EFFECT OF SUBSOIL TILLAGE ON POTATO RESPONSE TO BIOFERTLIZATION APPLICATION

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ABSTRACT

This study was carried out at Kafr El-Gonena Village, El-Dakhlia Governorate, during 2008 winter season to identify effect of subsoil tillage on potato response to biofertilization application. The experiment was designed statistically as a split split plots with three replications. The main plots involved the subsoil tillage treatment at 0.30, 0.40 and 0.50 m depth, comparing with no-subsoil tillage, the sub plots involved the soil biofertilization treatment using Blue green Algae, comparing with the bereaved of biofertilization and the sub-sub plots included the tuber inoculation treatment using a combination of microorganisms, comparing with the bereaved of inoculation. The results indicated the following:

1. *The subsoil tillage of 0.40 m depth under Blue green Algae application achieved the more desirable soil* characteristics *of 1.14 g/cm^3 bulk density, 6.04 pH, 2.54* dS/m *salinity, 14.14 mm/h infiltration rate and 47, 17.90 and 497 ppm available N, P and K concentration, respectively.*
2. *The subsoil tillage of 0.40 m depth under Blue green Algae application required the lower applied irrigation water amount of 5240 m^3/fed.*
3. *The subsoil tillage of 0.40 m depth under Blue green Algae application and tuber inoculation achieved higher potato tuber yield of 18.80 Mg/fed and higher water use efficiency of 3.58 kg/m3.*

Generally, it is recommended to apply the subsoil tillage under biofertilization application to achieve higher potato tuber yield.

INTRODUCTION

With the steadily increasing the price of the chemical fertilizers and the pollution problems, the biofertilization application is becoming more and more important. Potato requires highly relative amount of chemical fertilizers. It requires about 120-150 kg N/fed, 60-70 kg P/fed and 96 kg K/fed **(Ministry of Agriculture and**

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Land Reclamation, 2005). Biofertilizer is defined as live formulates of beneficial microorganisms, which when is applied to soil, roots or seeds, enhances the availability of different nutrients to the plant by its inherent metabolic activity **(Higa, 1991)**. **El-Karamany et al. (2000)** stated that the biofertilizers significant effect may be due to effect of different strain groups and nutrients mobilizing microorganisms which help in availability of metals and their forms in the composted material and increased levels of extractable minerals. Beneficial microorganisms are these that can fix atmospheric nitrogen, decompose organic wastes, animal manures, detoxicty pesticides, suppress plant disease and soil-borne disease **(Parr and Hornick, 1994)**. **Awad (1998)** and **Abdulla (1999))** reported that potato vegetative growth characteristics increased as a result of applying chicken manure combined with biofertilizer.

The compacted subsoil hard-pan would reduce potato yield and quality under different soil types **(van Loon and Bouma, 1978, Wolfe et al., 1995** and **Stahlman and Allen, 2001)**. It reduces nutrients diffusion and mechanical resistance to root growth and elongation, resulting in a limited area for both water and nutrient uptake (**Wolkowski, 1990; Lowery and Schuler, 1994 and Laboski et al., 1998**).

There is unintelligible image about the effect of subsoil tillage on potato yield and quality could be drawn. The use of subsoil tillage has been recommended by **Stark and Love (2003)**to alleviate the abominable effects of compacted layers on potato productivity. On the other hand, **Holmstrom and Carter (2000)** reported that subsoil tillage has not consistently improved yields of potato in compacted soils. He found that no evidence of improved potato yield or quality, and only marginal improvements in soil bulk density when subsoil tillage was used to loosen compacted subsoil hard-pan. Therefore, **Ibrahim and Miller (1989); Miller and Martin (1990); Halderson et al. (1993) and Alva et al. (2002) stated that** potato yield was only marginally affected by subsoil tillage because proper irrigation and water management alleviated any potential benefits.

This study aimed to identify the effect of subsoil tillage on potato response to biofertilizers application.

MATERIAL AND METHODS

Experimental Procedure:

1. Soil characteristics:

A field experiment of 1 feddan (70 x 60 m)was carried out during 2008 winter season at Kafr El-Gonena Village, El-Dakhlia Governorate. According to the standard procedures as cited by **El-Serafy and El-Ghamry (2006)**, the soil was analyzed mechanically as shown in table (1). Also, table (2) reveals some soil characteristics. Table (3) presents the soil hydrophysical properties which were determined using pressure extractor with regulated air pressure as pointed out by Garcia (1978).

Table (1): Soil mechanical analysis of the experimental site.

Soil layer, m	Sand, %			Silt, %	Clay, %	Soil texture class
	Corse, %	Fine, %	Total, %			
0-0.30	9.00	8.30	17.30	48.53	34.17	Silty clay loam
0.30-0.60	9.10	7.30	16.40	46.00	37.60	Silty clay loam

Table (2): Some soil characteristics of the experimental site.

Soil layer, m	Moisture content (d.b.), %	Bulk density, g/cm^3	Ec, dS/m	pH, 1:2.5	Available N, ppm	Available P, ppm	Available K, ppm
0-0.30	18.12	1.39	5.28	8.50	34.55	11.24	471.09
0.3-0.6	20.01	1.48	5.82	8.75	29.85	6.85	459.85

Table (3): Some soil hydrophysical properties of the experimental site.

