Effect of Foliar Spray with Zinc, Boron, Calcium and Potassium on Growth, Yield, and Tuber Root Quality of Sweet Potato.

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ABSTRACT

The research for this essay took place on recently reclaimed sandy soil at Ali Moubark Farm, at South Tahrir Research Station, Horticulture Research Institute (HRI), Agricultural Research Center (ARC), in Egypt, during the two successive growing seasons of 2022-2023. To investigate the effect of spray with chelated Zinc (Zn), Boron (B), chelated Calcium (Ca) and compound Potassium (K) on growth, yield and tuber roots quality of sweet potato *cv.* Abees. The randomized complete block design was used in four replications. From the results could be noticed that application of Zinc and Boron mixture showed the highest values of vegetative growth (vine length, number of branches per plant, leaf area and chlorophyll content) and total yield ton fed^{1}. The same application (Zn plus B) gave the best yield components (tuber root diameter, weight, length, and number per plant). Also, Zinc and Boron mixture treatment increased chemical content in plants vine [dry weight (gm)/plant, Zinc (ppm), Boron (ppm)] and chemical content in tuber root [dry matter (%), nitrogen (%), phosphor (%), potassium (%), calcium (%), zinc (ppm), boron (ppm), total carbohydrate (%), starch content (%) and protein (%)]. While, the control treatment recorded the lowest results of the previously mentioned characters.

Keywords: Sweet Potato- Chelated Zinc Boron - Calcium - Compound Potassium.

INTRODUCTION

Sweet potatoes, *Ipomoea batatas* (L.), belong to the convolvulaceae family. Sweet potatoes are regarded as vine plants with tuber roots in cultural groups with tropical, subtropical and mild temperatures without frost. Animals and humans both use sweet potatoes.

In Egypt, sweet potatoes are a commonly consumed vegetable. While the vine sections and other by products are excellent for animal nutrition, it has been cultivated for the starch and food industries as well. Great efforts have aim to better yield and quality of sweet potato for increasing exported yield (El-Seifi et al., 2014). Sweet potato is an exhausted crop with rise product and low term.

Therefore, it is crucial to classify nutrients in a balanced manner to improve the plant's quality and quantity of production. To achieve a useful expansion and growth of sweet potatoes, nutrient supplies for the plant must be available in adequate amounts to give high crop production and raise the quality of tuberous roots due to return soil fertility. In this research, foliar spray with Zinc and Boron as micronutrients as well as Calcium and Potassium as macronutrients were used an application for better performance of sweet potato. Zinc (Zn) as one of the micronutrients essential to plant growth and development. It plays a critical metabolic role (Khan et al., 2019). Also, Camacho-Cristbal et al. (2008) and El-Hadidi et al. (2017) noted that Born (B) plays a major role in the growth and strength of cell walls, cell division, fruit and seed development, sugar transfer, and hormone production. The types of components which constitute the soil mostly determine the amounts of Boron and Zinc in the soil. In general, clay soils have higher quantities of Zinc and Boron than sandy soils. Since sandy soils lack sufficient elemental content, mineral fertilizers containing Zinc and Boron may need to be added, either directly to the soil or through foliar spraying (Szulc and Rutkowska, 2013). Furthermore, Calcium is one of the macronutrients needed for optimum growth and development. It participated in physiological processes such as nutrition absorption, strongest cell extension, and cell wall structure (Reyes et al., 2013) and (Ismail et al., 2022). Potassium (K) is a macronutrient that is necessary for photosynthesis, photosynthetic translocation, protein synthesis, ionic balance regulation, tolerance to stress, and water use in crop growth and production (Marschner, 2013 and Christian et al., 2014).

So, the purpose of this study was to determine how effects of foliar spraying sweet potato cv. Abees in sandy soil with chelated Zinc, Boron, Calcium and potassium on the plant`s development, production and quality.

MATERIALS AND METHODS

During the two succeeding growing seasons of 2022–2023, a field study was conducted at Ali Moubark Farm, South Tahrir Research Station, Horticulture Research Institute, on recently reclaimed sandy soil. The data utilized to identify the physical and chemical properties soil parameters for the area experiment at **(Table 1)** was supplied by Rebecca (2004).

Table (1). Physical and chemical soil properties were tested in the area at depths ranging from 0 to 30 cm (average of the two seasons).

