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## **Biogat-fert technique for maximizing water and fertilizer units productivity for potato crop**

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**Abstract**---Biogat-fert technique ensure to maximizing water and fertilizer unit productivity for potato crop, Two field experiments were carried out during growing seasons 2019-2020 and 2020-2021, at research farm of National Research Centre in Nubaria region, Egypt to study management of biogat-fert technique on potato crop under drip irrigation system in sandy soil conditions. Study factors were fertigation techniques (fertigation, biogat-fert and fertilizers). The following parameters were studied to evaluate the effect of study factors: (1) mineral and biological fertilizers effect of soil, (2) microbial number, (3) NPK ratio, (4) Yield of potato, (5) water use efficiency of potato, (6) Crop water production function. The results conducted that soil fertility was enhanced greatly in bio-fertilizer treatment. The average total N, total P and total K in 0–40 cm soil layers increased to 29.17, 26.67 and 36.7% respectively. The average CFU of bacteria in soil layers increased by 15 Time. After drip irrigation, the CFU of bacteria had increased further, and reached more than  $7.8 \times 10^7$  CFU/g dry soil in the 0–40 cm soil layers. The results showed that the application of different bio-fertilizer along with fertilizers revealed significant positive impact on crop yield. This indicated that biogat-fert technique with drip irrigation had improved the soil environment

and it was more favorable for bacterial growth. The water productivity achieved high amount with fertilization technique compared with the others treatments. Data speculated that 25% of the applied mineral fertilizers could be saved without any significant crop reduction of potato with the application of biogat-fert technique under sandy soil conditions.

**Keywords**--bio-fertilizers, azotobacter, bacillus circullans, bacillus megaterium, soil microbial characteristics, potato yield, drip irrigation.

## Introduction

Potato (*Solanum tuberosum* L.) solanaceae family, is very popular and important vegetable grown in all over world. It is the fourth important crop after maize, wheat and rice. Nitrogen, phosphorus and potassium are the significant supplements influencing development, improvement and yield of potato. Chemigation is usually used to ensure stable productivity of potato and other economical crops but it becomes undesirable due to its potential hazardous to environment and humans. Biogation technique means the application of bio-fertilizers (bacterial inoculum broth) through the irrigation water system (drip irrigation) In this regard, El-Gindy *et al.* (2007) explained that applying bio-fertilizers via irrigation water, (biogation) induced improvement in tomato yield under sandy soil conditions with considerable increase over the traditional application (fertigation). Arafa (2016) stated that chemigation systems is usually used to ensure stable productivity of crop-unit area and improve yieldquality, but on the other hands, it represent a serious problem for applying such systems, as well as, its impact on either yield production and attributed quality parameters or agricultural physical resources. Jigme *et al.* (2015) mentioned that the highest value of heads yield of broccoli plants was recorded by application of mineral fertilizer compared with the organic treatments, but there was no significant difference in yield between mineral fertilizers and compost treatment. Densilin *et al.* (2010) stated that bio-fertilizers are living life forms utilized as a part of the preparation of soil and are helpful in supplementing the typical use of substance manures and help in improving the soil. Soil microorganisms assume an imperative part in change of supplement for plant utilize. On the off chance that the microorganisms are absent in sufficient sum in soil, they must be vaccinated by utilizing bio fertilizers. In recent decades, surface fertigation has been identified as a technology to increase fertilizer distribution uniformity and application efficiency (Playán *et al.*, 2014). Arafa *et al.*(2009) there is a positive proportional trend between the fertigation scheduling (fertigation rate) and the observed values of the vegetative growth indices and the maximization indices of irrigation water and fertilizer use efficiencies with corresponded pressurized irrigation systems under drought ecosystems of sandy soils. Recently one of the significant worries is the contamination and tainting of soil with the utilization of abundance substance manures and pesticides. Verma *et al.* (2014) mentioned that the highest values of cabbage head yield were obtained by treatment of 100% recommended fertilizers with seedling treated by *Pseudomonas fluorescens* and humic acid as compared with the other treatments. Applying bio-fertilizers via

irrigation water, i.e. biogation is thought to be an alternative technique for chemigation with the consideration of the use of appropriate injector, properly designed and operated irrigation system and optimized microbial dose. The system could be particularly important under sandy soil condition where water economy and utilization of microbial activities are two main factors affecting crop performance. No technically, economically and environmentally feasible studies focused on application possibility of the alternative technique; evaluation and performance consideration exists under field conditions. The goal of this study was management of biogation and fertigation techniques to evaluate water regime, (fertigation) and rhizobium inoculation (biogation) effects on potato productivity and water, fertilizers use efficiency and water movement under sandy soil condition product. as well as to improve the production capacity of the limited quality land while rationalizing the use of the water and fertilizer units. The consequences of this work may help in improving the development and nature of potato tuber and expanding its yield and enhancing the soil fertility.