Soil layer, m	Field capacity, Wt/wt%	Wilting point, Wt/wt%	Available water, mm	Infiltration rate, mm/h
0-0.30	12.50	6.58	5.92	24
0.30-0.60	11.85	7.04	4.81	26

2. Agricultural practices:

a. Subsoil tillage:

The subsoil tillage was carried out using a mounted single shank subsoiler. It was made from a toolbar with a three point hitch, it was linked with a straight shank made of rigid steel with dimensions of 0.80 x 0.09 x 0.03 m. A mole-ball has cube shape of 0.10 x 0.10 x 0.10 m was linked with the shank. A four by four tractor with 120 kW power was used to mount and operate the subsoiler plough.

b. Seed bed preparation:

The seed bed was prepared using a chisel plough in two perpendicular directions at 0.20 m depth.

The secondary tillage was performed using a tandem disc harrow. The land leveling was carried out using a mounted hydraulic land leveler of 1.26 m^3 capacity (0.60 x 3.00 x 0.70 m).

c. Planting:

An one row semi-automatic with horizontal divided tray planter was used to plant the cut potato seed tubers Sponta variety. It was operated at 1.30 km/h forward speed using 2 WD tractor of 48 kW power.

As the recommendations of the **potato developing and training center (2001)**, the seed tubers were planted with a rate of 0.75 Mg/fed at 0.10 m planting depth, 0.75 m row spacing and 0.25 m hill spacing apart along the same furrow.

d. Fertilization:

1. The mineral N fertilizer in the form of ammonium sulfate (21% N) with a rate of 60 kg N/fed was applied in two equal doses before planting and before the 1st irrigation. Also, the N fertilization in the form of ammonium nitrate (34% N) with a rate of 60 kg N/fed was applied in two equal doses before 2nd and 3rd irrigations.
2. The biofertilizer in the form of blue green Algae powder with the rate of 0.50 kg/fed was applied, at the tenth day after sowing, it was mixed with a suitable quantity of softy soil, then, the mixture was broadcasted above the irrigation water surface.
3. Tuber inoculation was conducted using a combination of Azospirilium sp., Azotobacter sp., Bacillus mega-theruim var. phosphaticum, Pseudomonas sp. And Mycorriza sp. With a rate of 0.50 kg/ton of potato tuber seeds.

e. Irrigation:

The border surface irrigation system was applied using an electric archimedean screw of 375 m^3/h discharge.

As presented in table (4), the irrigation water was analyzed chemically according to **El-Serafy and El-Ghamry** (**2006**).

Table (4): Irrigation water chemical analysis at the experimental site.

Ph, 1:2.5 (susp.)	EC_w, dS/m	Total soluble salts, ppm	Soluble anions, ppm				Soluble cations, ppm				SAR
			CO_3	HCO_3	Cl	So_4	Ca	Mg	Na	K	
8.37	4.43	2296.46	0.05	549.43	956.32	227.52	85.64	122.37	344.57	10.56	3.57

The irrigation was scheduled during potato growth stages as follows:

1. 1 irrigation during sprout development stage at 50% of the available soil water.
2. 1 irrigation during vegetative groth stage at 50% of the available soil water.
3. 3 irrigations with interval of 14 days during tuber set initiation stage at 60% of the available soil water.
4. 3 irrigations with interval of 14 days during tuber bulking stage at 60% of the available soil water.

All other practices were done according to the recommendations of Potato and Vegetatively Propagated Vegetables Res. Dept., Horticulture Inst., Ag. Res. Center, Ministry of Agriculture and Land Reclamation.

3. Treatments and statistical design:

During the experiment, the following treatments were tested:

1. Subsoil tillage: It included the subsoil tillage depth levels of 0.30, 0.40 and 0.50 m, comparing with no-subsoil tillage (control). In each plot, two trenches were holed longitudinally at 6.00 m spacing apart. Also, two trenches at 0.50 m depth and 20.00 m spacing apart were digged horizontally to separate between each replication and the other.
2. Soil biofertilization: It included the soil biofertlization application using Blue green Algae, comparing with the bereaved of biofertilization (control).
3. Tuber inoculation: It included the tuber inoculation, comparing with the bereaved of inoculation.

The experiment was designed statistically as a split split plots with three replications. The main plots involved the subsoil tillage treatment levels, the sub plots involved the biofertilization treatment levels and the sub-sub plots included the tuber inoculation treatment levels.

Measurements:

1. Soil characteristics:

At harvest, the soil moisture content and the soil bulk density were determined according to **ASAE (1992)**, the soil pH and the soil salinity were determined as cited by **Black et al. (1965)**, the soil infiltration rate was determined according to **Garcia (1978)** and the available soil macronutrients concentration was determined according to **Hesse (1971)**.

2. Total amount of irrigation water:

The total amount of irrigation water (TIW) was determined as follows:

$$TIW = \frac{LR + CR}{\eta A} m^3 / fed \qquad (1)$$

Where:

LR is leaching requirements, m^3/fed.

