Role of fertilizer types on total and available Boron concentrations in soil rhizosphere and Zea maize

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Abstract

the aim of studying the effect of fertilizer type on the availability of the boron element, a field experiment was conducted by planting local maize cultivar in one of the farmers' farms located in the Al-Diwaniyah Governorate / Al-Digharah District, which is about 18 km from the center of Al-Diwaniyah District for the autumn season of 2023. The experiment was implemented according to a completely randomized block design (R.C.B.D) with three replicates (12 experimental units) containing 4 treatments in each block, distributed randomly on the experimental units in each block. In addition, the field was fertilized with NPK fertilizer at a rate of 400 kg ha-1 for all experimental units. The available concentration of the boron element was estimated after 70 and 100 days of planting inside and outside the rhizosphere zone to determine the effect of organic, mineral, and humic acid fertilizers on their availability in the soil. The results showed that fertilization with humic acid was superior in available boron at 70 days after planting, and fertilization with organic residues was superior in available boron at 100 days after planting, while nitrogen fertilization was the least effective type of fertilizer in providing boron. The results showed the effect of adding sheep manure, as it gave the highest concentration of total boron in the rhizosphere soil and outside it, reaching 2.922, 1.115, 3.178, and 1.569 mg kg-1 soil at the 70 and 100 days of cultivation, respectively. The results also showed that fertilization of all types increases the availability of boron in the rhizosphere soil and outside it and that organic fertilization (humic acid and organic fertilizer) was superior in both periods (70 and 100) days after planting .

Keywords: Boron, Availability, Maize, Rhizosphere

- **Part of M.Sc. thesis of first author**

Introduction

Maize (Zea mays L.) is one of the important economic grain crops, ranking third after wheat and rice crops [1]. Boron is one of the important and essential micronutrients for plants. It is found in the soil in the form of boric acid H_3BO_3 and is adsorbed on aluminum and iron oxides and on the surfaces of clay minerals. It also binds to the organic matter present in the soil. The sources of boron in the soil are tourmaline and borosilicate minerals, which are the main minerals for it. It is also found in rocks and organic matter. However, due to the low solubility of these minerals, they affect the availability and supply of the element in the soil solution. The total concentration of boron in the soil ranges from 2-200 mg kg-1 soil. This means that less than 5% of this amount is available to the plant [2]. It is worth noting that an increase in the boron element, which is greater than 4 ppm, causes plant poisoning according to [3]. The deficiency in boron concentration is primarily caused by an increase in calcium levels. This is due to the antagonistic relationship between these two elements, especially when soil pH values are

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high. High calcium concentrations reduce the plant's ability to absorb boron. Often, plants absorb boron in the form of boric acid, which is the predominant form of boron when soil pH ranges from 5 to 9, Ali et al., [4] noted that organic complexes of boron are sources of boron, with available concentrations ranging from 5.0 to 6.5 mg kg-1 of soil.

Boron in plants is slow-moving, with toxicity symptoms appearing on older leaves, while deficiency symptoms appear on new growth. In dicotyledonous plants, boron concentration ranges from 20-60 mg kg-1, whereas in monocotyledonous plants, it ranges from 6-18 mg kg-1 [5]. Boron toxicity is significant in the soils of arid and semi-arid regions of North Africa and West Asia, including Iraq, where many studies have been conducted on boron toxicity [6, 7]. This research highlights the importance of boron (B) fertilization in the Rice-Wheat Cropping System (RWCS) in North-West India, addressing yield limitations due to B deficiency. A six-year field experiment found that alternate year B application at 1.5 kg ha−1 significantly improved crop yields, Sustainable Yield Index (SYI), and System Rice Equivalent Yield (SREY) by 6.7%. The optimal B dose was determined to be 1.422 kg ha−1, balancing productivity with ecological safety [8.[

Material and Methods

Prepare samples:

The field experiment was conducted on a farm located in the Al-Daghara district of Al-Diwaniyah Governorate, approximately 18 km from the center of Al-Diwaniyah. The soil of the field was classified as clay loam for the fall season of 2023. The field was prepared by performing necessary plowing, leveling, and smoothing operations. Three main irrigation channels were opened along the field, with secondary channels for each plot. The field was divided into three blocks, each separated by a distance of 1.5 meters. Each block was further divided into four plots (Experimental Units), with each experimental unit measuring 3 x 3 meters, resulting in an area of 9 m² per unit. A distance of 1 meter was left between each experimental unit. The experiment was carried out using a Randomized Complete Block Design (R.C.B.D) with three blocks, each containing four treatments, resulting in a total of 12 experimental units. The treatments included in the experiment were as follows:

- Addition of mineral fertilizer (M) in a single treatment labeled (M) at a rate of 400 kg ha-1 for each experimental unit. The fertilizer was applied in two doses: the first 15 days after planting, and the second 35 days after the first application [9.[
- Addition of organic fertilizer (sheep manure) (O) in a single treatment at a rate of 8 tons ha-1. The organic fertilizer was mixed with the topsoil before planting.
- Addition of humic acid in a single treatment labeled (H) at a rate of 500 cm³ per liter per dunam for each experimental unit. This was added with irrigation every 10 days until harvest, according to the instructions provided with the fertilizer.

Maize seeds (Zea mays L.), of a local variety, were planted on July 29, 2023, in rows

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with a spacing of 70 cm between rows and 25 cm between planting holes, resulting in 4 rows per plot and a planting density of 53,333 plants ha-1. Three seeds were placed in each hole, and 10 days after germination, the seedlings were thinned to one plant per hole, resulting in 48 plants per plot. The field was fertilized with NPK fertilizer at a rate of 400 kg ha-1 for all experimental units. Corn borer (Sesamia cailica) was controlled using granular diazinon 10% active ingredient, applied to the growing tips of the plants twice: the first time 25 days after germination, and the second time 10 days after the first application. Mealybugs were controlled by spraying the plants with Lambda cyhalothrin (EC5%). Additionally, manual weeding was conducted as necessary. The experimental units were irrigated by flooding (regular irrigation) according to the plants' needs.

Soil samples were randomly collected from the field before planting at a depth of 0-30 cm. These samples were thoroughly mixed to homogenize them, and a composite sample was taken to represent the entire field soil. The composite sample was air-dried in the laboratory, ground with a wooden hammer, and passed through a sieve with 2 mm openings for conducting some physical and chemical analyses of the field soil, as shown in Table 1

Physical Analyses:

• Particle Size Distribution: The particle size distribution of the soil was determined using the Hydrometer method as described by Black [9.[

• Bulk Density: Bulk density was measured using the Core sample method as described by Black [10.[

Chemical Analyses:

• Electrical Conductivity (EC): The electrical conductivity of the soil was measured using an EC meter in a 1:1 soil to water extract, according to the method described by Page et al. [11.[

• pH: The pH of the soil was measured in a 1:1 soil to water suspension using a pH meter, following the method described by Page et al. [11.[

• Cation Exchange Capacity (CEC): The cation exchange capacity was measured using ammonium acetate and sodium acetate, as described by Black [10.[

Organic Matter:

• Organic Matter: Organic matter was estimated using the Wet Digestion method with 1N K2Cr2O7, following the Walkley and Black method as described in Black [10.[

Soluble Cations and Anions:

• Calcium (Ca^{2+}): Calcium was determined by titration with Na_2 -EDTA using Ammonium Purpurate as an indicator, according to the method of Heald and Lanyon described in Page et al. [11.[

• Magnesium (Mg^{2+}): Calcium and magnesium were determined by titration with Na_2 -EDTA using Eriochrome Black T as an indicator. Magnesium was calculated by subtracting the calcium content from the total calcium and magnesium content, according to the method of Heald and Lanyon described in Page et al. [11.[