### Materials and Methods

Description of study site:

#### Location and Meteorological data

Field experiments were conducted during two successive growing seasons from Nov. to March of 2019-2020 and 2020-2021 at the experimental farm of National Research Centre, El-Nubaria, Egypt (latitude 30° 30' 1.4" N, and longitude 30° 9' 10.9" E, and mean altitude 21 m above sea level). The experimental area has an arid climate with cool winters and hot dry summers prevailing in the experimental area. The monthly mean climatic data for the two growing seasons, for El-Nubaria area, are nearly the same. The data of maximum and minimum temperature, relative humidity, and wind speed were obtained from Central Laboratory for Agricultural Climate (CLAC).

#### Soil properties

Representative soil samples were taken at different soil layer depths (0-15, 15-30, 30-45, and 45-60 cm) Soil chemical characteristics were measured as follows: Soil pH and  $E_c$  were measured in 1:2.5 (soil: water suspension) and in soil paste extract, respectively. Table (1) presents some soil chemical properties at the experimental site.

Table (1): Some soil chemical characteristics at the experimental site.

Depth, (cm)	pH 1:2.5	EC, dS/m	Soluble Cations, meq/L				Soluble Anions, meq/L			
			Ca <sup>++</sup>	Mg <sup>++</sup>	Na <sup>+</sup>	K <sup>+</sup>	CO <sub>3</sub> <sup>-</sup>	HCO <sub>3</sub> <sup>-</sup>	SO <sub>4</sub> <sup>-</sup>	Cl <sup>-</sup>
<b>0-15</b>	8.3	0.35	0.50	0.42	1.05	0.23	0	0.11	0.82	1.27
<b>15-30</b>	8.2	0.36	0.51	0.43	1.04	0.24	0	0.13	0.86	1.23
<b>30-45</b>	8.3	0.34	0.55	0.41	1.05	0.23	0	0.12	0.85	1.27

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45-60	8.4	0.73	0.57	0.43	1.06	0.25	0	0.17	0.86	1.28
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### Irrigation system Components

The irrigation system consisted of a centrifugal pump with 45 m<sup>3</sup>/h discharge rate, a screen filter and a backflow prevention device, a pressure regulator, pressure gauges, control valves and a flow meter. The main line, a polyvinyl chloride (PVC) pipe with 110mm outer diameter (OD), conveyed the water from the source to the main control points in the field. Sub-main lines, connected to the main line, were PVC pipes with 75mm OD. Manifold lines, polyethylene (PE) pipes of 63 mm OD, were connected to the sub-main line and control valves and discharge gauges. The emitters were built in lateral PE tubes, 50 m long and 16 mm OD. Emitter discharge was 4 l/h at 1.0 bar operating pressure, spacing between the emitters was 30cm fig. (1). Venturi injector (1" in diameter) was used for injecting bio-fertilizers (liquid broth media) via irrigation (bio-gation), as well as chemical fertilizers added via irrigation system.

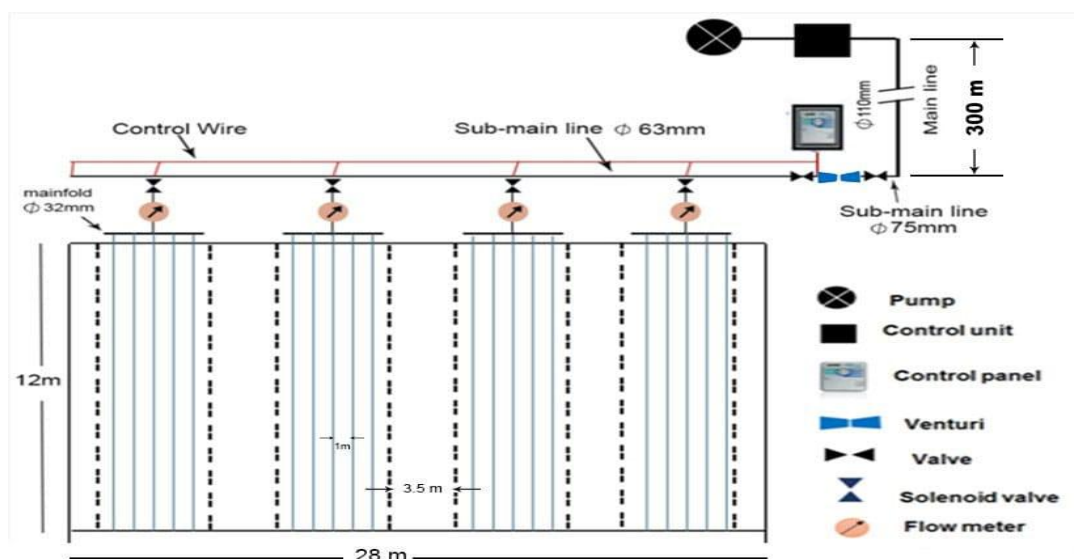


Figure (1): Layout of the experiment.

### Irrigation water analysis

The experiment was conducted under drip irrigation system. Irrigation water was obtained from an irrigation channel (Nile water) going through the experimental site, with pH 8.3, and an electrical conductivity of 0.60 ds m<sup>-1</sup> as shown in Table (2).