CR is crop water requirements, m^3/fed.

η is irrigation system efficiency, %.

A is irrigated area, fed.

LR is estimated as outlined by Doorenbos and Prutt (1977) as follows:

$$LR = \frac{ECi}{EC_d} \qquad (2)$$

Where:

EC_i is irrigation water electrical conductivity, dS/m.

EC_d is drainge water electrical conductivity, dS/m.

The net crop water requirements and the irrigation interval (*II*) are calculated as cited by **FAO (1979)** and **Israelson** and **Hansen (1962)** as follows:

$$WHC = (FC - PWP)\, p_b \,.\, d\,.10 \text{ mm} \qquad (3)$$

$$Max.CR = \frac{MAD.WHC}{100} \text{ mm} \qquad (4)$$

$$Max.CR = \frac{Max.g.w.r}{\eta} mm \quad (5)$$

$$II = \frac{Max.CR}{Etcrop} day \quad (6)$$

$$Et = Et_0 \times k_c \ mm/day \quad (7)$$

Where:

WHC. is soil water holding capacity, mm.

FC is soil field capacity, %.

PWP is soil permanent wilting point, %.

ρ_b is soil bulk density, g/cm^3.

D is effective root zone depth, m.

MAD is management allowable deficit,mm/m.

Max. g.w.r is maximum gross water requirements, mm.

Et is net crop water requirements, mm.

Et_0 is potential evapotranspiration, mm/day.

K_c is crop factor.

Et_0 was calculated according to the data recorded by Kafr Ssad weather station, Domiat *Governorate* which is affiliated to the Central Laboratory for Agricultural Climate, Ministry of Agriculture and Land Reclamation.

The irrigation water amount was measured using a rectangular shape crested weir. It was determined according to **James (1988)** as follows:

$$Q = k.c_d.A\sqrt{H} \quad \text{L/s} \quad (8)$$

Where:

Q is orifice discharge ,L/s

k is discharge coefficient.

c_d is constant unit.

A is orifice area, m^2.

H is effective water head over the orifice center, m.

3. Potato tuber yield:

At harvest, for each experimental unit, an area of 1 m^2 was selected randomly to determine the potato tuber yield.

4. Water use efficiency (*WUE*):

$$WUE = \frac{\text{grain yield, kg/fed.}}{\text{appllied irrigation water amount, m}^3\text{/fed.}} \quad \text{kg/m}^3 \quad (9)$$

Statistical Analysis:

SAS computer software package was used to employ the analysis of variance and the LSD tests for potato tuber yield data.

Regression and Correlation Analysis:

Microsoft Excel 2007 computer program was used to carry out the simple regression and correlation analysis to represent the relation between the subsoil tillage depth and the potato tuber yield.

RESULTS AND DISCUSSIONS

1. Soil Characteristics:

Through figures (1) to (8), it is clear that the subsoil tillage of 0.40 m depth under Blue green Algae application achieved the more desirable soil characteristics of 1.14 g/cm^3 bulk density, 6.04 pH, 2.54 dS/m salinity, 14.14 mm/h infiltration rate and 47, 17.90 and 497 ppm available N, P and K concentration, respectively.

It is obviously that the desirable effect of the subsoil tillage on the soil characteristics could be arranged in the following descending order: 0.40> 0.50> 0.30 m depth. This trend may be illustrated that as the subsoil tillage depth increased, the subsoiler mole-ball stacks the soil clods under its middle beating and shooting them upwards, which allows them to be charged with a higher kinetic energy, giving higher degree of soil rupture. Then, the irrigation water streams, detaches soil particles from the surface and pushes fine particles into surface pores, creating smaller pores which offer greater resistance to gravity, where they may impede gradually the infiltration process with the soil depth. Then, at the deeper soil layer, the exceed soil resistance against the subsoiler mole-ball the diminishes the soil rupture, resulting in lower soil pulverization, creating relative larger soil clods that increase slightly the soil infiltration process. Consequently, the soil characteristics relate strongly with the soil moisture content which is negatively proportional to the soil bulk density, pH and salinity, consequently, increasing the availability of macronutrients.

Also, data show the significant effect of the biofertilization on improving the soil characteristics. It is attributed to the biological process in which microorganisms decompose the soil organic materials, consuming oxgen and producing carbon dioxide, water and heat into the soil, maintaining the soil fertility.

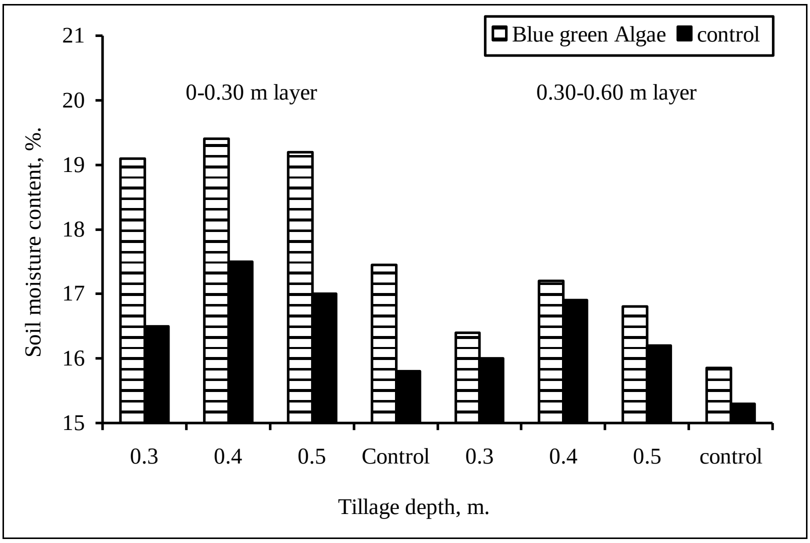

Fig. (1): Effect of subsoil tillage on soil moisture content.

