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Effect of morenga extract on performance of growth and yield characteristics on sunflower *(Helianthus annuus L.)* plant in sandy soil

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ABSTRACT

The main purpose of this work was evaluate the effect of moringa oleifera leaf extract; MLE on improving of some chemical properties and macro-nutrients of salt affected loamy sandy soils , Evaluate the effective role of applied moringa oleifera leaf extract; MLE as solely in combined treatments on the tolerance of sun flower plants grown under a slight soil salinity condition and Evaluate these amendments economically. **From the obtained result, of this experiment it could be concluded that:**

A.They improved the physiological properties of sunflower plants in salt affected soil.

B.Application of T3 = MO steep + MO spray gave the highest increase of sun flower yield.

C.The results showed that the top two practical and economic parameters of the field experiment were (T1 and T3) respectively where the increase values of macro-nutrients (N, P and K) vs decrease values of ECe and pH as compared to control.

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KEY WORDS: moringa oleifera leaf extract; MLE, sun flower plants and Salt-affected Soils.

INTRODUCTION

Sunflower (*Helianthus annuus L.*) is considered one of the most important oil crops in the world due to its wide range of adaptability in addition to the high percentage of excellent edible oil of its seeds (45 – 55 %). Sunflower is considered as the third oil seed crop grown in the world, although it is the second liquid oil produced and consumed in the world.

All plants require certain amounts of nutrients for growth; sunflower like other crops needs special cultural practices to give satisfactory yield of seeds and oil.

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Moringaoleifera Lam., a multipurpose tree from Moringaceae family is native to the sub-Hamaylian tract of India and Pakistan (Makkar and Becker, 1996; Shahzad et al., 2013). The MLE obtained from fresh moringa leaves posses' high antioxidant activity are rich in some plant secondary metabolites and osmoprotectants. It is also a source of zeatin, a natural derivative of cytokinin, vitamins and several mineral elements, making it a potential natural growth stimulant (Rady et al., 2013). Like other biostimulants, the potential of MLE when applied through seed or plant foliage have been shown to improve the plant tolerance to abiotic stresses, including salinity (Yasmeen et al., (2013a); Rady et al., 2013; Howladar, 2014). These reports and others have been shown that MLE application improved crop performance, resulting from vigorous seedling growth, maintained optimum tissue water status, improved membranes stability, enhanced antioxidant levels and activated plant defense system, increased levels of plant secondary metabolites, reduced uptake of undesirable Na+ and/or Cl-, and enhanced shoot or leaf K+(Yasmeen et al., 2012; Rehman et al., 2014). The MLE act at low or even diluted concentration of 1:30, and the chemical composition of this extract may vary with species, season of collection and extraction procedure used.

MATERIALS AND METHODS

Location of experiments, soil analyses, materials and treatments

The current work was executed on a newly reclaimed saline soil at a private farm in the Kom Oshim village, North Tamia district, El-Fayoum Governorate, Egypt, during the summer season 2019. Some physical and chemical characteristics of the studied soil as profile mean values are given in Table (1).

2-1)Physical properties of the experimental soil

The following soil physical determinations were conducted according to the methods described by **Klute (1986)** as follows:

1. Particle size distribution, the particle size distribution of the soil samples was carried out by the International Pipette method. Soil texture class was obtained from the data of particle size distribution.
2. Soil particle density, the soil particle density was determined on duplicate 50 g soil sample using pycnometer and toluene as a liquid.
3. Soil dry bulk density, the soil dry bulk density was determined on three replicates using the metal tube method for the all soil samples.
4. Total porosity, the total porosity (E) was calculated from the particle density (γ_S) and the dry bulk density (γ_d) values according to the following equation:

$$E = \left(\frac{\gamma_S - \gamma_d}{\gamma_S}\right) \times 100 \quad \ldots\ldots\ldots\ldots (3.5)$$

5. Void ratio, the void ratio (e) was calculated from the total porosity values (E) according to the following equation:

$$e = \left(\frac{E}{1 - E}\right) \quad \ldots\ldots\ldots\ldots (3.6)$$

6. Water release characteristics, the water release characteristics were determined by measuring both the volumetric water content (θ) and matric potential or suction (ψ_m). They were determined in the laboratory using a tension table and pressure plate. A flat porous surface was prepared at one end of each core sample to ensure the hydraulic contact with the tension table. The samples were then placed on the saturated surface of

the tension table after which they were subjected to different suctions. The samples were weighed after the equilibrium at each successive suction.