Table (2): Irrigation water chemical characteristics at the experimental site

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pH	EC, dS/m	Soluble cations, meq/L	Soluble anions, meq/L
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		<b>Ca<sup>++</sup></b>	<b>Mg<sup>++</sup></b>	<b>Na<sup>+</sup></b>	<b>K<sup>+</sup></b>	<b>CO<sub>3</sub><sup>-</sup></b>	<b>HCO<sub>3</sub><sup>-</sup></b>	<b>SO<sub>4</sub><sup>-</sup></b>	<b>Cl<sup>-</sup></b>
7.3	0.60	0.76	0.24	2.6	0.12	0	0.9	0.32	2.51

**PH:** power of hydrogen; **EC:** Electrical conductive; **SAR:** Sodium absorption ratio.

### Water application

Table (3): Amount of irrigation water added throughout Potato growth season according to, Doorenbos and Kassam (1979)

Stage	Length of stage	K <sub>c</sub>	ET <sub>o</sub> , mm stage <sup>-1</sup>	ET <sub>c</sub> , mm stage <sup>-1</sup>	Total amount of irrigation water m <sup>3</sup> ha <sup>-1</sup>
Initial	25	0.50	6.7	14.07	351.75
Development	30	0.63	5.6	14.82	444.6
Midseason	30	1.15	5.49	26.51	795.3
Late	35	0.75	6.8	21.42	744.9
Total	120 days		24.59	76.82	2336.5

### Crop type

One crop type, Potatoes Spunta Netherland production has been selected. The plot has been applied with recommended fertilization and agronomic practices, which has been stated in the official agricultural bulletins. The experimental areas were cultivated from (5-Nov.:5-Mar.) at two seasons 2019-2020 and 2020-2021. Growing stage lengths, crop coefficients (K<sub>c</sub>), crop height (*h*), and root depth (Z<sub>r</sub>) of the four growth stages (initial stage, crop development stage, mid-season stage, and late season stage) for Potatoes crop according to single-K<sub>c</sub> are tabulated in Tables (4).

Table (4): Reference values of Lengths, the single crop coefficient (K<sub>c</sub>), crop height (*h*), and root depth (Z<sub>r</sub>) for the four growth stages of Potatoes.

Stage	Period	Days	K <sub>c</sub>	<i>h</i> , m	Z <sub>r</sub> , mm
<b>I. Potatoes</b>					
<b>Initial stage</b>	5-Nov.:30-Nov.	25	0.50	0.14	0.20
<b>Development stage</b>	1-Dec.:30-Dec.	30	0.77	0.36	0.49
<b>Mid-season stage</b>	1-Jan.:30-Jan.	30	1.15	0.60	0.80
<b>Late season stage</b>	1-Feb.: 5-Mar.	35	0.75	0.51	0.80

### Investigated techniques

#### Mineral fertilizer

The recommended doses of mineral fertilizer The recommended doses of chemical fertilizer were considered according to the recommendation of the Horticulture Research Institute, ARC, Ministry of Agriculture and Land Reclamation, were added as fertigation *i.e.* nitrogen fertilizer was added at a rate of 120 kg/Fed as

ammonium sulfate (20.6 % N), 150 kg calcium super phosphate/fed (15.5% P<sub>2</sub>O<sub>5</sub>) and 50 kg potassium sulfate (48 % K<sub>2</sub>O) were added. Mineral fertilizers were applied by injection through the irrigation water. Fertigation applied through venture injector using 16 mm valves constructed on the opening mouse of irrigation line.

### **Bio-fertilizer**

The bio-fertilizer was supported by Microbiology department, Agricultural and Biological Research division, National Research Centre. It was containing a mixture of N<sub>2</sub>-fixing bacteria (*Azotobacter chroococcum*) and (*Bacillus megaterium*) or phosphate mobilizing and (*Bacillus circulance*) or Potassium dissolving. The first concentration: after 10 days after planting.

- The second concentration: after 15 days of the first treatment.
- The third concentration: after 20 days of the second treatment.
- Dilution is done by 2 liters/ 20 liters of water, and then the irrigation process is done.

Bio-fertilization treatments were applied by injection through the irrigation water. And the microbial data analysis had been conducted according to **Gracias (2004)**.

### **Treatments**

1. Biogat-fert technique with drip irrigation (T1).
2. Fertigation technique with drip irrigation (T2).
3. Fertilization technique with drip irrigation (T3).

### **Measurements and calculation**

1. Distribution of bacteria, with the different growing stages.
2. Correlations between soil microorganisms and salt distribution pattern.
3. Crop water production function.
4. Crop yield.
5. Irrigation Water Use Efficiency of Potato Crop.
6. Water unit productivity of potato crop.
7. Fertilizers use efficiency.

