

Effectiveness of Hydrogel Application on Tomato (*Solanum lycopersicum* L.) Growth and some Sandy Soil Chemical Properties under Drip Irrigation System

Noha A. Mahgoub

Soil and Water Department, Faculty of Agriculture, Suez Canal University, 41522 Ismailia, Egypt

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Abstract: A field experiment was conducted at the experimental site of Faculty of Agriculture of Suez Canal University, Ismailia, Egypt, to evaluate the effect of hydrogel addition on tomato (*Solanum lycopersicum* L.) growth and some soil chemical properties. The experiment was laid out in a randomized complete block design having six treatments with three replicates as follow: control, two hydrogel levels (HG₁, 2 g plant⁻¹ and HG₂, 4 g plant⁻¹), recommended fertilizers for tomato (F) and combination of hydrogel and half amounts of recommended fertilizers (HG₁+0.5 F and HG₂+0.5 F). The obtained results showed that hydrogel application to plants with 4 g hydrogel + half the recommended amount of fertilizer (HG₂+0.5 F) enhanced nitrogen (N), phosphorus (P) and potassium (K) content of fruits. The highest value of root dry weight was obtained with the treatment (HG₁+0.5 F). Also, the highest dry weight of the shoots was in the case of treatments (HG₁+0.5 F) and (HG₂+0.5 F). The highest weight of fruits was recorded in the treatment of 4 g hydrogel plant⁻¹ (HG₂). Also, adding 2 g plant⁻¹ (HG₁) hydrogel and 4 g plant⁻¹ (HG₂) reducing pH ranged between 0.08-0.18 units. The addition of hydrogel at the rate of (4 g plant⁻¹) with half of the recommended amounts of fertilizers (HG₂+0.5 F) led to an increase in the value of the soil cation exchange capacity (CEC) from 9.30±0.12 to 11.5±0.12 and increased available nutrients from 3.47±0.15 to 15.8±0.9, 21±1.5 to 78±1.5 and 283±4 to 343±23 mgkg⁻¹, for N, P and K, respectively.

Keywords: Hydrogel, Tomato growth, nutrients uptake, Soil chemical properties, Sandy soils, Drip Irrigation

INTRODUCTION

Sandy soils have several limitations for agricultural production, including low fertility, poor water retention, and tendency to wind erosion on dunal sands (Hoang *et al.*, 2010). Because of the high porosity of sands, excessive losses of water and leaching of fertilizers will occur, particularly if surface irrigation methods are used (El-Hady *et al.*, 2003). Hydroabsorbents or hydrogels can play an important role in increasing water availability in sandy soils. They are known to increase water holding capacity of soil, they may be a proper technique to enhance water and fertilizers use efficiencies (Dehkordi and Seyyedboveir, 2013).

Hydrogel is a hydrophilic cross-linked biodegradable polymer that can absorb water by 100 times the original weight in a short time. When hydrogel is applied to soil, it forms an amorphous gelatinous mass upon hydration, resulting in water absorption and desorption over a long period of time. As a result, it acts as a slow-release water source in the soil. The granule size of the hydrogels, moisture of the background soil, degree of crosslinking, and solubility of the active agents are the factors that influence nutrient release from controlled released fertilizer (Yousefzadeh *et al.*, 1994). Also, controlled released fertilizers have considered a proper way to reduce fertilizer loss through irrigation water effects, providing long-term nutrition, reducing pollution for the environment, and minimizing the use of fertilizers.

The aim of this research is to study the effect of hydrogel fertilizer which is known commercially barbary plante when it mixed with soil or conventional fertilizer, on soil chemical properties and plant growth

in sandy soils under drip irrigation. Tomato plant (*Solanum lycopersicum* L.) was chosen because it is one of the main vegetable crops that need to be cultivated in Egyptian soils, especially in Ismailia governorate.

MATERIALS AND METHODS

Field experiment

A field experiment was carried out during the summer season (2019/2020) at the experimental site of Faculty of Agriculture of Suez Canal University, Ismailia, Egypt, to evaluate the effect of hydrogel on tomato (*Solanum lycopersicum*) growth, soil available nutrients content and soil chemical properties. Some physical and chemical properties of a sandy soil before planting were shown in Table (1). The experiment was laid out in a randomized complete block design having three replicates using drip irrigation system. The experimental plot was 100 m² included 18 lines each with 5.5 m in length and 1 m in width and the planting distance 30 cm between the plants. The experimental treatments comprised of control (without any fertilizer), two hydrogel levels (HG₁, 2 g plant⁻¹ and HG₂, 4 g plant⁻¹), recommended fertilizers for tomato (F) and combination of hydrogel and half amounts of recommended fertilizers (HG₁+0.5 F and HG₂+0.5 F).