• Sodium (Na^+) and Potassium (K^+): These elements were determined using a Flame photometer, following the method described by Jackson [12.[

• Potassium (K^+): Soluble potassium was determined using a Flame photometer, following the open method by Knudsen et al., as described in Page et al. [11.[

• Chloride (Cl^-): Chloride was determined by titration with 0.01N $AgNO_3$ in the presence of potassium chromate, following the method described by Page et al. [11.[

• Carbonates and Bicarbonates ($CO_3{}^{2-}$ and $HCO_3{}^{-}$): Bicarbonates were determined by back-titration with 1N H_2SO_4 in the presence of methyl orange indicator, as described in Jackson [12.[

• Sulfates ($SO_4{}^{2-}$): Sulfates were determined by precipitation as barium sulfate, according to the method described in Black [10..[

Table (1) Some physical and chemical characteristics of the field soil before planting

Characteristics		**Value**	**Unit**
pH1:1		7.68	-
EC1:1		3.17	$ds.m^{-1}$
CEC		19.14	$Cmol.kg^{-1}$
Carbonates minerals		183.9	$gm.kg^{-1}$
Organic matter		7.2	$gm.kg^{-1}$
Soluble cations	Ca^{+2}	11.05	
	Mg^{+2}	9.73	
	Na^{+1}	5.08	
	K^{+1}	0.42	
Soluble Anions	$CO_3{}^{-2}$	Nil	
	$SO_4{}^{-2}$	8.60	$mmol.L^{-1}$
	$HCO_3{}^{-1}$	2.15	
	Cl^{-1}	18.41	
Available Boron		0.0278	$mg.kg^{-1}$
Bulk Density		1.24	$Mg.m^{-3}$
Soil Separetes	sand	257	$gm.kg^{-1}$
	Silt	414	
	clay	329	
Texture		Clay Loam	

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Available Boron: The available boron ion in the soil was determined according to the method described by Lindsay and Norvell [13] Twenty milliliters of 0.005M DTPA extraction solution (pH 7.3) was added to 10 grams of soil and shaken for two hours using an oscillating electric shaker. The solution was then filtered, and the elements were measured using an Atomic Absorption Spectrophotometer (model 7000-AA.(

Statistical Analysis:

The results were statistically analyzed using the Analysis of Variance (ANOVA) method, considering the experiment as a Randomized Complete Block Design (RCBD). The Least Significant Difference (LSD) was calculated to test the differences between treatments at a significance level of 0.05, following the method described by El-Sahookie and Wehaib [14] The Genstat software was used for this analysis.

Results and Discussion

Shoot length (cm(

Table (2) illustrates the effect of adding organic fertilizer (sheep manure), nitrogen fertilizer (urea), and humic acid on the concentration of available boron 70 days after planting in the rhizosphere and non-rhizosphere areas of maize. The results

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showed significant differences at the 0.05 significance level for the treatments compared to the control (cont), except for the nitrogen fertilizer treatment, which did not show a significant difference from the control outside the rhizosphere. The control treatment resulted in the lowest concentration and average of available boron in both the rhizosphere and non-rhizosphere soil, with values of 0.102 and 0.093 mg kg-1, respectively, and an overall average of 0.097 mg kg-1. In contrast, the treatment with humic acid (H) gave the highest concentration and average of available boron inside and outside the rhizosphere soil 70 days after planting, with values of 0.620 and 0.413 mg kg-1, respectively, and an overall average of 0.517 mg kg-1. This represents an increase of 83.5% and 78.2%, respectively, compared to the control treatment. The reason for this is attributed to the fact that humic acid lowers soil pH. Soil pH is one of the factors that affect the amount of available boron in the soil. There is a correlation between available boron and soil solution pH [15]. This is consistent with the findings of Sheng-Bin [16.[