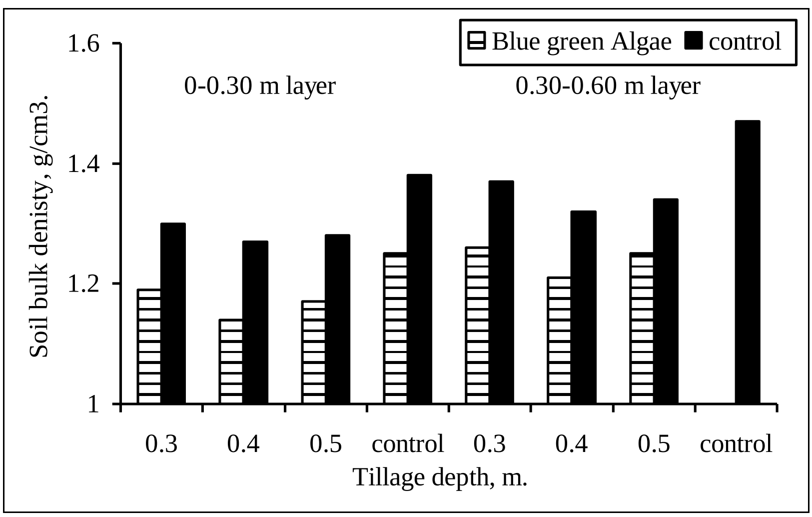

Fig. (2): Effect of subsoil tillage on soil bulk density.

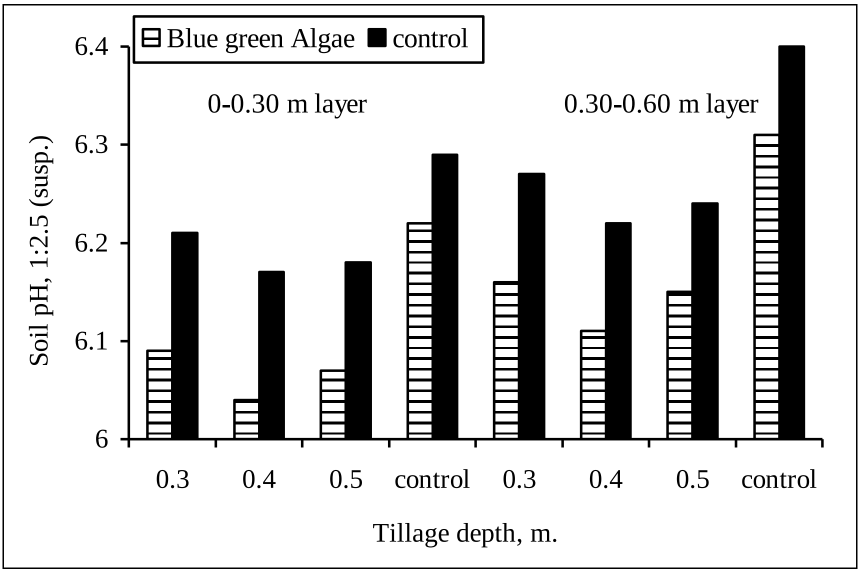

Fig. (3): Effect of subsoil tillage on soil pH.

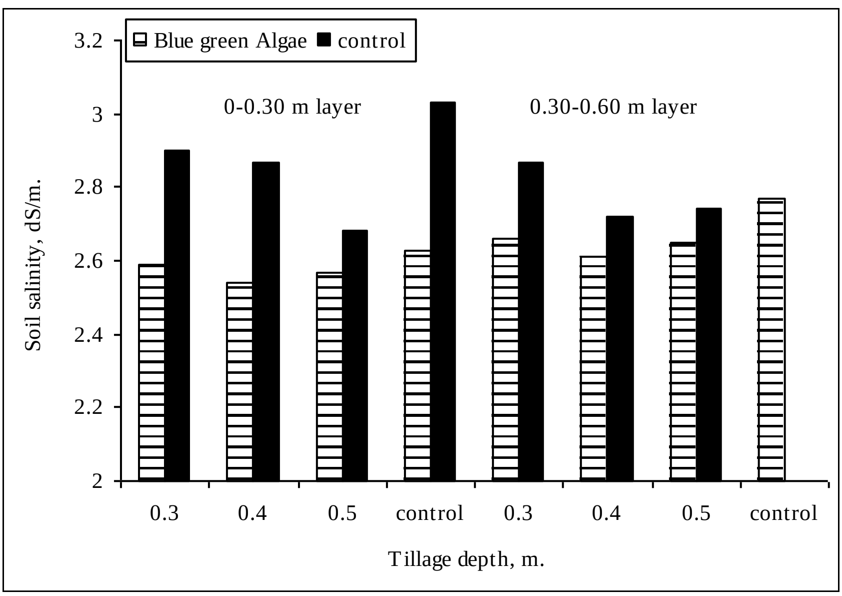

Fig. (4): Effect of subsoil tillage on soil salinity.