Hydrogel and other treatments were thoroughly mixed at surface layer (0-15 cm) of the soil for each plant. The recommended amounts of fertilizers were 39 kg P₂O₅ fed⁻¹, 20.5 kg N fed⁻¹ and 24 kg K₂O fed⁻¹. The fertilizers used in the experiment namely potassium phosphate, diammonium phosphate and potassium sulfate, were applied three times through the experimental period. Some properties of hydrogel are shown at Table (2).

*Corresponding author e-mail: noha_mahgoub@agr.suez.edu.eg

Soil samples measurements, plant growth parameters and nutrient content

The soil samples were dried by a 2 mm screen and analyzed using standard procedures for electrical conductivity (EC in dSm^{-1}), pH (1:2.5), available nitrogen, phosphorus, and potassium were determined according to (Burt, 2004). After physiological maturity, ten plants were taken from each treatment at random select for measuring fruit yield per plant (g plant^{-1}), branch number, shoot length (cm), root length (cm), shoot and root dry weight (g). The samples of tomato plants dried at 70°C after that the samples were grinding and stored for analysis. Samples were digested by H_2SO_4 and H_2O_2 then were analyzed for N, P and K as described by (Page *et al.*, 1982).

Table (1): Some properties of the soil at the beginning of the experiment

Properties	
Particle size distribution %	
Sand	92.5
Silt	5.50
Clay	2.00
Texture class	Sand
pH (1:2.5)	7.50
EC (dSm^{-1})	1.40
Soluble cations (meqL^{-1})*	
Ca^{2+}	2.20
Mg^{2+}	4.80
Na^+	3.80
K^+	3.20
Soluble anions (meqL^{-1})*	
CO_3^{2-}	0.00
HCO_3^-	3.50
Cl^-	7.00
SO_4^{2-}	3.50
Available N (mgkg^{-1})	3.00
Available P (mgkg^{-1})	20.0
Available K (mgkg^{-1})	300
Cation Exchangeable Capacity (CEC) c mol kg^{-1}	9.00

*In soil paste extraction

Table (2): Some properties of applied hydrogel (barbary plante)

Properties	
Appearance	White to Slightly green grains
Grain size (mm)	1-2.5
Bulk density (g cm^{-3})	0.7
Solubility	Insoluble in water
pH in distilled water (1:100)	6.5
Absorption capacity (g/g gel)	400
Absorption time (hours)	1
CEC c mol kg^{-1}	605

RESULTS AND DISCUSSION

Effect of hydrogel fertilizer on tomato growth parameters and nutrient content

Results presented at Figures (1 - 4) reveal some growth parameters of the tomato (*Solanum lycopersicum* L.) plants due to using hydrogel. The effect of hydrogel on the number of branches plant⁻¹ of the tomato plant is shown in Figure (1). It was found that the highest number of branches for plants was in the case of treatment 4 g hydrogel + half the recommended amount of fertilizer ($\text{HG}_2+0.5\text{F}$), followed by an addition of 4 g hydrogel per plant (HG_2). In general, the number of plant branches in the case of adding hydrogel or with half the recommended amount of fertilizer, is higher than when adding fertilizers. This finding agrees with (Sultana *et al.*, 2016) who found that the application of super water absorbent hydrogel (0.5% SWA) increased branch number of tomatoes from 14 in soil untreated with SWA to 20 in soil treated with SWA.