### **Results and Discussion**

#### **Distribution of bacteria, with period of cultivation**

The CFU of bacteria increased with the duration of drip irrigation especially under bio-fertilizers treatment compared with mineral fertilizers. The CFU of bacteria in 0–40-cm soil layers on the uncultivated land was low. The average CFU of bacteria in 0–40-cm soil layers increased by 112 times, After two years of drip irrigation, the CFU of bacteria had increased further, and reached more than  $78 \times 10^6$  CFU g<sup>-1</sup> dry soil in the 0–10-cm soil layers, and this indicated that cultivation had improved the soil environment and it was more favorable for bacterial growth. In the vertical direction, the CFU of bacteria in the surface soil layers were higher

than the sub soil on uncultivated land. This is because the vertical distribution of soil microbes is restricted by the soil physical and chemical characteristics and soil nutrient status. With increased depth, the soil temperature, organic matter and N all decrease, which is not suitable for growth of most microbes. The roots were mainly distributed in 0–10-cm soil layers, and so soil in this layer has good nutrition – the CFU of soil microbes was greater in this layer than in subsoil (Jin *et al.*, 1996). In the horizontal direction, for irrigated land the bacteria activity was always higher near the emitter than further away. After the end of cultivation, the bacteria activity near the emitter was 2.24 times that on the land before irrigation. The activities under the emitter, and 10 cm away were higher than at 15, 20 and 30 cm away, in the irrigated land.

### Correlations between soil microorganisms and salt distribution patterns

After the period of irrigation with T1, the growing conditions of Potatoes changed as the soil environment greatly improved. The soil salinity decreased significantly in Bio-fertilizer treatment more than other treatments. The soil salinity decreased significantly, the average ECe in 0–45-cm soil layers was  $0.33 \text{ ds m}^{-1}$  figure (2, 3 and 4), and average pH was 7.8. Soil fertility was enhanced greatly.