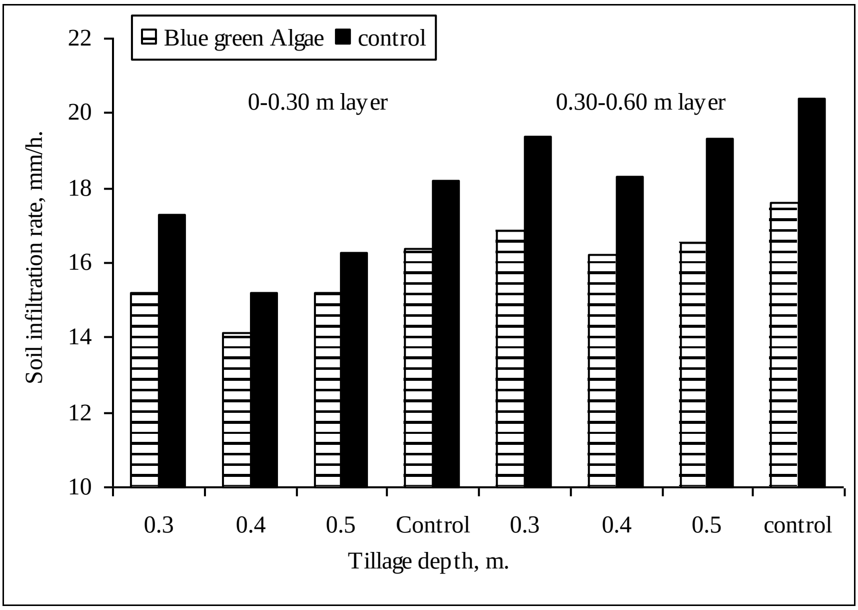

Fig. (5): Effect of subsoil tillage on soil infiltration rate.

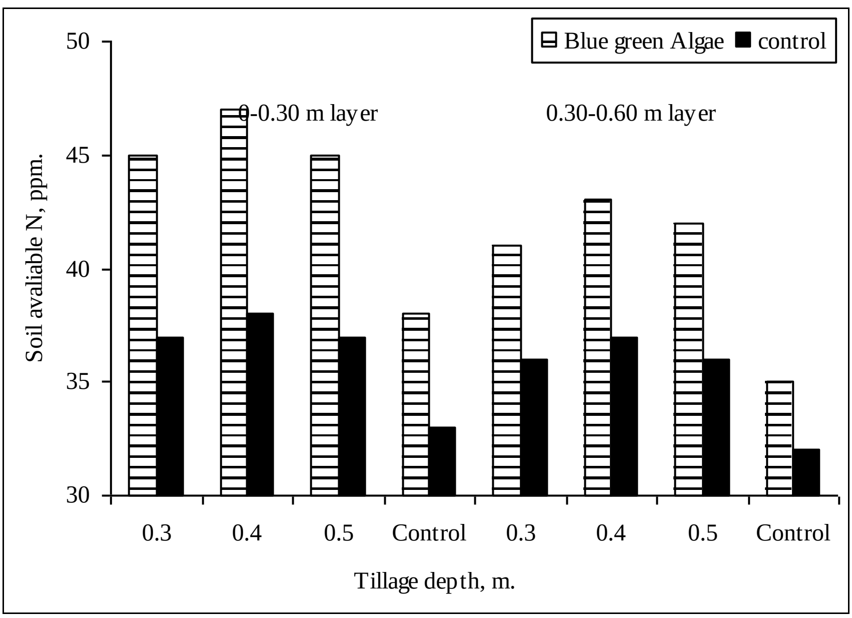

Fig. (6) Effect of subsoil tillage on soil available N.