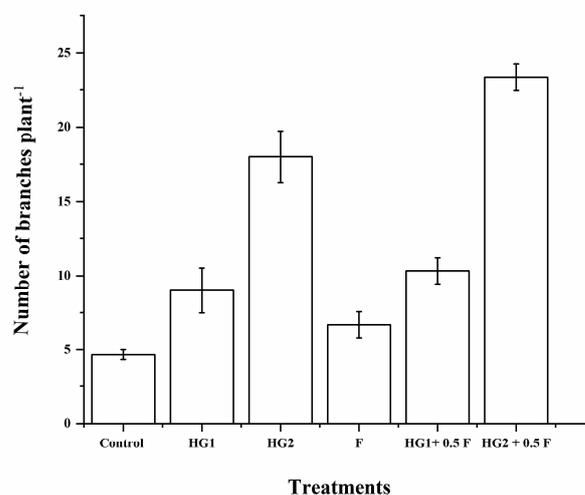


Fig (1): Effect of hydrogel application on branch number plant⁻¹ of tomato plants

As for the shoot growth of tomato plants, it is shown in Figures (2 a and b) in terms of the shoot length (cm) and dry weight (g). The results show that the shoot length in all treatments with added hydrogel fertilizer are greater than in the case of control or when chemical fertilizers only were applied. These results are compatible with (Yazdani *et al.*, 2007) who observed that soybean height increased with application of super water absorbent hydrogel. Also, the highest dry weight of the shoots was in the case of treatments 2, 4 g with adding half of the recommended amount of fertilizer.

Effect of hydrogel fertilizer application on root growth was shown in Figures (3 a and b). The results show that the highest root length was recorded in the treatment 4 g with half the recommended amount of fertilizer ($\text{HG}_2+0.5\text{F}$), followed by the addition of only 4 g (HG_2) of hydrogel treatment, followed by the other treatments. Moreover, the highest value of root dry weight was obtained with the treatment 2 g with half the recommended amount of fertilizer ($\text{HG}_1+0.5\text{F}$). In general, the addition of hydrogel fertilizer leads to an

increase in the dry weight of the roots. These results may show the ability of the hydrogel to retain water and nutrients in the root zone of the plant, which works to

release them slowly to be absorbed by the plant (Hüttermann *et al.* (1999) and Tomaszewska and Jarosiewicz (2002).

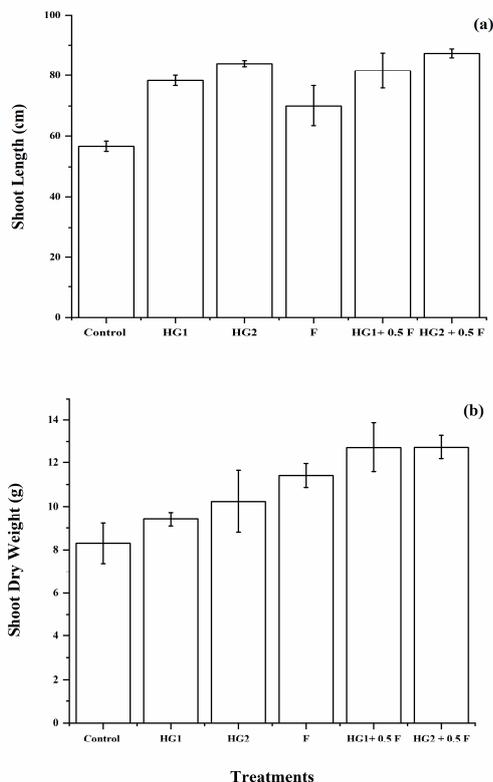


Fig (2): Effect of hydrogel application on tomato shoot growth where, a) shoot length (cm) and b) shoot dry weight (g)

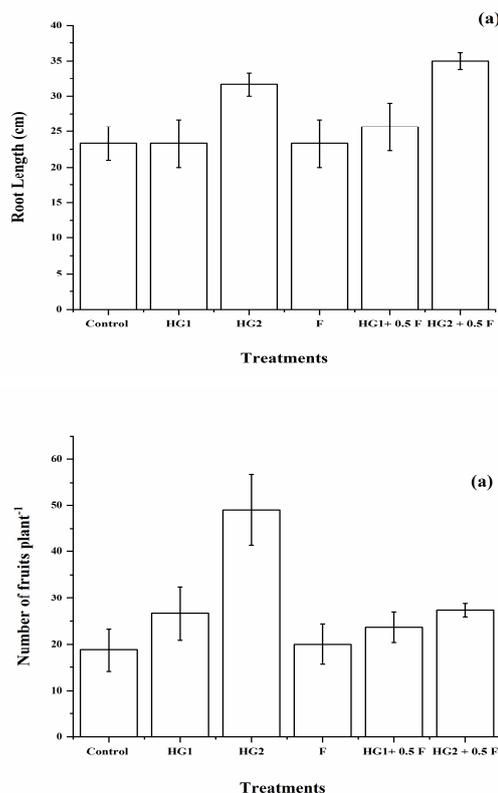


Fig (3): Effect of hydrogel application on tomato root growth where, a) root length (cm) and b) root dry weight (g)