Particle size distribution						
Sand (%)	**Silt (%)**	**Clay (%)**	**Texture class**	**pH (1:2.5)**	**EC (dSm^{-1})**	**Organic matter %**
90.5	5.4	4.1	Sandy	7.2	0.43	0.45

Catoins and anions (meq)								**Available NPK (mg/ kg soil)**		
Ca^{+2}	**Mg^{+2}**	**Na^{+}**	**K^{+}**	**Co_3^{-}**	**Hco_3^{-}**	**Cl_{-1}**	**So4-2**	**N**	**P**	**K**
1.30	**0.75**	**1.9**	**1.69**	**0**	**1.19**	**2.4**	**2.05**	**10**	**13**	**65**

Stem cuttings of sweet potato cv. Abees, about 20 cm length, were planted on two-line drip irrigation with 10 m long and 70 cm wide, at 25 cm apart, on 10/5/2022 and 24/5/2023. The plot area was 14 m^2. A Randomized Complete Block Design was used with four replications. Another cultural practice was applied accepting to recommendation Ministry of agriculture.

The experiment included 6 treatments as follows:

1. Control (spray with distilled water).
2. Chelated Zinc Zn-EDTA (Zn) at 2.0 gm /L.
3. Boron as from Boric acid H_3BO_3 (B) at 750 gm/fed. B with rate 2.5 gm /L.
4. Chelated Calcium Ca-EDTA (Ca) at 1.5gm/L.
5. Compound Potassium as from Potassium citrate KNO_3 (K) at 2.5gm /L.
6. Mixture of Zinc and Boron.

Foliar spray was applied four times, at 40, 55, 70 and 85 days after planting. The compounds utilized were prepared on the same day and were commercial products of El-Gomhorya Company in Egypt.

Note: Chelated Zinc contains 13 % Zn, Boric acid contains 17 % B, chelated Calcium contains 10% Ca and compound Potassium contains 37 % K.

The concentrations used in this experiment from the different elements were selected according to best results stated in many reviews.

The Zn and B are trace elements, thus adding them as combined to the sandy soil – which has insufficient amounts from both elements- may gave the best results.

Data that is recorded:

A- Vegetative growth

After 105 days of planting, five plants were randomly selected from each plot to calculate the average of the subsequent data:.

1. Length of vine (cm).
2. The number of branches/plants.
3. Leaf area. The LI-3100 area meter (LI-COR, Inc., Lincoln, Nebraska, USA) was used to measure the leaf area/plant of the fifth top completely leaf.
4. The fresh fifth top completely leaf was used to measure the amount of chlorophyll in the leaf. (A digital chlorophyll meter; Minolta Chlorophyll meter SPAD-502, Minolta Company, produced). 10 mg/100g fresh weight of leaves is the SPAD unit (Netto et al., 2005)

B- The components of yield

At harvest time (140 days after planting), all tuber roots in each plot were collected, and the following parameters were recorded.

1. The total yield in ton/ fed [1].
2. Diameter of tuber root (cm).
3. Root weight of tuber root (g).
4. Length of tuber root (cm).
5. Number of tuber roots.

C- Chemical composition

Plant samples (vine and tuber roots) were kept at a relatively dry temperature of 70°C until a fixed weight of 0.5 g was utilized for the chemical analysis, which was performed using a dry weight basis. According to Cottenie et al. (1982), 0.5 g (plant sample power) of each sample was digested using 5 cm^3 of a mixture of sulfuric acid (H_2SO_4) and perchloric acid ($HClO_4$) rate (1:1). The modified micro Kjeldhal method (Cottenie et al., 1982) was used for determining total Nitrogen (N %). Additionally, Phosphorus (P) utilizing a spectrophotometer and colorimetric technique (Ryan et al., 1996). Using an atomic absorption spectrophotometer, the concentrations of the macro and microelements Calcium, Potassium and Zinc were determined (Jones, 2001). The Azomethine-H technique was used in a spectrophotometer set at 420 nm to detect the colorimetric concentration of Boron (Wolf 1971).

According to A.O.A.C. (2016), the protein percentage in tuber roots was calculated by multiplying the nitrogen percentage by a factor of 6.25. The colorimetric method published by Dubois et al. (1956) was used to determine the total amount of carbs. The percentage of starch in the tuber was calculated using the A.O.A.C. (2016) procedures.