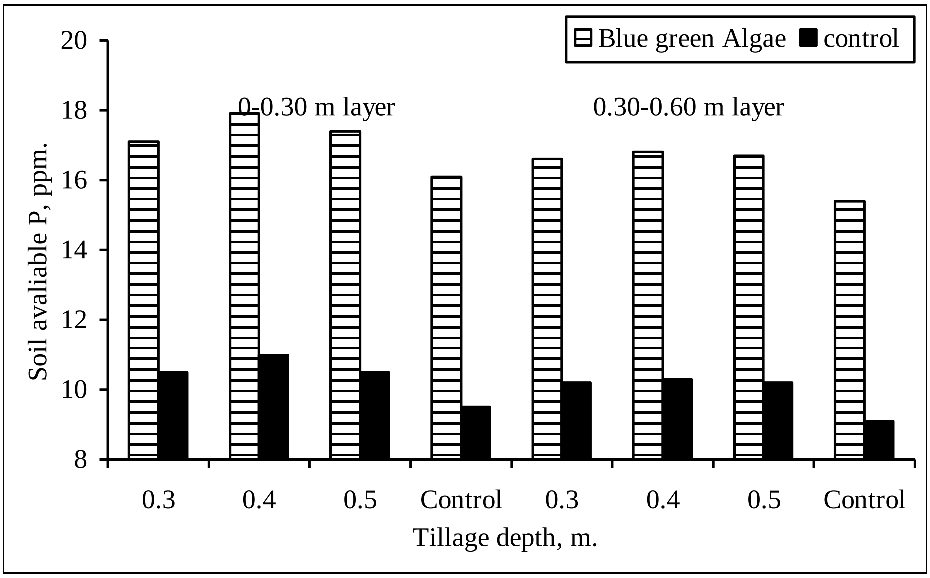

Fig. (7) Effect of subsoil tillage on soil available P.

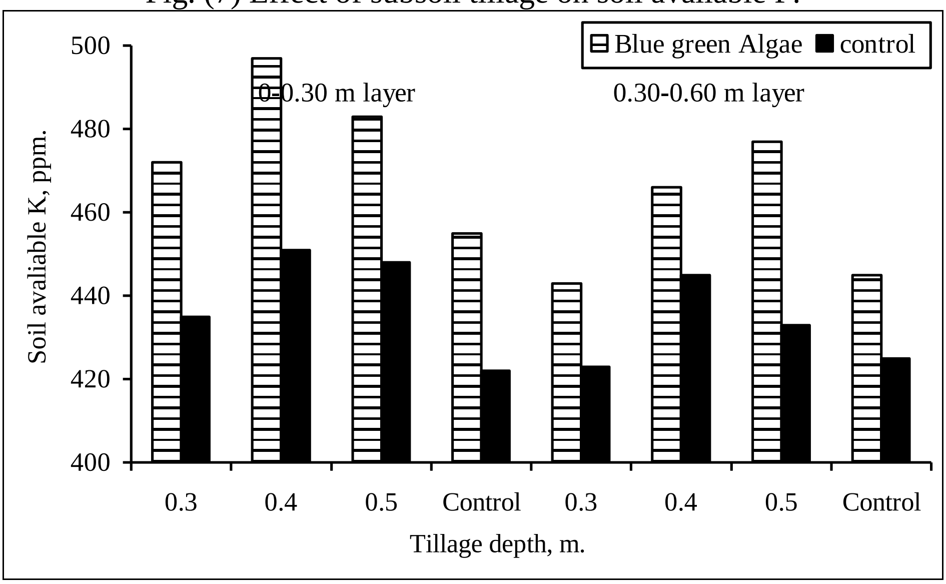

Fig. (8): Effect of subsoil TILLAGE on soil available K.

2. Applied Irrigation Water Amount:

Figure (9) demonstrates the effect of subsoil tillage under biofertilizer application on the applied irrigation water amount during potato growing stages. Data exhibits that the subsoil tillage at 0.40 m depth under Blue green Algae application required the lower irrigation water amounts of 1218, 937, 1400 and 1685 m^3/fed during sprout development, vegetative growth, tuber set initiation and tuber bulking growing stages, respectively. In other meaning, it required the lower total irrigation water amount of 5240 m^3/fed during the growing season.

Data shows that the subsoil tillage at 0.30, 0.40 and 0.50 m saved the total irrigation water amount by about 6.57, 20.00 and 14.00%, respectively of the irrigation water amount that was required without using the subsoiler. It is due to the desirable soil characteristics after subsoiling which decreases the irrigation water losses by evaporation and run-off. On the other hand, the biofertilizer application at 0.30, 0.40 and 0.50 m subsoiling depth saved the total irrigation water amount by about 6.00, 11.00 and 11.00%, respectively of the irrigation water amount that was required in case of the bereaved of biofertilizer application. This finding is illustrated that the biofertilization enhance to improve the soil structure, resulting in the increase of water retention.

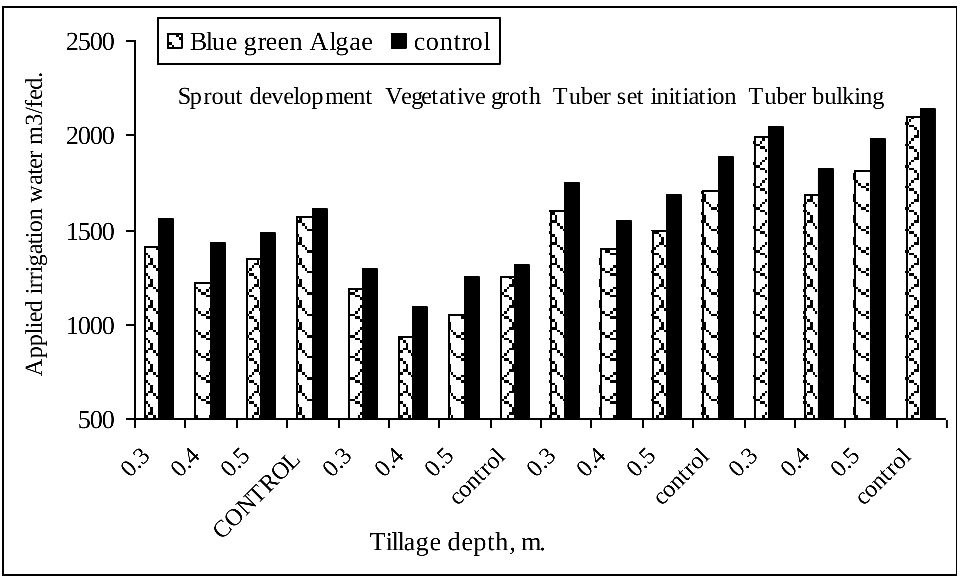

Fig. (9): Effect of subsoil tillage on applied irrigation water amount .