7. Pore size distribution, the pore size distribution was calculated according to De Leehneer and De Boodt (1965), using the flowing equation:

$$P = 2\ \alpha \cos \theta / r \text{ ....} \quad (3.8)$$

Where:

P is the applied pressure (Pa),
A is the surface tension (dyne cm^{-1}),
Θ is the contact angle of water and
R is the pore radius (cm).

Thus, the volume of water removed between consecutive steps will be equal to the soil pore volume drained. Then, the size-range of pores drained during each step, can be calculated. The pore size distribution was then classified according to their diameters into; quickly drainable pores, QDP (> 28.8 µm), slowly drainable pores, SDP (28.8 – 8.62 µm), volume drainable pores, VDP (>8.62 µm), water holding pores, WHP (8.62 – 0.19 µm), and fine capillary pores, FCP (< 0.19 µm).

8. Field capacity, permanent wilting point and available water

Field capacity (soil water content at 0.33 bar) was measured and calculated using the tension table when applied tension of 0.33 bar. The permanent wilting point (soil water content at 15 bar) was measured using the pressure membrane device in the laboratory. The soil water content at which the plant wilts and remains permanently wilted is the (PWP). In the pressure membrane apparatus, soil samples were placed on a porous plate and equilibrated with an applied pressure, of 15 bars.

The available water content (AWC) of a soil is the amount of water retained in the soil reservoir that can be removed by plants. This was estimated by the difference in water content between field capacity and permanent wilting percentage as follows:

$$AWC = FC - PWP \text{ ....} \quad (3.9)$$

9- Hydraulic conductivity coefficient, the saturated hydraulic conductivity values ($K_{sat.}$) was determined for soil samples and calculated according to the Darcy's equation as follow:

$$q = K\ \frac{\Delta H}{L} \text{ ....} \quad (3.10)$$

Where: q = the water flux density, cm sec^{-1},

$\frac{\Delta H}{L}$ = the hydraulic potential gradient, cm of water, cm^{-1},

K = the hydraulic conductivity coefficient of soil to water, cm sec^{1}.

2.2). Chemical properties of the experimental soil

Determinations of some soil chemical properties were carried out using the techniques described by **Page et al. (1982) as follows*:***

a) Soil pH, Soil pH values were estimated in 1: 2.5 soil-water suspension using Beckman pH-meter **(Jackson, 1973).**

b) Total soluble salts, as an electrical conductivity (ECe) was determined in the soil paste extract by using the EC meter **(Jackson, 1973).**

c) Soluble cations, (i.e., Ca^{2+} and Mg^{2+}) in the soil paste extract were determined by titration, while (Na^{+} and K^{+}) were photometrically determined using a

Perkin Element Flame-photometer **(Jackson, 1973)** *.*

d) Soluble anions (i.e., CO_3^{2-} , HCO_3^- and Cl^-) in the soil paste extract were determined by titration and SO_4^{2-} by the difference **(Jackson, 1973*)*.**

e) Calcium carbonate content was determined volumetrically using a Collin's calcimeter **(Jackson, 1973)** *.*

Organic matter content was determined using the wet combustion method following modified Walkley and Black's method **(Jackson, 1973).**

2.3) Preparation and analysis of moringa leaf extract

Fresh leaves harvested from fully matured Moringa oleifera trees were air-dried, grinded and extracted **(Rady et al., 2013).** For extraction, ethyl alcohol was added to leaf powder and the mixture was put for 4 hours on a Rotary Shaker. Extract was purified by filtering twice through Whatman No. 1 filter paper. After purification, the extract was subjected to a Rotary Evaporator to fully evaporate the alcohol. Centrifugation at 8,000 × g for 15 min was then conducted for supernatant. Supernatant was diluted to 30 times and used to seed soaking and foliar spray applications. The chemical characteristics of moringa leaf extract as shown in Table(2)

2.4) Applications of moringa leaf extract (MLE)

For seed soaking, sunflower seeds were soaked in distilled water, MLE (1:30) using seed weight to solution volume ratio (1:5) for 2 hr at room temperature. After soaking, seeds were given washings with distilled water and re-dried overnight at room temperature. At early morning, treated seeds were sown as mentioned before. Foliar spray of water or MLE was done at early morning with a backpack sprayer (Vol. 20 L) to run-off twice, at 25 and 40 days after sowing. The concentrations of MLE, the number and timing of sprays, and the soaking duration were based on results from a preliminary petri dishes and pot trials (data not shown). To ensure optimal penetration into leaf tissues, 0.1% (v/v) Tween-20 was added to the foliar sprays as a surfactant.