Regarding the number and weight of tomato fruits in the experiment, the results indicated that the highest number and weight of fruits were recorded in the treatment of 4 gm hydrogel per plant (HG₂), followed by the treatment in which 4 g was added with half of the recommended amount of fertilizer (HG₂+0.5F). The lowest number and weight of fruits were found in the two treatments, *i.e.*, control (C) and adding only chemical fertilizers (F), respectively, as shown in the

Figure (4 a & b). This may be attributed to the availability of hydrogel fertilizer for fast nutrient delivery to the plant and water in the root zone, resulting in an increase in nutrient absorption within the plant, which leads to an increase in production. These results are compatible with Ahmed and Fahmy (2019); Sultana *et al.* (2016) and Yazdani *et al.* (2007) who reported that, the application of super water absorbent hydrogel increased plant production.

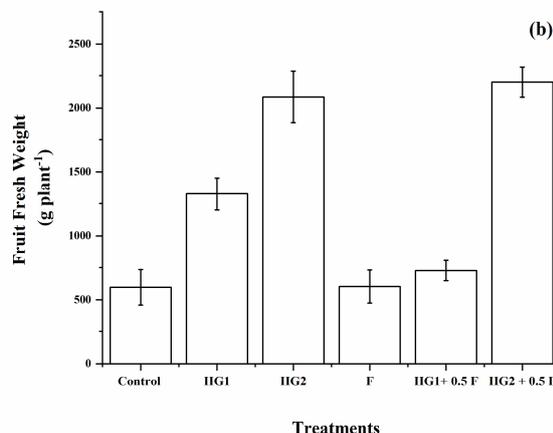
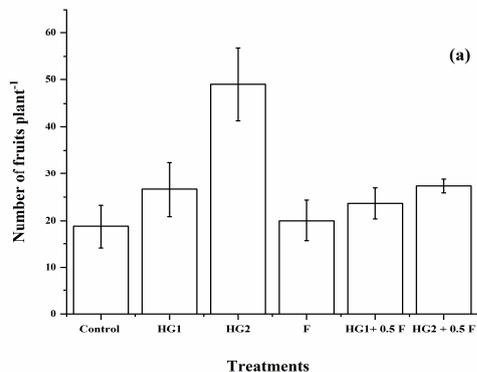


Fig (4): Effect of hydrogel application on tomato fruits where, a) fruit number plant⁻¹ and b) fruit fresh weight (g plant⁻¹)

Nutrient content in tomato plants (shoot, root and fruits) were shown in Table (3). Tomato treated with 4 g hydrogel in soil showed the highest content of N, P and K in shoot in addition to N and K in root. Furthermore, the highest content of N, P and K were recorded in fruits of tomato treated with 4 g hydrogel with half amount of recommended fertilizer ($HG_2+0.5F$) compared to control. It has been noticed that there is a significant increase in the nutrient content in plants by using hydrogel. This result in agreement with those of El-Hady *et al.* (2012) who found that adding hydrogel as a conditioner to organic compost in sandy soil improved water and nutrient use efficiency for tomato plants. Hydrogel application reduces the amount of fertilization needed by preventing nutrients from leaching and increasing water consumption. Hydrogels that contain fertilizers and have a regulated water release, allowing the fertilizer dose to be adjusted over time. Thus, the nutrients are available to the plant for a longest period of time (Abobatta, 2018; Ni *et al.*, 2009; Rahman *et al.*, 2001). Briefly, hydrogels indirectly affect nutrients uptake by conservation soil moisture and nutrients mobility (El-Hady *et al.*, 2003).