The organic fertilization treatment (O) significantly outperformed the control treatment, with available boron concentrations in the rhizosphere and non-rhizosphere soil reaching 0.378 and 0.302 mg kg-1, respectively, and an overall average of 0.340 mg kg-1. This represents an increase of 73% and 69.2%, respectively. This improvement is attributed to the fact that organic matter is one of the soil components that directly affects the availability of boron by increasing the activity of soil microorganisms [17]. This finding is consistent with the results of Jarallah and Al-Mayaly [18,19] and Niaz et al., [20]. Organic matter is an important soil component that influences the behavior and state of available boron in the soil. The results in the table also show that the concentration of available boron in the nitrogen fertilization treatment (M) in the rhizosphere and non-rhizosphere soil reached 0.254 and 0.120 mg kg-1, respectively, with an overall average of 0.187 mg kg-1. This represents an increase of 59.8% and 22.5%, respectively. However, this treatment did not show significant differences compared to the control treatment outside the rhizosphere. This is because nitrogen fertilizers increase the meristematic activity of cells, positively reflecting the size of the vegetative mass and flower production, as well as enhancing the root system, which helps improve the plant's efficiency in absorbing nutrients from the soil) [21.[

Table 2: The effect of fertilizer type on the concentration of available boron (mg kg-1 soil) 70 days after planting

Fertilizer type	Inside rhizosphere	Outside rhizosphere
Ccontrol	0.102	0.093
Nitrogen fertilizer	0.254	0.120
Organic fertilizer O	0.378	0.302
humic acid H	0.620	0.413
$LSD_{0.05}$	Fertilizer 0.120	Rhizosphere 0.085

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Concentration of available boron in soil 100 days after planting

The results in Table (3) show the effect of organic, nitrogen, and humic acid fertilization levels on the concentration of available boron in the rhizosphere and non-rhizosphere soil 100 days after planting. The organic fertilization treatment (sheep manure) resulted in the highest concentration of available boron in both the rhizosphere and non-rhizosphere soil, with values of 0.930 and 0.642 mg kg-1, respectively, and an overall average of 0.786 mg kg-1. This represents an increase of 50.6% and 67.4%, respectively, compared to the control treatment. The reason for this is the significant positive correlation between boron concentration and organic matter in cultivated soils, as increased organic matter reduces boron leaching and increases boron adsorption [22]. This finding is consistent with the results of Jarallah and Al-Zayadi [23]. The organic residues underwent decomposition over time, releasing dissolved organic carbon and breaking down carbon bound to functional groups that carry a negative charge, which tends to bind with the positively charged ions of micronutrients .

The results also showed the effect of humic acid fertilization (H) on boron availability, which significantly outperformed the control treatment

The concentration of available boron in the rhizosphere and non-rhizosphere soil was 0.729 and 0.496 mg kg-1, respectively, with an overall average of 0.612 mg kg-1. This represents an increase of 37% and 57.8%, respectively, compared to the control treatment. This is attributed to the fact that humic acid enhances nutrient absorption by acting as a medium for nutrient transport. It also increases root biomass and affects the protoplasm and cell wall, leading to rapid cell division and growth [24 .[

The results also show the effect of nitrogen fertilizer (M) on the rhizosphere and non-rhizosphere soil, with available boron concentrations reaching 0.528 and 0.315 mg kg-1, respectively, and an overall average of 0.422 mg kg-1. This represents an increase of 13% and 33.6%, respectively. This is due to the importance of nitrogen in building chlorophyll molecules, enzymes, proteins, cellular membranes, and in cell division and elongation. Nitrogen fertilizers contribute to increased nutrient absorption, positively affecting plant growth and productivity when used [25.[

Table 3: The effect of fertilizer type on concentration of available boron in soil 100 days after planting

Fertilizer type	Inside rhizosphere	Outside rhizosphere
Ccontrol	0.459	0.209
Nitrogen fertilizer	0.528	0.315
Organic fertilizer O	0.930	0.642
humic acid H	0.729	0.496
$LSD_{0.05}$	Fertilizer 0.261	Rhizosphere 0.185

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Figure (1) shows an increase in the concentration of available boron for all treatments, indicating that the added fertilizers enhanced boron availability in the soil. The highest concentration of available boron in the rhizosphere soil was observed with the organic fertilization treatment after 100 days, while the lowest concentration outside the rhizosphere was seen with the control treatment after 70 days.