Statistical analysis

Data were submitted using the Snedecor and Cochran (1980) test of difference method. Duncan Multiple Range Test at 5% was used to compare the treatment means (Duncan 1955). The STATISTIX version 8.0 program was used for all data analysis.

RESULTS AND DISCUSSIONS

A- Growth measurements

Results at Table (2) showed the effect of foliar spray with chelated Zinc, Boron, chelated Calcium, and compound Potassium on plant vine parameters (vine length, branches number, leaf area and chlorophyll content). It clears that, all growth parameters and chlorophyll content were significantly affected in both seasons. Generally, the foliar spray treatments had promoting effectiveness on all studied morphological parameters of sweet potato. Using the spray with mix of Zinc and Boron recorded the maximum rate of vine length, number of branches, leaf area (per plant) and chlorophyll content (SPAD), whilst the minimum values were recorded with control (spray with distilled water). The other treatment has not been far cried between might be due to their have vital functioning in plants, but the same line in increasing. The beneficial effects of macro- and micronutrients on plant vine characteristics may be due to their metabolic function in plant growth and development (El-Hadidi et al., 2017 and Khan et al., 2019). Foliar sparing with Zn plus B gave the highest amount of growth parameters due to increase absorbed nutrients by leaves (Ismail et al., 2022). The results obtained are consistent with those of Awad et al. (2010) on potatoes, Abd El-Baky et al. (2010) on sweet potatoes, and Saif El-Deen et al. (2015) on sweet potatoes. These studies show that foliar spraying plants with a combination of micronutrients increases plant vine when compared to the control group.

Table (2): The effect of foliar spraying with zinc, boron, calcium, and potassium on vegetative growth of sweet potatoes in the 2022 and 2023 seasons.

. Treatments	Length of Vine (cm)		Number of branch / plants		Leaf area (cm^2/plant)		Content of chlorophyll (SPAD)	
	2022	2023	2022	2023	2022	2023	2022	2023
Control	155.0d	151.3c	8.7d	9.7b	308.3b	267.7b	41.1b	44.4b
Zinc (Zn)	185.3b	163.3b	11.0c	10.0b	310.3ab	273.7b	45.9ab	49.5ab
Boron (Bo)	191.0ab	166.7ab	11.3c	10.3ab	314.7ab	285.7ab	45.2ab	49.5ab
Calcium (Ca)	166.0c	160.3bc	12.0bc	10.3ab	315.3ab	281.7ab	46.5ab	50.8ab
Potassium (K)	170.0c	165.3b	14.0ab	11.0ab	316.3ab	285.0ab	47.9ab	51.2a
Zn + Bo	196.0a	175.7a	15.0a	12.0a	320.7a	298.0a	48.6a	53.0a

The means inside the same column shared by the same letters do not significantly differ at 5%, according to Duncan's Multiple Range Test.

B- Yield and its components

The effects of foliar spraying sweet potatoes with Zinc, Boron, Calcium, and Potassium on yield and component parts were displayed in Tables 3 and 4. Applying a foliar spray with a Zinc and Boron mixture to plants proved to be more effective than other treatments. Furthermore, this treatment significantly increases total yield (ton/ fed.), tuber root diameter per plant, tuber root weight per plant, tuber root length per plant and tuber root number per plant during both seasons. From data, it was noted that tuber roots that were longer and smaller in diameter recorded lower weight and vice versa.

Table (3). The effect of foliar spraying sweet potatoes with zinc, boron, calcium, and potassium on yield and their constituents in the 2022 and 2023 seasons.

Treatments	Total yield (ton $fed.^{-1}$)		Tuber root diameter (cm)		Tuber root weight (g/plant)		Tuber root length (cm)	
	2022	2023	2022	2023	2022	2023	2022	2023
Control	8.6c	7.0c	6.1b	5.4d	5787.8b	3751.3b	12.7d	15.5c
Zinc (Zn)	10.0bc	8.4bc	7.3ab	7.0b	6019.5b	5206.5ab	16.3ab	18.6ab
Boron (Bo)	12.0ab	10.1ab	7.5ab	6.3c	5833.3b	4562.8ab	15.3bc	17.8ab
Calcium (Ca)	10.7b	9.3ab	7.6ab	6.1c	7005.8ab	5801.2ab	15.2bc	17.6b
Potassium (K)	11.5b	9.9ab	7.0ab	6.1c	6180.8ab	4288.5ab	13.9cd	17.4b

Zn + Bo	13.8a	10.8a	8.4a	7.8a	7275.5a	6831.0a	17.4a	19.1a

The means inside the same column shared by the same letters do not significantly differ at 5%, according to Duncan's Multiple Range Test.