2.5) Plant growth and yield parameters

Measurements of plant parameters that are listed below were carried out during the vegetative stages of the grown and at harvesting of Sunflower plants.

1- Plant height (cm),2- Stem diameter (cm), 3- Leaves No. per plant,4- Cob weight (g), 5- 100-grain weight (g). 6- Roots weight (g), 7-Grains yield (t fed^{-1}). 8- Biomass yield (t fed^{-1}).

2.6) Oil percentage:

is determined by extraction method using Soxhlet Apparatus with hexane as an Organic solvent, according to **A.O.A.C. (2000)**. Afterwards, oil yield was calculated by multiplying oil % x seed yield fed^{-1}, for each treatment.

Table 1. Some initial physical and Chemical characteristics of the studied soil samples

Soil physical characteristics		Mean	Soil chemical properties		Mean
Particle size distribution	sand, %	76.2	pH (1: 2.5 soil-water suspension)		8. 82
	Silt, %	12.8	ECe (dS m-1)		19.16
	Clay, %	10.9	Soluble cations, (mmol$^+$ L^{-1})	Ca++	26.08
	Texture class	S.L.		Mg++	23.28
Bulk density (Mg m^{-3})		1.66		Na+	127.28
Particle density (Mg m^{-3})		2.66		K+	12.19
Total porosity, %		37.64	Soluble anions, (mmol$^+$ L^{-1})	$CO_3^{=}$	-
Air porosity, %		24.62		HCO_3^-	12.14
Void ratio (e)		0.61		Cl^-	128.58
Hydraulic conductivity (cm hr^{-1})		2.18		SO_4^{--}	48.11
Soil moisture constants, % at:	Field capacity	23.81	Available (mg kg-1 soil)	N	18.2
	Wilting point	14.17		P	12.0
	Available water	8.97		K	146.4
			CaCO3 %		9.15
			Organic matter%		0.74

Table 2. Some chemical constituents of *Moringa oleifera* leaf extract (on dry weight basis)

Parameter/component	Value (mg g^{-1} DW) 2019 season
Amino acids	125.7
Proline	27.19
Total soluble sugars	159.3
Ash	114.7
Calcium	9.022
Magnesium	6.21
Potassium	29.03
Phosphorus	6.231
Sodium	0.661
Iron	1.910
Manganese	1.030
Zinc	0.520
Copper	0.225
Soluble phenols	2.163
Total carotenoids	2.461
Total chlorophyll	5.007
Ascorbic acid	3.436
Indole-3-acetic acid	0.902
Gibberellins	0.814
Zeatin	0.963
Abscisic acid	0.283

2.7) Statistical and data analysis

The experiment was conducted in a complete randomized design with three replicates, with an area of 3.0×3.5m= 10 m2 for each one the data obtained were subject to statistical analysis according to **Snedecor and Cockran, (1980)** and the treatments were compared by using LS.D. at 0.05 level of probability

RESULTS AND DISCUSSION

3.1) Effect of treatments on some soil chemical properties and available macro-nutrients:

3.1.1) Some soil chemical properties:

Presented data in Table (1) that response of some soil chemical properties i.e. pH and Ec_e to the sun flower treatments particularly those treated with the T_2= KH (8.45 and 17.48 dmS^{-1}), T_4= MO spray + KH (8.43 and 17.30 dmS^{-1}), T_6 = MO (steep) + KH (8.40 and 17.17 dmS^{-1}) and control (8.6) and 18.30 dmS^{-1}), respectively.

That was true, because of the combined effects of applied some organic substances (such as potassium humate), MO steep and MO spray treatments for the noticeable reduction in the values of soil pH and EC_e that could be interpreted as follows: organic substances decomposition tends to active organic and inorganic acids that led to decrease soil pH, on the other hand, it's clear that the applied organic wastes play an important role in reducing accumulation of salts in the experimental soil reached to lowest value when soil was treated with T_{3f}= MO steep + MO spray + KH (8.34 and 17.10 dmS^{-1}).