3. Potato Tuber Crop Yield:

Figure (10) clarifies that the higher potato tuber yield of 18.80 Mg/fed was obtained using the subsoil tillage of 0.40 m depth under Blue green Algae application and the tuber inoculation. Data exhibit that the subsoil tillage of 0.30, 0.40 and 0.50 m depth increased potato tuber yield by about 147.00, 153.00 and 148.00%, respectively of the tuber yield value tha was obtained in case of no-subsoil tillage. This finding could be illustrated that the subsoil tillage leads to improve the soil drainage and aeration, which help plant roots to penetrate and well root distribute in the soil. Therefore, potato tuber yield was affected significantly using the biofertilizer. Blue green Algae application increased potato tuber yield by about 132.00, 127.00 and 135.00%, at subsoil tillage depth of 0.30, 0.40 and 0.50 m, respectively of the tuber yield value that was obtained in case of the bereaved of biofertilizer application. This finding is explained that biofertilizer improves the soil conditions, resulting in the increase of nutrients solubility and nutrient availability to the plants that enhance plant growth and development. In addition, the tuber inoculation influenced potato tuber yield positively. The tuber inoculation increased potato tuber yield by about 17.00, 15.85 and 16.00% at subsoil tillage depth of 0.30, 0.40 and 0.50 m, respectively under biofertilizer application. This result could be explained that the inoculated biofertilizer with the combination of N mineral fertilization may increase the crude protein in the tuber tissues.

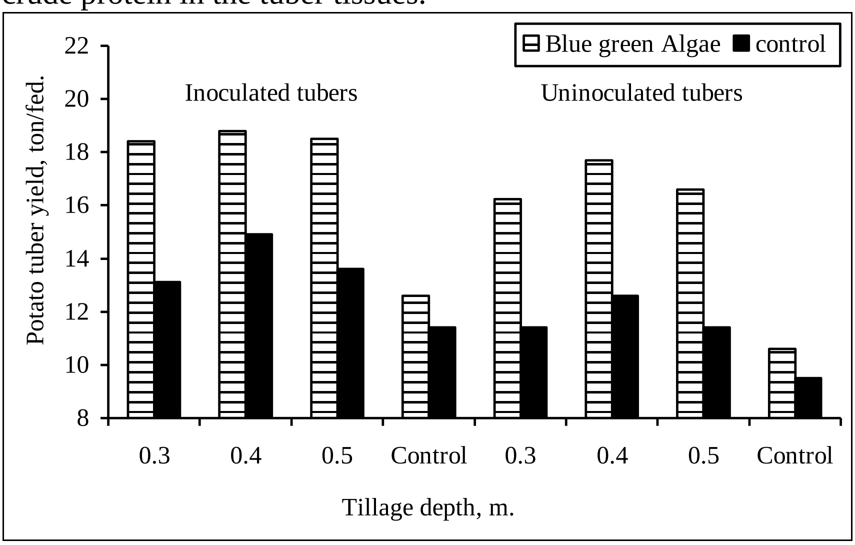

Fig. (10): Effect of subsoil tillage on potato tuber yield.

The analysis of variance test indicates that there is a highly significant difference in potato tuber yield due to the subsoil tillage and the biofertilization application.

The L.S.D. test at 0.05 level shows that the subsoil tillage depth of 0.04 m under Blue green Algae application and tuber inoculation achieved the highest potato tuber yield among the other treatments.

The regression and correlation analysis reveals that the potato tuber yield (y) correlates positively with the subsoil tillage depth (x) under Blue green Algae application and tuber inoculation as follows:

Blue green Algae: $y = - 0.350 x^2 + 1.450 x + 17.300$ ($R^2 = 1.000$)

control : $y = - 0.085 x^2 + 0.602 x + 12.190$ ($R^2 = 0.407$)

4. Water Use Efficiency:

Figure (11) demonstrates that the higher water use efficiency value of 3.58 kg/m^3 was achieved using the subsoil tillage at 0.40 m depth under Blue green Algae application and tuber inoculation. Data indicate that the subsoil tillage depth of 0.30, 0.40 0.50 m increased the water use efficiency by about 152.00, 176.00 and 162.50% respectively of the water use efficiency value that was obtained in case of no-subsoil tillage. While, Blue green Algae application at subsoil tillage depth of 0.30, 0.40 and 0.50 m increased the water use efficiency by about 130.00, 135.00 and 132.00%, respectively of the water use efficiency value that was obtaine by the bereaved of biofertilizer application. Whereas, the tuber inoculation at subsoil tillage depth of 0.30, 0.40 and 0.50 m increased the water use efficiency by about 110.00, 108.00 and 112.00%, respectively of the water use efficiency that was obtaine incase of the bereaved of tuber incolation.