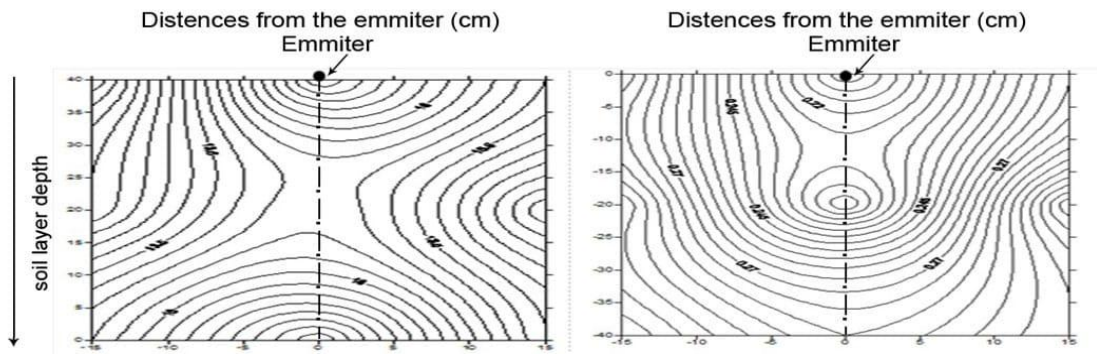


Figure (2): Total count and salt distribution patterns for fertigation technique

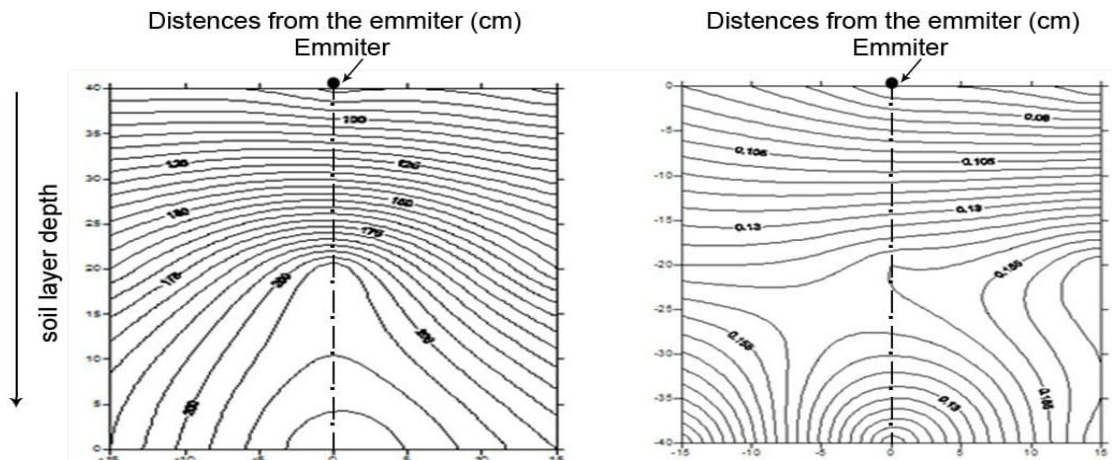


Figure (3): Total count and salt distribution patterns for biogat-fert technique

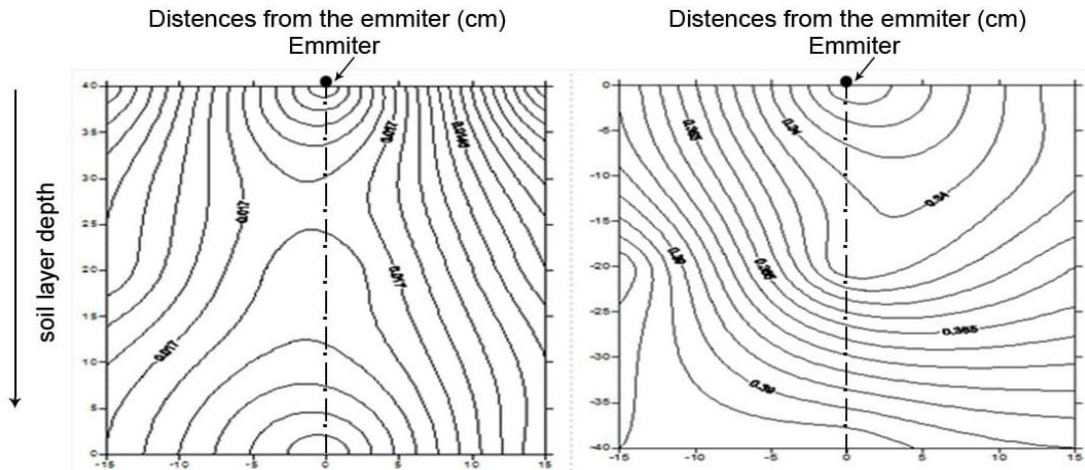


Figure (4): Total count and salt distribution patterns for fertilization technique

Soil fertility was enhanced greatly in Bio-fertilizer treatment more than all treatments. The average total N, total P and total K in 0–45 cm soil layers increased to 29.17, 26.67 and 36.7% respectively. The soil environment was improved greatly, and there were significant positive correlations between bacteria, phosphate, urea activities; and significant negative correlations with  $E_c$  and Ph. The value of urea activities is shown in Figure (5). There was no clear change in urea activities in the horizontal direction for both the initial and mid stages. After drip irrigation for the season, urea activity near the emitter was greatly improved, but decreased with increased distance from the emitter. Urea activity under the emitter was 1.6 times that at 45 cm away from the emitter. Urea activity in the surface layer was higher than in deeper soil, similarly to alkaline phosphate and potassium activity as shown in figure (6, 7). Data indicated that the residues nutrients concentration in potato was higher by using biogation method than that when using fertigation method of fertilization by 29.17, 26.67 and 36.7% for total N, total P and total K in 0–45 cm soil layers respectively. Percentage %

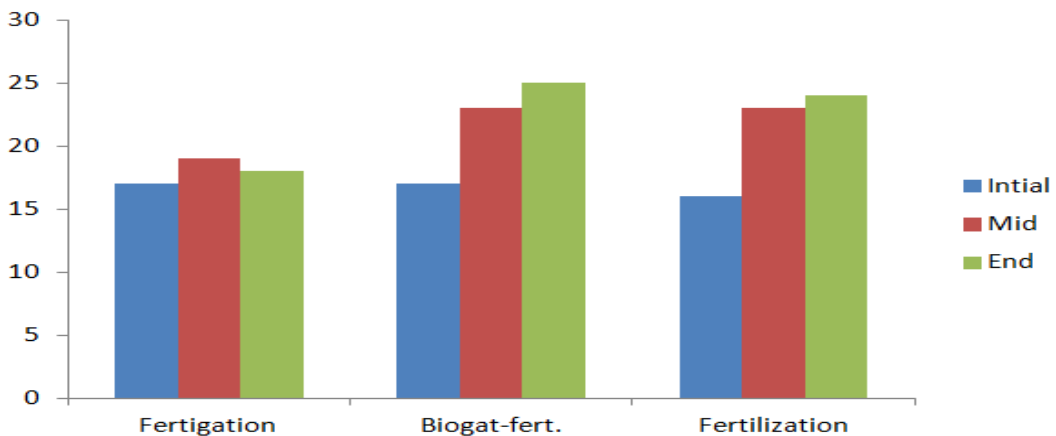


Figure (5): Available N for all technique during different growth stages.

Percentage %

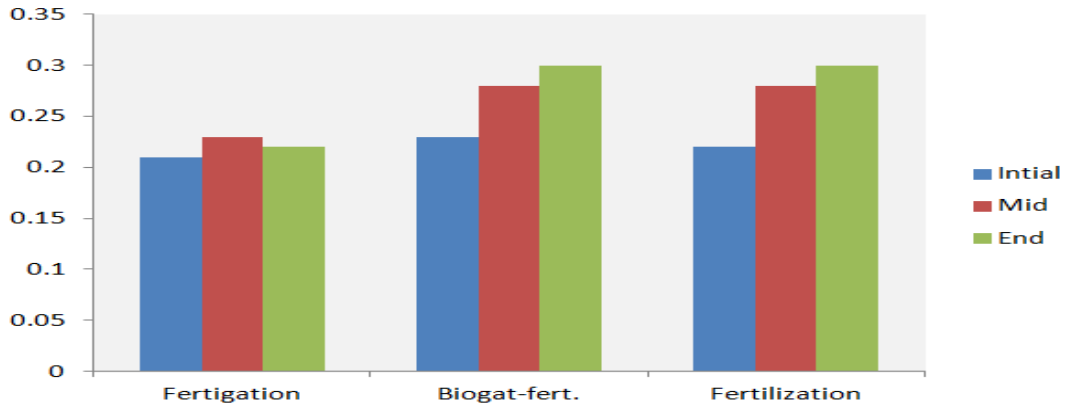


Figure (6): Available P for all technique during different growth stages.