Under such favorable conditions of soil salinity the associated soil chemical properties i.e. pH and Ec_e should be improved compared with control as shown in Tables (3). These results are in harmony with those reported by **Osman and Ewees, (2008).**

As a general, the obtained results indicated that building up of salinity in control treatment herein was due to the influence of water salinity in the absence of organic substances. On basis of soil pH and ECe values were generally lower in case of amended treatments with potassium humate added solely or in combination vs a greater pH and salinity levels in the case of untreated soil (control). These findings are in harmony with those outlined by **Ewees and Abdel Hafeez, (2010)**. So, the sequence of the third best treatments superiority of the applied treatments under current experimental conditions could be arranged into a descending order $T_3 < T_2 < T_1$ < control.

3.1.2) Available macro-nutrients:

The effects of organic substances (such as potassium humate) added as either solely or combined with MO steep and MO spray to the experimental soil plots under cultivation with sun flower crops caused a pronounced ameliorated effect in the soil content of some available macronutrient (i.e. N, P and K) shown in above-mentioned Table (2) .

The data showed that a significant increase in the amount of available macronutrients upon treating the soil with organic substances in combination with MO steep and MO spray as compared with other treatments the third best treatments were ($T_3 < T_2 < T_1$) = MO (steep) + MO (spray) > MO (steep) + KH > MO (spray) .

In general, the increase in available nutrient contents may be attributed to the pronounced decreases in the values of soil pH, EC and the favourable amelioration in soil biological conditions that encouraging the released of available macro-nutrients from soil native sources as well as easily mobility towards plant roots, and in turn their uptake by plants.

Moreover, such prevailing condition enhancing the slow release of nutrients during the mineralization processes as well as minimizing their possible lose by irrigation water. These findings are also in agreement with **Ewees and El-Sowfy, (2013).**

Generally, the beneficial effects of the applied different treatments on the tested soil chemical properties under sun flower plants could be arranged in the following order:

For pH value: $T_3 < T_2 < T_1 <$ control.

For ECe values: $T_3 < T_2 < T_1 <$ control.

For available macro-nutrients (N, P and K): $T_3 < T_2 < T_1 <$ control.

Table 3. The effect of the studied treatments on some chemical properties and macro-nutrients of soil after sun flower cultivation.

Treatments	pH	ECe dSm^{-1}	N (mg kg^{-1} soil)	P (mg kg^{-1} soil)	K (mg kg^{-1} soil)
Control	8.60	18.30	12.7	12.00	67
T1	8.55	18.20	14.00	12.50	72
T2	8.50	18.10	14.30	12.90	78
T 3	8.48	18.00	15.40	13.20	80
L.S.D. 0.05	0.089	1.19	1.08	0.896	8.84

Control /T_1 = MO (spray) / T_2 = MO (steep) / T_3 = MO (steep) + MO (spray)

3.2) Influence of applied treatments on growth parameters, grain yield and quality of sun flower plants grown on salt affected soil.

Data presented in Table (4) indicate that the achieved favourable soil conditions due to the applied treatments, particularly the combiation ones of potassium humate in combination with either MO steep or MO spray were positively reflected on the studied values of sun flower plants growth parameters (*i.e.* plant height (m), head diameter (cm), leaf area index and root length), biological yield (grain yield kg/fed.) and some parameters of grain quality (100 grain weight and percentage of oil) grown in salt affected soil as compared to the applied solely ones.

The obtained data in Table (4) showed a positive effect of the applied treatments on growth parameters, grain yield and quality of the studied crop and the greatest values were achieved by plants grown on soil treated with (T_3). Meanwhile, the lowest values were recorded at the control treatment. The results can be explained on the basis that the organic substance, MO steep and MO spray treated soil plots became enriched in the release nutrient contents, especially those of macronutrients, which are involved directly or indirectly in the formation of starch, protein, and biological components through their roles in the respiratory and photosynthesis mechanisms as well as in the activity of various enzymes **(Nassar et. al., 2002).**

So, It could be noticed that from data in Table (4) plots that received the combination of (MO (steep) + MO (spray)) produced higher growth parameters (plant height (m), head diameter (cm), leaf area index and root length (cm)) than the control and the previous materials with corresponding values of 1.25 m for plant height, 15 cm for head diameter,5.17 for leaf area index and 12 cm for root length. Increases in these characters due to the application of (MO (steep) + MO (spray). respectively, compared with that of control.