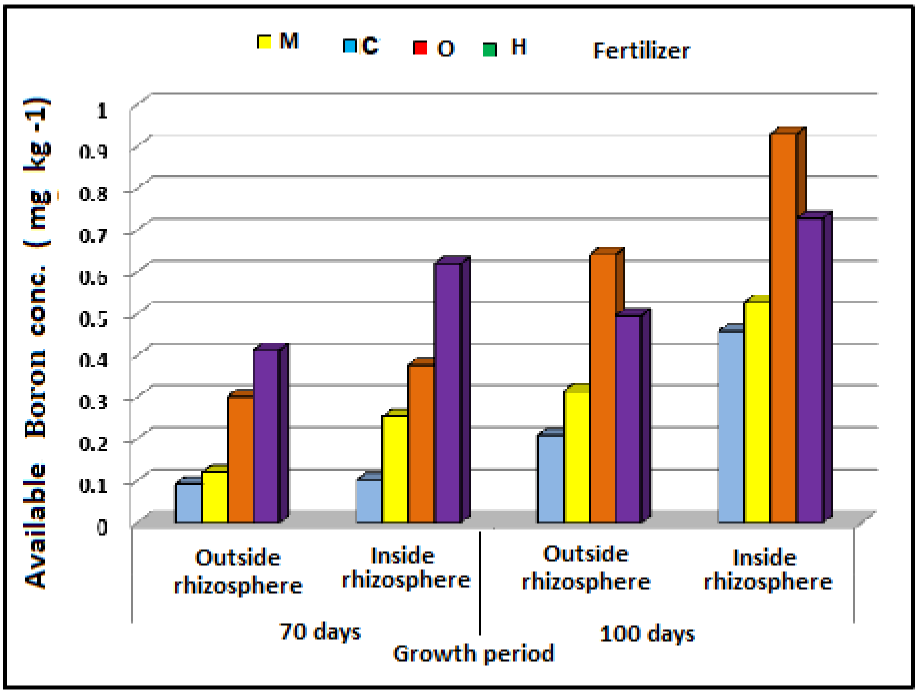

Figure 1: Effect of growth duration (70, 100 days) on the concentration of available boron in the soil (mg kg-1 soil .(

From the results, we find that the concentration of available boron in the treatments followed this order from highest to lowest after 100 days of growth :

$M<H<O$ This sequence indicates that organic fertilizer and humic acid provided more boron compared to nitrogen fertilization. For all fertilizer treatments, the available boron values followed this order from highest to lowest after 70 days of growth :

$M<O<H$ This sequence indicates that nitrogen fertilization was the least effective in providing boron among the studied fertilizers.

Total boron concentration in the soil 70 days after planting:

The results of Table (4) showed the effect of the treatments of adding organic fertilizer (sheep waste), nitrogen fertilizer (urea), and humic acid on the total boron concentration after 70 days of planting in the rhizosphere zone and outside it for yellow corn plants, as the highest value for the organic O fertilization treatment was in the rhizosphere zone. It reached 2.922, while the control treatment gave the lowest value in the area outside the rhizosphere. When comparing the organic fertilization treatment with the control