Percentage (%)

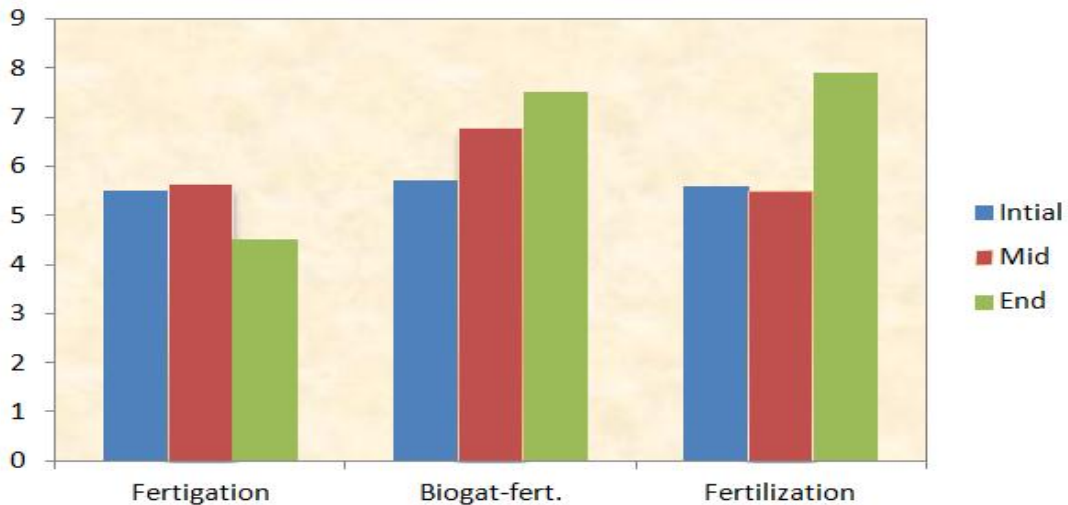


Figure (7): Available K for all technique during different growth stages

### Crop water production function

There were high significant differences between values of WP under fertilization technique and other techniques. These findings may be due to the drip biogate-fert technique gave the chance for nutrients to move into the wetted volume in a manner consistent with the flux of the water in the soil, while applying the fertilizers using conventional method causes non-uniformity distribution of fertilizer through the soil profile and consequently, decreasing fertilizer utilization efficiency and crops productivity fig. (8).