Data presented in Table (4) revealed that the, biological yield (grain yield) and some parameters of grain quality (100 grain weight and percentage of oil) were substantially improved by the application of humate potassium in combination with either MO (steep) or MO (spray).

Results presented in Table (4) showed that grain yield, 100 grain weight and percentage of oil were significantly increased by the application of different materials as single or in combination. The highest yield of grain, 100 grain weight and percentage of oil were associated with sun flower plants received (MO (steep) + MO (spray) treatment, values were 756 kg/fed, 48.43 g and 41.83% , respectively. These values represented 29, 12 and 37 % of that of the control, respectively. These results are also in the line with those obtained by **Ewees and El-Sowfy, (2013).**

Table 4. Effect of treatments on growth parameters, grain yield and quality of sun flower plants grown on salt affected soil.

Treatments	Plant height (m)	Head diameter (cm)	Leaf area index	Root length (cm)	seed weight (kg/fed.)	100-seed weight (g)	Oil %
Control	1.14	11.23	2.53	8.87	588	43.30	30.46
T_1	1.18	12.67	3.50	9.07	714	46.60	37.27
T_2	1.21	12.70	3.83	11.23	720	47.47	38.45
T_3	1.25	15.00	5.17	12.00	756	48.43	41.83
L.S.D. 0.05	0.157	2.19	0.632	1.155	45.02	2.001	2.48

Control / T_1 = MO (spray) /T_2 = MO (steep) /T_3 = MO (steep) + MO (spray)

3.3) Nutrient contents in sun flower grains as affected by treatments:

Data of Table (5) which illustrated by represent values of macronutrients (N, P and K and) uptake by sun flower plants. The obtained results exhibited pronounced increases due to the applied combined treatments that contain organic substance (potassium humate) MO steep and MO spray compared to the control. So, the superiority of applied treatments attained potassium humate plus either MO steep or MO spray (especially T_3) could be attributed to enrichment this potassium humate in the organic substance that ameliorates biological soil conditions, which have the ability to reserve the released nutrients as a storehouse in available forms to uptake by sun flower plants roots.

Also, such treatments had a great extent favourable effect on the mobilization of the released nutrients as compared to MO steep and MO spray treatments alone. This beneficial effect could be explained by many aspects i.e., increasing the released macro nutrient contents through the decomposition of applied organic substance, reduction of nutrient fixation and forming the stable complex of macronutrients–humic substances supplied from such substance and keeping them in available forms for extended period **(Shanmugam and Veeraputharn, 2001).**

Thus, the above-mentioned results are also in harmony with many various benefits of organic matter which have been reported to promote an increase nutrient uptake and stimulate plant growth. however, it promotes plant growth by its effect on ion transfer at the root level by activating the oxidation-reduction state of the plant growth medium and so increased absorption of nutrients, especially macronutrients, by preventing precipitation in the in the nutrient solution.

In addition, it enhances cell permeability, which in turn made for a more rapid entry of nutrient into root cells and so resulted in higher uptake of plant nutrients. This effect was associated with the function of hydroxyls and carboxyls in these compounds. The principal physiological function of organic waste maybe that they reduce oxygen deficiency in plants, which results in better uptake nutrients **(Humax, 2006).**

The macronutrients contents in grain of sun flower plants could be arranged in the following order:

For grain sun flower for (N): $T_3 > T_2 > T_1 <$ control..
For grain sun flower for (P): $T_3 > T_2 > T_1 <$ control.
For grain sun flower for (K): $T_3 > T_2 > T_1 <$ control.

The effect of the studied treatments on macro-nutrients uptake by after sun flower.

In general, the favourable effect of the combined treatments attained organic substance (potassium humate), MO steep and MO spray were commonly achieved may be due to lowering soil pH that improve nutrients availability, mobility and ability to uptake by plant roots. In addition, the superiority of applied treatments attained (MO (steep) + MO (spray)) were more attributed to their richness in organic substances that ameliorate chemical soil properties. This beneficial effect could be explained by many aspects, *i.e.*, increasing the released either macro-nutrient contents through the applied potassium humate, reduction of nutrient fixation and forming the stable complexes of macronutrients-humic substances supplied and keeping them in available forms for extended period. On the other hand, the significant response of nutrients contents in sun flower grain to application of potassium humate, may be due to increased root growth that enable the grown plants to absorb more nutrients.

