plant products (May and Pritts, 1993), so to identify the suitable amount of the nutrients is necessary for increasing the quality and quantity of yield in plants. In this manner, it is expected that the different parts (leaf, peduncle, root and sugar) of the sugar beet plant could have been shown varying response to the iron quantity. Glyn [4] has identified through the researches that the different rates of the micronutrients affect the dry weight of *Artemisia dracunculus* L. It is shown that the micro-nutrients had more effective on the essential oil percent and composition [4]. Iron plays the important role in synthesis of chloroplast. Sommer [17], reported that iron deficiency caused to reduction in chloroplast size and the plants height. Also iron deficiency causes reduction in chlorophyll synthesis, leaf surface, fresh and dry weight of leaf, and the growth of the new sub stems in which flowering was delayed, and the yield was significantly reduced [15].

The economic yield, according to the production purpose may be root, leaf, and other parts of plant, and the biologic yield was needed to balance between the photosynthesis apparatus, translocation rate of assimilates and distribution of the photosynthetic materials to the plant parts, number and the size of the seed and the capacity of them. The results of present study show that the mobilization of stem resources belonged to surplus products before seed filling caused to increase the seed yield. Baybordi and Mamedov [2], reported that spraying 25 kg /ha Sequestrene Fe (2 ppm iron) produced the highest yield of seed in canola. They also reported that the optimal amounts of micronutrient increase the photosynthesis rate and caused to rise up the yield by elongation of leaf area duration. This is maybe because of assimilates accumulation in seeds during the last stage of growth, and finally caused to produce bigger seeds.

REFERENCES

[1] Andaluz S, Lo´pez-Milla´n AF, Peleato ML, Abad´ıa J and Abad´ıa A. 2002. Increases in phosphoenolpyruvate carboxylase activity in iron-deficient sugar beet roots: Analysis of spatial localization and post-translational modification. Plant and Soil. 241: 43-48.
[2] Baybordi A and Mamedov G. 2010. Evaluation of Application Methods Efficiency of Zinc and Iron for Canola (Brassica napus L.). Notulae Scientia Biologicae. 2(1): 21-30.
[3] Elliott MC and Weston GD. 1993. Biology and physiology of the sugar-beetplant In: The sugar beet crop: Science into practice.Cooke DA, ScottRK (eds), Chapman and Hall, London pp 37-66.
[4] Glyn M. 1996. Mineral nutrition and artemisin content in. Acta Horticulture، No. 426
[5] Hemantaranjan A and Gray OK. 1988. Iron and Zinc fertilization with reference to the grain quality Triticum aestivum L. Journal of Plant Nutrition. 11: 1439-1450.

[6] Holleman F, Wiberg E and Wiberg N. 1985. "Iron" (in German). Lehrbuch der Anorganischen Chemie (91–100 ed.). Walter de Gruyter. pp. 1125–1146aestivum .L. Journal of Plant Nutrition. 11: 1439-1450.
[7] Lindsay W L and Schwab A P. 1982. The chemistry of iron soils and its availability to plants. Journal of Plant Nutrition. 5: 821–840.
[8] Lippard S and Berg J. M. 1994. Principles of Bioinorganic Chemistry. Mill Valley: University Science Books.
[9] May G and Pritts M. 1993. Phosphorus, Zinc and Boron influence yield components in 'Earliglow' strawberry. Journal of the American Society of Horticultural Science. 118: 43-49.
[10] McDonald I, Sloan G, Zijlstra AA, Matsunaga N, Matsuura M, Kraemer K. E, Bernard-Salas J and Markwick AJ. 2010. "Rusty Old Stars: A Source of the Missing Interstellar Iron?". The Astrophysical Journal Letters. 717 (2): L92-L97.
[11] Milford GFJ. 1973. The growth and development of the storage root of sugar beet. Annals of Applied Biology. 75 (3): 427–438.
[12] Morgan JW and Anders E. 1980. "Chemical composition of Earth, Venus, and Mercury". Proceedings of the National Academy of Sciences.77 (12): 6973–6977.
[13] Mortvedt JJ, Cox FR, Shuman LM and Welch RM. 1991. Micronutrients in Agriculture. Soil Science Society of America, Madison, Wisconsin, 760 p.
[14] Nam W. 2007. High-Valent Iron(IV)–Oxo Complexes of Heme and Non-Heme Ligands in Oxygenation Reactions. Accounts of Chemical Research. 40 (7): 522–531.
[15] Nijjar GS. 1990. Nutrition of fruit trees. Kalyani Pub. New Dehli.
[16] Seilsepour M and Ghaemi MR. 2007. Effects of Different Irrigation Water Quantities and Use of Fe and Zn on Yield and Water Use Efficiency of Tomato. Journal of Soil and Water Sciences. 20(2):71-80.
[17] Sommer AL. 1928. Further evidence of the essential nature of zinc for the growth of higher green plants. Plant Physiology. 3(2): 217-221.