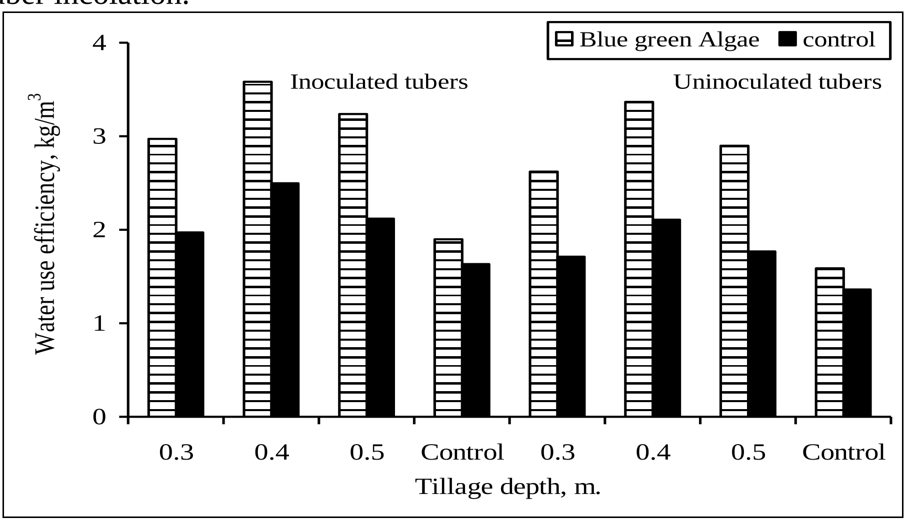

Fig. (11): Effect of subsoil tillage on potato water use efficiency.

CONCLUSION

The obtained results of this study could be concluded as follows:

1. The subsoil tillage under biofertilizer application achieved the proper soil characteristics.
2. The subsoil tillage under biofertilizer application saved the total applied irrigation water amount.
3. The subsoil tillage under biofertilizer application and tuber inoculation produced the higher potato tuber yield and the reached the higher water use efficiency.

Finally, it is recommended to use the subsoil tillage under the biofertilizer application due to the desirable soil characteristics, the higher potato tuber yield and the higher water use efficiency.

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الملخص العربي

تأثير الحرث تحت التربة على إستجابة البطاطس للتخصيب الحيوي

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أجريت هذه الدراسة بقرية كفر الجنينة بمحافظة الدقهلية خلال الموسم الشتويي ٢٠٠٨, وذلك للوقوف على تأثير الحرث تحت التربة على إسجابة البطاطس للتخصيب الحيوي, وقد تم تصميم التجربة إحصائياً في قطع تحت منشقة في ثلاثة مكررات, وقد تضمنت القطع الرئيسة معاملة الحرث تحت التربة عند أعماق ٠,٣٠, ٠,٤٠, ٠,٥٠ م, بينما إشتملت القطع الشقية على معاملة التخصيب الحيوي للتربة باستخدام المخصب بلوجرين بالمقارنة مع عدم التخصيب الحيوي للتربة, أما القطع تحت الشقية فقد إشتملت على معاملى التخصيب الحيوي لدرنات البطاطس بالمقارنة مع عدم التخصيب الحيوي للدرنات, ويمكن تلخيص أهم النتائج كما يلي:

١. حقق الحرث تحت التربة عند عمق ٠,٤٠ م مع إستخدام المخصب الحيوي بلوجرين أفضل القيم لخصائص للتربة, فكانت الكثافة الظاهرية للتربة ١,١٤ جم/سم^{3}و درجة حموضة التربة ٦,٠٤و ملوحة التربة ٢,٥٤ ملليموز/سمو معدل رشح التربة ١٤,١٤ مم/سو تركيز للعناصر الغذائية الكبرى الميسرة بالتربة ٤٧, ١٧,٩٠, ٤٩٧ جزء في المليون للنتروجين والفوسفور والبوتاسيوم على الترتيب.
٢. حقق الحرث تحت التربة عند عمق ٠,٤٠ م مع إستخدام المخصب الحيوي بلوجرين أقل كمية مستهلكة من مياه الري بمقدار ٥٢٤٠ م^{3}/فدان.
٣. حقق الحرث تحت التربة عند عمق ٠,٤٠ م مع إستخدام المخصب الحيوي بلوجرين والتخصيب الحيوي للدرنات أعلى إنتاج لدرنات البطاطس (١٨,٨٠ طن/فدان) وأعلى كفاءة للإستفادة من مياه الري بمقدار ٣,٥٨ كجم/م^{3}).

وبصفة عامة, فإنه يوصى باستخدام الحرث تحت التربة مع إستخدام التخصيب الحيوي للتربة ولدرنات البطاطس, وذلك لتحقيق أعلى إنتاج لدرنات البطاطس مع توفير أكبر قدر ممكن من مياه الري.

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