Table5. The effect of the studied treatments on macro-nutrients uptake by sun flower.

Treatments	N (mg g−1 DW)	P (mg g−1 DW)	K (mg g−1 DW)
Control	16.1	0.09	14
T_1	16.70	0.12	15.10
T_2	17.20	0.14	15.60
T_3	18.3	0.17	16.2
L.S.D. 0.05	1.785	0.172	1.182

Control / T_1 = MO (spray) / T_2 = MO (steep) /T_3 = MO (steep) + MO (spray)

SUMMARY AND CONCLUSION

Afield experiment was carried out on sandy loamy soil at Kom Oshim village, North Tamia district, El-Fayoum Governorate, Egypt, during the summer season 2019 to study the use of some unconventional methods in the improvement of salt-affected soils. This work was conducted to minimize hazard of salinity and its effects on plant growth through different treatments associated with growing sun flower crop. Hence, soil management practical of salinity is usually carried out through the addition of organic substances as soil amendments that have one of the most important practices for improving soil properties. In addition, improving some soil properties of salinity soil using potassium humate, MO steep and MO spray.

The Experimental soil was cultivated with a sun flower grain (*Helianthus annuus L.*)

at march 15, 2019. All sun flower plots received fertilizer according to recommended of agricultural ministry where superphosphate fertilizer (15.5 % P2O5) at a rate of 150 kg fed[1]. All treatments received a similar fertilization with recommended dose of nitrogen in the form of ammonium nitrate (33.5 % N) at the rate of 150 kg fed^{-1} for sunflower in to five equal doses during the growing period. Also, potassium sulphate (48 % K2O) was added at a rate of 50 kg fed^{-1} in two equal doses, i.e., after 15 and 40 days from planting. The sun flower was harvested at 5 of June 2019.

Response of some soil chemical properties i.e. pH and EC to the studied treatments particularly those treated with the $T_3 > T_2 > T_1 >$ control. that was true because of the combination effects of applied organic substance, MO steep and MO spray treatments for the noticeable reduction the values of soil pH and EC which resulted in a significant increase in growth parameters, grain yield and quality of sun flower.

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تأثير مستخلص المورينجا بالنقع والرش على نمو محصول دوار الشمس في الأراضي الملحيه

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قسم الاراضى والمياه – كليه الزراعه – جامعه الفيوم

الملخص العربى

اجريت هذه التجربة على تربه مالحه حديثة الاستصلاح بمزرعة خاصه بكوم اوشيم الواقعة في شمال مدينة طامية بمحافظة الفيوم بمصر خلال موسم صيف 2019.

وكان الهدف من هذه التجربة دراسة بعض الأساليب لتحسين خواص التربة المتأثرة، كذلك الحد من المخاطر والتأثيرات الناتجة من الملوحة على النبات عن طريق المعاملات المختلفة المرتبطة بنمو محصول عباد الشمس وذلك من خلال استخدام هيومات البوتاسيوم كمادة عضوية مع نقع بذور عباد الشمس في بمستخلص المورينجا ورش نبات عباد الشمس بمستخلص المورينجا) .

وتم ترتيب معاملات التجربة على النحو التالي:

الكنترول / م1 = مستخلص المورينجا رش / م2= مستخلص المورينجا نقع / م3 = مستخلص المورينجا نقع + مستخلص المورينجا رش.

يمكن تلخيص النتائج التي تم الحصول عليها فيما يلي:

1-تعتبر المعاملة رقم (3) = مستخلص المورينجا نقع+ مستخلص المورينجا رش افضل المعاملات من حيث انخفاض قيم الرقم الهيدروجيني و التوصيل الكهربي وزيادة قيم العناصر الكبري (النيتروجين – الفوسفور – البوتاسيوم) بالمقارنة بمعاملة الكنترول.

2-اشارت النتائج إلي أن افضل معاملتين من حيث انخفاض قيم الرقم الهيدروجيني و التوصيل الكهربي وزيادة قيم العناصر الكبري (النيتروجين – الفوسفور – البوتاسيوم) كانت (م3 > م1) بالمقارنة بمعاملة الكنترول.