Effect of hydrogel fertilizer on some soil chemical properties

Some soil chemical properties were shown at Table (4). The results showed that there was no difference in soil salinity values till the end of the experiment. Among soil chemical properties, soil pH is the most important property of soil. Hence, soil pH influences soil chemical transformations and nutrient availability to plants. In this study, all treatments with hydrogel provided a slight decrease in soil pH values. The decreases in soil pH were ranged between 0.08 and 0.18 unites by adding 2 g (HG_1) and 4 g (HG_2) of hydrogel in the rootzone of plants. While using hydrogel with 50% fertilizers, the pH decreased by 0.05 and 0.14 unites, respectively. The longer the hydrogel in the soil, the higher the acidity. These results were compatible with El-Saied *et al.* (2016)) and Rajakumar and Sankar (2016) who found that dissociation of H^+ from hydrogel, other cation-cation like functional group to the surface results in negative charge, which neutralizes cation exchange sites and causes an increase in soil acidity.

One of the most significant limitations of soil fertility in sandy soil is its low CEC, and thus its low specific surface area. Data referred that, adding hydrogel to soil increases CEC (Table 4). The addition of hydrogel at the highest rate (4 g) with half of the recommended amounts of fertilizers ($HG_2+0.5F$) led to an increase in the value of the soil CEC (11.5 ± 0.12) compared to the other treatments. The results showed that adding only 2 g of hydrogel has no effect on CEC. In general, the addition of hydrogel only or with half recommended fertilizers led to an increase in CEC in the root zone as compared to the control treatment. Also, found that the CEC of hydrogel-treated soil was 1.8 and 2.1 times greater than the control treatment, which included 2 and 4 g hydrogel per plant,

respectively. These results may be due to the high CEC of hydrogel (605 c mol kg^{-1}) (El-Saied *et al.*, 2016).

Regarding the soil nutrient availability, it is well known that the sandy soils have a low content of nutrients. Data in Table (4) that the available N, P and K were 3.47 ± 0.15 , 21 ± 1.5 and 283 ± 4 , respectively in soil without hydrogel (control). There were increases in the availability of N, P and K by applying 2 and 4 g of hydrogel per plant. The highest value of available N, P and K were 15.8 ± 0.9 , 78 ± 1.5 and $343\pm 23\text{ mgkg}^{-1}$, respectively, at the treatment 4 g hydrogel with the half amounts of recommended fertilizers. These results were consistent with those of Abobatta (2018), Rajakumar and Sankar (2016) and El-Hady *et al.* (2009). This result may be due to the high absorption of water by hydrogels from the soil, and the nutrients that dissolve in the soil solution or from fertilizer solutions which can be adsorbed on its surface. Also, the absorbed nutrients can be released slowly between nutrients in soil solution and hydrogels (El-Saied *et al.*, 2016; El-Hady *et al.*, 2009).

CONCLUSION

Sandy soil is known as a low fertility soil and plants suffer to get their nutrient requirements. By adding hydrogel to soil, plant growth and some soil chemical properties were improved as following;

1. An increase in tomato growth parameters such as, branches number, shoot and root dry weight, shoot and root length, fruit number and fruit weight per plant.
2. An increase in N, P and K uptake by plants.
3. A decreased in soil pH.
4. An increase in cation exchangeable capacity of the soil.
5. An increase in nutrient availability.

Also, hydrogel reduce the cost and efforts of fertilizers addition and fertilization process as it was applied once from the beginning of the experiment (HG_1 , HG_2 , $HG_1+0.5 F$ and $HG_2+0.5 F$) compared to fertilizers (F) which were added three times through the growth season.

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Table (3): Effect of hydrogel fertilizer on nutrients content (gkg^{-1} dry weight) in tomato