C- Chemical composition

1) Plants vine:

Results presented in **Tables (4 and 5)** indicated that plants foliar spray with mix of Zinc and Boron increase plant vine dry weight/ plant compared with the untreated plant in both two seasons. In both examined seasons, foliar spray applications had no discernible effect on the percentage of macro elements (Nitrogen, Phosphorus, Potassium, and calcium) in sweet potato vine plants. There were obvious effects on plant concentrations of Zinc and Boron in plants vine in both seasons, while the maximum value of Zinc and Boron in plants vine achieved by spraying Zinc and Boron mixture compared to the control.

Also, from the data was found that, Zinc content of plants vine recorded the next highest values (after spaying with Zn + B) when plants sprayed with Zinc, while Boron content of plants vine recorded the next highest values (after spraying with Zn + B) with Boron treatment.

Table (4). The effect of foliar spraying sweet potatoes with zinc, boron, calcium, and potassium on tuber root number and plants vine dry weight, Nitrogen and Phosphor during 2022 and 2023 seasons.

Treatments	Tuber root number/plant		Plants vine dry weight/ plant (gm)		Plants vine Nitrogen (%)		Plants vine Phosphor (%)	
	2022	2023	2022	2023	2022	2023	2022	2023
Control	29.3c	33.7b	105.7c	112.1c	1.60a	1.87a	0.162a	0.171a
Zinc (Zn)	40.0ab	47.0a	114.6bc	117.5bc	2.65a	2.78a	0.206a	0.235a
Boron (B)	36.0abc	42.0ab	122.8b	125.7bc	2.76a	1.82a	0.210a	0.224a
Calcium (Ca)	32.7bc	37ab	107.4c	127.3bc	2.53a	2.62a	0.171a	0.204a
Potassium (K)	36.0abc	43.0ab	126.8b	139.2ab	2.74a	2.81a	0.188a	0.241a
Zn + B	42.3a	49.0a	142.1a	161.0a	2.86a	2.92a	0.253a	0.264a

The means inside the same column shared by the same letters do not significantly differ at 5%, according to Duncan's Multiple Range Test.

Table (5). The effect of foliar spraying sweet potatoes with zinc, boron, calcium, and potassium on potassium, calcium, zinc and boron contents of plant vine during 2022 and 2023 seasons.

Treatments	Potassium (%)		Calcium (%)		Zinc (ppm)		Boron (ppm)	
	2022	2023	2022	2023	2022	2023	2022	2023
Control	1.92a	2.01a	0.94a	1.09a	22.7d	25.5e	18.3e	19.8e
Zinc (Zn)	2.16a	2.23a	1.26a	1.45a	35.6ab	36.8b	24.6c	26.3d
Boron (B)	2.18a	2.27a	1.21a	1.42a	34.4bc	35.2c	31.8b	34.4b
Calcium (Ca)	2.11a	2.18a	1.36a	1.55a	32.5c	32.8d	22.7d	24.7d
Potassium (K)	2.41a	2.48a	1.32a	1.48a	34.4bc	35.3c	25.3c	28.3c
Zn + B	2.45a	2.53a	1.35a	1.63a	36.6a	37.3a	35.2a	38.2a

The means inside the same column shared by the same letters do not significantly differ at 5%, according to Duncan's Multiple Range Test

2) Tuber root quality

Concerning the effect of the foliar spraying with Zinc, Boron, Calcium and Potassium on tuber roots, **Tables (6 and 7)** results indicated that the highest value to tuber roots dry matter percentage recorded with applying mixture of Zn + B and Potassium treatment (as foliar spray) compared with other treatments on the first season only. While Nitrogen, Phosphor and Potassium of tuber roots increased with foliar application of Zn + B mixture compared to control treatment during first season too, **Table (6).** In the second season these characters (Nitrogen, Phosphor and Potassium of tuber roots) were no significant affected with applied treatments. These results are consistent with those achieved by El-Morsy et al. (2006) on potato and Ismail et al. (2022) on globe artichoke.