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treatment, we notice significant differences at a significance level of 0.05, as the organic fertilization treatment gave the highest value for total boron in the soil of the rhizosphere and outside it, amounting to 2.922, 1.115 mg kg-1 respectively, and an average of 2.018, with an increase rate of 70.7 and 55.6% respectively. The reason for this is attributed to the effect of sheep waste in improving the physical and chemical properties of the soil. It works to prevent changes in the degree of soil interaction and preserve nutrients from loss to the bottom of the rhizosphere, and the products of their decomposition increase the supply The soil contains many nutrients. Sheep manure is also an important source of microorganisms in the soil, which increases their activity and makes micronutrients easily available to plant roots [26]. As for the humic acid fertilization treatment, we notice from the table that the treatment was significantly superior to the control treatment, as the total boron concentration in the rhizosphere soil and outside it reached 2.665 and 0.888 mg kg-1, respectively, with an average of 1.776 and an increase rate of 67.8, 43.8%, respectively. This is attributed to the ability of humic acid to High humic acid in ion exchange, as it allows cations to be carried easily to the plant roots, thus increasing the concentration of microelements in the soil and transferring nutrients to the plant's exchange system [27]. The results of the table also showed that the total boron concentration in the nitrogen fertilization treatment M in the rhizosphere soil and outside it reached 1.277 and 0.676 mg kg-1, respectively, with an average of 0.977 and an increase rate of 32.9, 26.9% respectively, with significant differences in the rhizosphere region and non-significant outside it compared to the treatment. Control, this is due to the fact that nitrogen fertilization provides plants with the
element nitrogen and the elongation of plant parts due to cell division .

Table (6) Type of fertilizer effect on total boron concentration (mg kg-1 soil) after 70 days of planting

Fertilizer type	Inside Rhizosphere	Out Rhizosphere
Control	**0.856**	**0.499**
M	**1.277**	**0.676**
O	**2.922**	**1.115**
H	**2.665**	**0.888**
$LSD_{0.05}$	**Fertilizer type 0.317**	**Rhizosphere 0.224**

From the above results, we find that the total boron values for all fertilizer treatments took the following sequence from highest to lowest at the growth period of 70 days from planting:

M < H < O

This sequence shows that the organic fertilization treatment had the highest total boron values among the types of fertilizers studied. This sequence shows that the organic fertilizer and humic acid treatments gave higher values of total boron than the nitrogen fertilization treatment.

It has a significant impact on plant growth by increasing the rate of the photosynthesis

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process and increasing the leaf area and seed development, by building metabolic materials and working to regulate plant hormones (Cytokines and auxins, which lead to meristematic cell division and an increase in the size of the root and shoot [28.[

Total boron concentration in soil 100 days after planting

The results of Table (5) showed the effect of the levels of organic and nitrogen fertilization and humic acid on the total boron concentration in the rhizosphere soil and outside it after 100 days of cultivation. We notice from the results of the table below that the organic O fertilization treatment (sheep waste) gave significant differences compared to the control treatment, as it was higher The concentration of total boron in the rhizosphere soil and outside it reached 3.178 and 1.569 mg kg-1respectively, with an average of 2.374 and an increase rate of 27.2 and 74.9% respectively compared to the control treatment. The reason for this is that the organic matter affects the behavior of boron in the soil. It has been shown There is a positive correlation between total boron and the organic matter content in the soil [29]. We also note from the results of the table the effect of the fertilization treatment with humic acid added to the soil on total boron, as it was significantly superior to the control treatment. The total boron concentration in the rhizosphere soil and outside it reached 2.855 and 1.351 mg kg-1, respectively, and the average reached 2.103, with an increase rate of 19.70.6% over The reason for this is that adding humic acid has positive effects on the development of the root system and shoots, seed germination, and improving the utilization of nutrients, and that adding 1 kg of humic acid is equivalent to 1 ton of mineral fertilizer [30]. The results of the table also showed the effect of adding nitrogen fertilizer M to the rhizosphere soil and outside it, as the total boron concentration reached 2.716 and 0.962 mg kg-1, respectively, and the average reached 1.839, with an increase rate of 14.9, 58.7% respectively .

Table (5) Effect of fertilizer type on total boron concentration (mg kg-1 soil) 100 days after planting.