Treatments	Shoot			Root			Fruits		
	N	P	K	N	P	K	N	P	K
	gkg^{-1} dry weight								
Control*	14.84 ^c ±0.71	0.92 ^b ±0.05	9.57 ^d ±0.26	10.9 ^a ±0.1	1.03 ^b ±0.19	9.21 ^c ±0.68	14.78 ^c ±0.61	1.45 ^a ±0.30	15.94 ^c ±0.02
HG₁	18.34 ^b ±0.98	1.42 ^a ±0.06	13.78 ^b ±0.77	11.2 ^a ±0.25	1.44 ^a ±0.03	10.71 ^{bc} ±1.4	20.30 ^{bc} ±1.82	1.79 ^a ±0.03	17.81 ^{ab} ±0.16
HG₂	22.07 ^a ±0.71	1.5 ^a ±0.07	16.85 ^a ±0.99	12.7 ^a ±0.80	1.31 ^{ab} ±0.14	13.18 ^{ab} ±0.18	25.20 ^b ±1.85	1.83 ^a ±0.21	17.69 ^{ab} ±0.28
F	15.07 ^c ±1.12	1.38 ^a ±0.24	14.68 ^{ab} ±1.67	13.6 ^a ±0.9	1.51 ^a ±0.02	15.11 ^a ±1.8	19.41 ^{bc} ±0.85	1.69 ^a ±0.40	17.09 ^b ±0.37
HG₁+ 0.5 F	15.17 ^c ±0.12	1.41 ^a ±0.01	10.89 ^{cd} ±0.12	13.4 ^a ±0.2	1.45 ^a ±0.05	12.59 ^{abc} ±0.21	25.53 ^b ±1.61	1.83 ^a ±0.14	18.04 ^a ±0.27
HG₂+ 0.5 F	18.03 ^b ±0.15	1.48 ^a ±0.09	13.00 ^{bc} ±0.29	12.13 ^a ±0.20	1.43 ^a ±0.07	15.63 ^a ±0.35	36.53 ^a ±0.33	1.89 ^a ±0.06	19.53 ^a ±0.38

*Control, without any addition; HG₁ is 2 g hydrogel plant⁻¹; HG₂ is 4 g hydrogel plant⁻¹; F is recommended chemical fertilizers, HG₁+ 0.5 F is 2 g hydrogel plant⁻¹ + half amounts of recommended fertilizers and HG₂ + 0.5 F is 4 g hydrogel plant⁻¹ + half amounts of recommended fertilizers

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فاعلية إضافة الهيدروجيل على نمو نبات الطماطم وبعض الخواص الكيميائية للتربة الرملية تحت نظام الري بالتنقيط

نهى عادل محجوب

قسم الأراضي والمياه - كلية الزراعة - جامعة قناة السويس - الاسماعيلية - مصر

أجريت تجربة حقلية بالمزرعة التجريبية لكلية الزراعة - جامعة قناة السويس بالاسماعيلية - مصر وذلك لتقييم أثر إضافة الهيدروجيل على نمو نبات الطماطم وبعض الخواص الكيميائية للتربة الرملية. وتمت التجربة كقطاعات كاملة العشوائية بثلاث مكررات لكل معاملة، وكانت المعاملات كالاتي الكنترول، مستويين من الهيدروجيل بمعدل (٢ و ٤ جم للنبات الواحد)، إضافة الأسمدة المعدنية الموصى بها لزراعة الطماطم فقط، خليط من مستويات الهيدروجيل السابق اضافتها مع نصف كمية السماد الموصى بها كلا على حدة وكان نظام الري المتبع هو الري بالتنقيط. وقد أظهرت النتائج أن إضافة الهيدروجيل بمعدل ٤ جم مع نصف كمية السماد الموصى بها (HG₂+0.5F) أدت إلى زيادة محتوى الثمار من النيتروجين والفوسفور والبوتاسيوم. أما بالنسبة للوزن الجاف للجذور فسجلت أعلى قيمة لها في معاملة إضافة الهيدروجيل بمعدل ٢ جم مع نصف كمية السماد الموصى بها (HG₁+0.5F) وسجل أعلى وزن للمجموع الخضري في المعاملتين (HG₁+0.5F) و (HG₂+0.5F). أما بالنسبة للخواص الكيميائية للتربة، فإن إضافة مستويين من الهيدروجيل بمعدل (٢ و ٤ جم للنبات الواحد) أدى الى انخفاض رقم الحموضة بمقدار تراوح بين ٠.٠٨ - ٠.١٨ وحدة في منطقة الجذور. وأدت إضافة معاملة ٤ جم هيدروجيل للنبات الواحد مع نصف كمية السماد الموصى بها (HG₂+0.5F) الى زيادة السعة التبادلية الكاتيونية للتربة من ٩.٣٠ ± ٠.١٢ إلى ١١.٥ ± ٠.١٢، كما أدت الى زيادة محتوى التربة من العناصر الميسرة حيث زادت من ٣.٤٧ ± ٠.١٥ إلى ١٥.٨ ± ٠.٩ ومن ٢١ ± ١.٥ إلى ٢٨ ± ١.٥ ومن ٢٨٣ ± ٤ إلى ٣٤٣ ± ٢٣ مجم كجم⁻¹ للنيتروجين والفوسفور والبوتاسيوم على التوالي.