Table (6). The effect of foliar spraying sweet potatoes with zinc, boron, calcium and potassium on dry matter, Nitrogen, Phosphor and Potassium contents of tuber roots during 2022 and 2023 seasons.

Treatments	Tuber root dry matter (%)		Tuber roots Nitrogen (%)		Tuber roots Phosphor (%)		Tuber roots Potassium (%)	
	2022	2023	2022	2023	2022	2023	2022	2023
Control	12.0b	11.0a	1.33f	1.43a	0.096f	0.097a	1.11e	1.08a
Zinc (Zn)	13.5ab	12.0a	2.33c	2.54a	0.154c	0.153a	1.24c	1.20a
Boron (B)	13.8ab	12.0a	2.21d	2.43a	0.159b	0.143a	1.25c	1.27a
Calcium (Ca)	13.3ab	13.0a	1.82e	1.93a	0.122e	0.127a	1.16d	1.14a
Potassium (K)	14.2a	13.0a	2.47b	2.66a	0.135d	0.148a	1.35b	1.38a
Zn + B	15.2a	13.4a	2.54a	2.75a	0.174a	0.181a	1.38a	1.43a

The means inside the same column shared by the same letters do not significantly differ at 5%, according to Duncan's Multiple Range Test

Data in **Table (7)** showed the effect of different foliar spray on chemical of sweet potato tuber roots i.e. Calcium (%), Zinc (ppm), Boron (ppm) and total carbohydrates. Results indicated that there were significantly effects among treatments. Foliar spray with mixture Zn + B treatment gave highest values in measured chemical of tuber roots compered the control in 2022 and 2023 seasons of study. These results coincide with the findings, as reported by Abd El-Baky et al. (2010) on sweet potato, El-Hadidi et al. (2017) on potato and Ismail et al. (2022) on globe artichoke.

Concerning the effect of foliar spray on starch content % and protein % of sweet potato tuber roots **Fig. (1and 2),** the results showed that, all foliar spraying treatments recorded the same result except untreated plant for starch content during both seasons (Fig. 1).

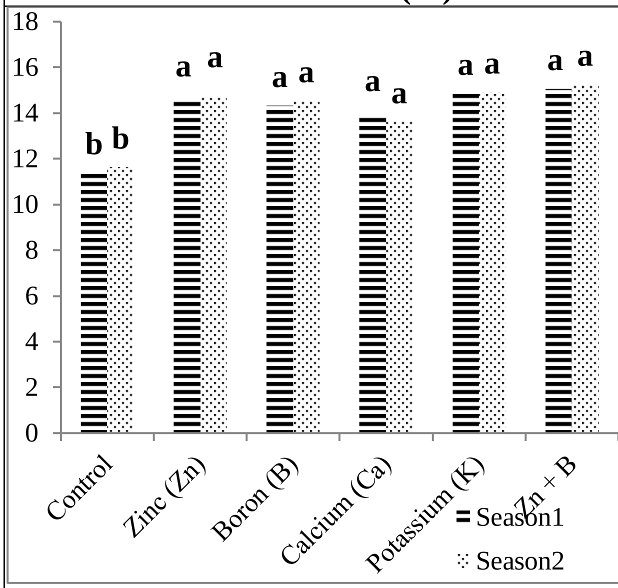
While the protein percentage in the two seasons recorded significant differences as affected by different treatments, it is clear from the results in the **Fig. (2)** that Zn + B treatment gave the highest values for protein compared with other treatments and control. These results are in line with the findings, which have been reported by El-Hadidi et al. (2017) on potato and Ismail et al. (2022) on globe artichoke.

Table (7). The effect of foliar spraying sweet potatoes with zinc, boron, calcium and potassium on calcium, zinc, Boron and total carbohydrates contents of tuber roots during 2022 and 2023 seasons.