Fertilizer type	**Inside Rhizosphere**	**Out Rhizosphere**
Control	**2.311**	**0.397**
M	**2.716**	**0.962**
O	**3.178**	**1.569**
H	**2.855**	**1.351**
$LSD_{0.05}$	**Fertilizer type 0.317**	**Rhizosphere 0.224**

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Figure (2) shows an increase in the total boron values for all treatments. This indicates that the added fertilizers increased the total boron values in the soil, as the highest boron value was in the rhizosphere soil during the 100-day period for the organic fertilization treatment, and the lowest value was in the soil outside the rhizosphere for the control treatment. For the same period.

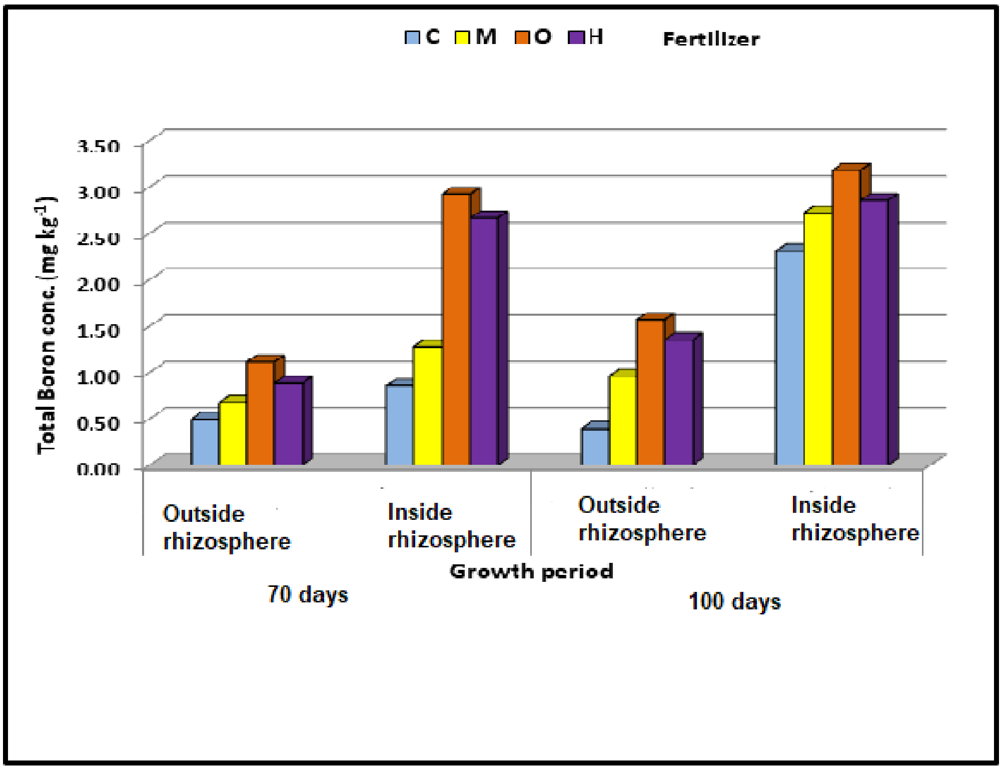

Figure (2) Effect of growth period (70, 100) days on total soil boron concentration (mg kg-1 soil(

The reason for this is attributed to the fact that adding nitrogen stimulates the vegetative growth of the plant. By increasing the size and number of cells, thus increasing the leaf area and thus increasing the outputs of the photosynthesis process [31.[

The coefficients took the following sequence in the amount of total boron M < H < O

Conclusion

According to obtained results the girdling lead to improve all studied parameters compared with non-girdle one. Girdling of Zark cultivar have a significant effect on number of clusters, shoot length, number of leaves per shoots,

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number of berries per clusters, Total sugar in berries and TSS in berries. Also, the girdling of Kamali cultivar led to enhancement in number of clusters, shoot length, number of shoots per vine, number of leaves per shoots and size of berries. Spraying of phosphorus especially at 10g.L-1 had a significant effect on all studied parameters compared with control.

The combination of girdling and 10 g.L-1 with either cultivar was superior treatment with most of parameters compared to the control of both cultivars.

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