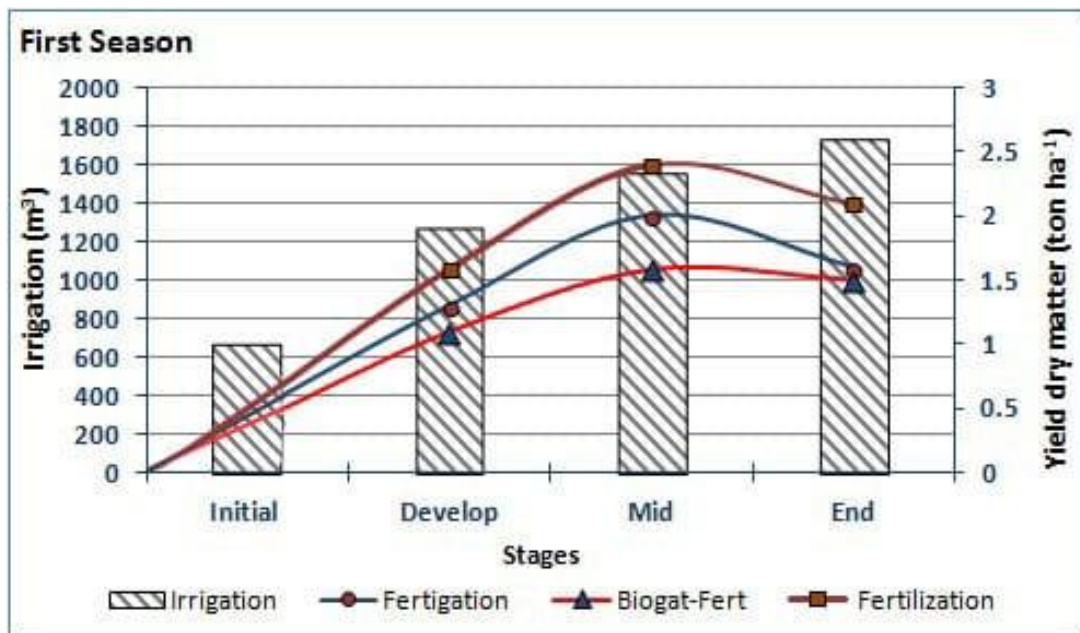


Figure (8): Crop water production function during different growth stages

### Potato yield

The fertilization technique had a positive effect and increased the productivity of potato plants. Potato yield was 34.5, 32.1 and 42.9 ton ha<sup>-1</sup> under fertigation, biogat-fert and mineral+ bio-fertilizer treatments respectively, for season 2019/2020 and 31.9, 30 and 41.2 ton ha<sup>-1</sup> under fertigation, biogat-fert and fertilization respectively, for season 2020/2021. The fertilization technique achieved an increase of 54 and 44% compared to the other treatments for seasons 2019/2020 and 2020/2021, respectively as shown in fig. (9). The relationship between the shapes showed that the use of fertilization technique increased productivity. While biogat-fert technique is weak, but it has improved quality of the crop, and that will be studied in another study.

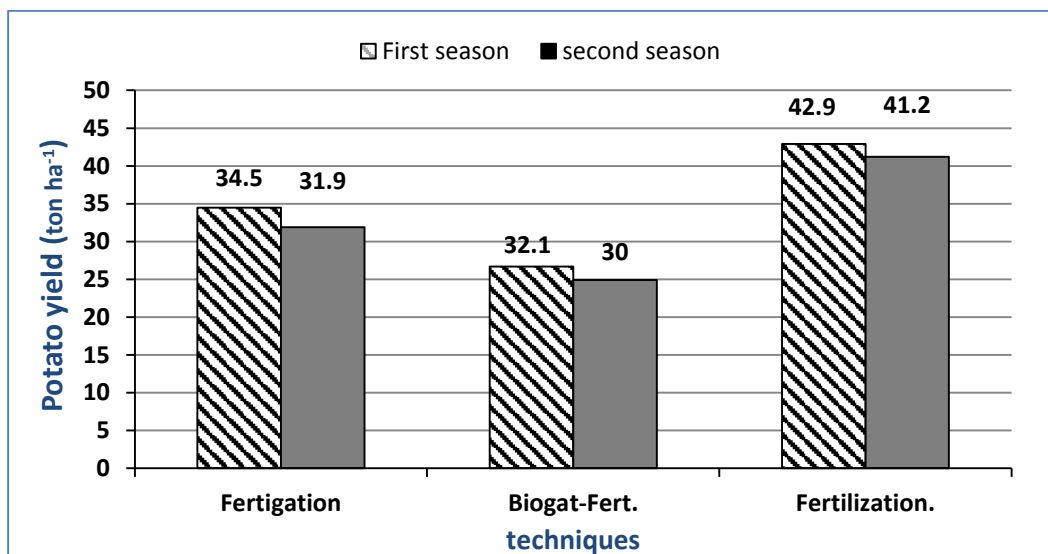


Figure (9): Yield of potato for the three Techniques during first season (2019/2020) and second season (2020/2021)

### Irrigation Water Use Efficiency of Potato Crop

Irrigation water use efficiency "IWUE" is an indicator of effectiveness use of irrigation unit for increasing crop yield. WUE =6.6, 5.1 and 8.2 kg/m<sup>3</sup> for season 1 and 5.9, 4.6 and 7.57 for season 2 for fertigation, biogat-fert and fertilization techniques respectively. This indicated that the highest effectiveness use of irrigation unit came with the use of fertilization technique. This may be due to the higher moisture distribution uniform values under in the effective roots zone of potato plants under drip irrigation, moreover, high frequency application of nutrients under drip irrigation allows splitting of the fertilizers amount, so that the elements availability are fitted to nutritional needs of the crop fig.(10).

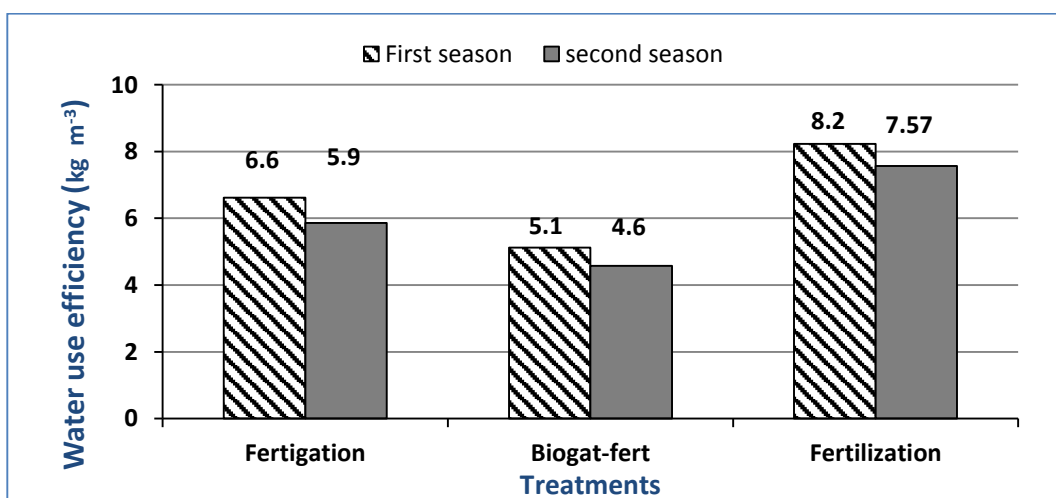


Figure (10): Water use efficiency under different investigated techniques

### Water unit productivity of potato crop

The water productivity of potato was calculated as amount of crop yield produced in kg per cubic meter of irrigation water according to James (1988) as follows:

$$WP_{\text{potato}} = Ey/Ir$$

Total water volume irrigation was 1729 m<sup>3</sup> for 2020 and 1763 m<sup>3</sup> for 2021. There were significant differences between values of water productivity of potato during two seasons 2020 and 2021. The highest values of WP potato were 1 and 0.97 kg m<sup>-3</sup> under mineral+ bio-fertilizer treatment for 2020 and 2021 respectively fig. (11), and there were high significant differences between values of WP under mineral+ bio-fertilizer and other treatments.

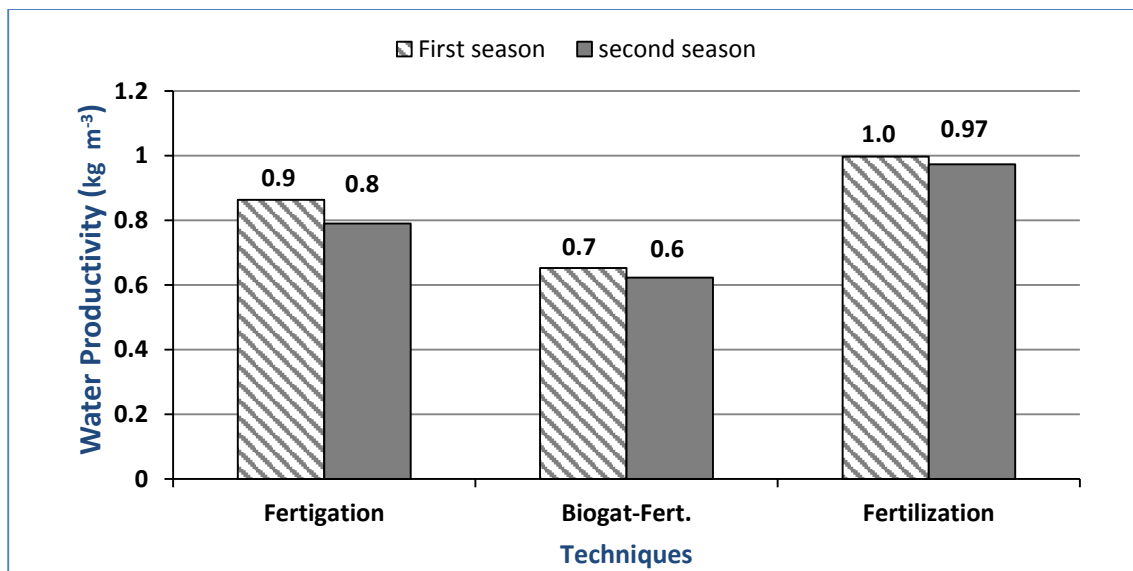


Figure (11): Water productivity for the three treatments during first season (2019/2020) second season (2020/2021).

### Fertilizer use efficiency

It is an indicator of effectiveness use of irrigation unit for increasing crop yield. Nitrogen productivity was calculated according to Barber (1976):

$$NP_{\text{potato}} = Ey/Nr$$

$NP_{\text{potato}} = 140$ , and  $192.5 \text{ kg}_{\text{potato}}/\text{kg}_{\text{Nitrogen}}$  for fertigation and fertilization techniques. This indicator that the highest effectiveness use of fertilizers unit came with the use of fertilization technique. This may be due to the high uniformity of fertilizer distribution and fertilizer elements already in solution become available to the plant root faster than when placed dry in the soil. This may be due to the high uniformity of fertilizer distribution and fertilizer elements already in solution become available to the plant root faster than when placed dry in the soil.

## Summary and Conclusion

Planting potato under drip irrigation had substantial effects on levels of bacteria. With increased number of cultivated years under drip irrigation, the soil biological properties were greatly improved. After two years of cultivation, the respective increases in the levels of bacteria were 112 times compared with uncultivated land. In the vertical direction, the CFU of bacteria all decreased with increased soil depth. The development of biogat-fert technique as an alternative technique for improving yield productivity under sandy soil conditions had been evaluated and resulted in a considerable increase in potato yield over the traditional application (fertigation). However, Biogat-fert appeared to be an economically, technically and environmentally feasible alternative technique for enhancement of potato yield productivity and reduce the amounts of added mineral fertilizers by about 25 percent of the crop nutrient requirements.

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