Treatments	Calcium %		Zinc (ppm)		Boron (ppm)		Total carbohydrates (%)	
	2022	2023	2022	2023	2022	2023	2022	2023
Control	1.31c	1.55f	24.0e	24.5d	17.8d	19.1e	19.7b	20.3c
Zinc (Zn)	3.44b	3.62e	39.3b	40.8ab	22.5bc	25.6c	22.6a	23.7ab
Boron (B)	4.43ab	4.64d	37.2c	37.3c	29.9a	32.5b	22.1a	23.3ab
Calcium (Ca)	4.62 ab	4.91 b	35.6d	35.8c	20.9c	22.6d	21.6ab	22.6b
Potassium (K)	4.47ab	4.76c	38.6bc	39.3b	24.1b	26.8c	22.8a	23.8ab
Zn + B	5.51a	5.55a	41.3a	42.2a	30.5a	34.6a	23.5a	24.6a

The means inside the same column shared by the same letters do not significantly differ at 5%, according to Duncan's Multiple Range Test.

Starch content (%)



Protein (%)

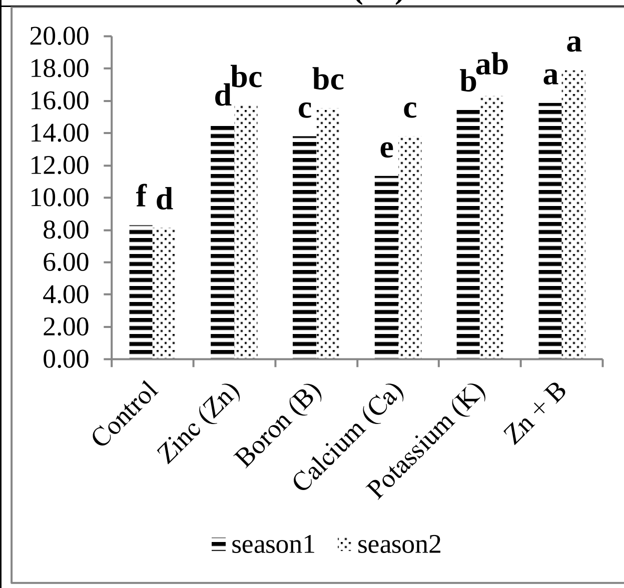


Fig. (1 and 2). The effect of foliar spraying sweet potatoes with Zinc, Boron, Calcium and Potassium on starch and protein contents of tuber roots during 2022 and 2023 seasons.

Conclusions and Recommendations

Based on the findings it could be recommended to use application of foliar spraying with mixture of Zinc (2.0 gm/L) and Boron (2.5 gm/L) to improve sweet potato growth, productivity and quality.

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الملخص العربى

تأثير الرش الورقى بالزنك والبورون والكاليسيوم والبوتاسيوم على نمو ومحصول وجودة جذور البطاطا المتدرنه

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أجريت التجربة فى أراضى رملية حديثه الإستصلاح فى مزرعة على مبارك محطة بحوث جنوب التحرير معهد بحوث البساتين, مركز البحوث الزراعية، مصر خلال موسمى زراعة 2022 و2023م. لدراسة تاثير الرش الورقى بالزنك المخلبى والبورون والكاليسيوم المخلبى والبوتاسيوم المركب على نمو ومحصول وجودة البطاطا صنف أبيس. وقد صممت التجربة فى قطاعات كاملة العشوائية لأربع مكررات للمعاملة.

وقد أوضحت النتائج أن معاملة الرش بمخلوط من عنصرى الزنك والبورون قد أعطت أعلي نتائج للنمو الخضرى (طول العرش وعدد الأفرع لنبات ومساحة الورقة ومحتوى الكلورفيل فى الأوراق) والمحصول الكلى ومكونات المحصول (مثل قطر ووزن وطول وعدد الجذور المتدرنة) والتحليل الكيماوى لعرش نبات البطاطا من الكيماوى (مثل الوزن الجاف للعرش ونسبة عنصرى الزنك والبورون) ومحتوى الجذور المتدرنة من الكيماوى (مثل نسبة المادة الجافة للجذور المتدرنة ونسبة عناصر النيتروجين والفوسفور والبوتاسيوم والكالسيوم والزنك والبورون والكربوهيدرات الكلية ومحتوى النشا ونسبة البروتين). وقد سجلت معاملة الكنترول (الرش بالماء المعقم) أقل قيم لجميع الصفات المدروسة.