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Changes of Soil Microbial Characteristics and Nutrient Content in Sandy Soil Under Drip Irrigation System

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Abstract. A field experiment was conducted to investigate the changes in soil bacteria when using the bio fertilizers such as; *azotobacter*, *bacillus circullans* and *bacillus megaterium* in sandy soils across varied numbers of cultivated years using drip irrigation. Drip irrigation had a significant effect on bacterial levels. The biological qualities of the soil improved significantly as the number of years planted under drip irrigation rose. After two years of cultivation, the bacterial levels increased 102 times more than on uncultivated ground. The vertical direction, the number of bacterial colonies reduced as soil depth increased. The Bio-fertilizer treatment improved soil fertility more than any other therapy. The average total N, total P, and total K in 0-45 cm soil layers rose to 29.17, 26.67, and 36.7%, respectively. The soil environment was considerably improved, with significant positive relationships between bacterial, phosphate, and urea activity, as well as significant negative correlations with Ece and pH. We anticipate that soil microbial properties in drip-irrigated sandy soils will improve after 6-7 years of cultivation.

Keywords: *Azotobacter, Bacillus circullans, Bacillus megaterium,* potato yield, soil microbial characteristics

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1. Introduction

An essential part of soil ecosystems, soil microorganisms control the cycling of nutrient components and are crucial for preserving soil quality [1]-[3]. Since microorganisms react quickly to environmental changes after disturbance, it is anticipated that modifications to the soil will have an impact on the composition, activity, and organization of microbial communities. The biological characteristics of soil have frequently been suggested as sensitive early signs of ecological stress in the soil or any other environmental changes. Discovered that soil indicators have significantly expanded in the literature [4]. Important indices for assessing the quality of soil are the characteristics of the soil microbial. Microorganisms in the soil play a crucial role in the transformation of fertilizer for plant uptake. Biological fertilizers, or "bio-fertilizers," are living

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organisms that are added to soil to improve its quality and supplement the usual application of manures [5]. Microorganisms in the soil play a crucial role in the transformation of fertilizer for plant uptake. In the unlikely event that there aren't enough microorganisms in the soil, bio fertilizers must be used to vaccine the soil. The pollution and contamination of soil caused by the overuse of chemical pesticides and fertilizers is one of the biggest issues facing the globe today. Arafa and Salabi [6] claimed that chemigation systems are typically used to guarantee consistent crop-unit productivity and enhance yield quality; however, they also pose a significant challenge for their application and have an impact on agricultural physical resources and yield production as well as quality parameters. Chemigation is typically employed to guarantee consistent yields of potatoes and other profitable crops, but because of its possible risks to the environment and human health, it is no longer recommended. The key to fixing this issue may lie in biological nitrogen and phosphorus, as well as in ecologically friendly fertilizer species like fungi, bacteria, and cynobacteria. Numerous research have demonstrated that drip irrigation, or DI, is a useful strategy for making sense of saline-alkaline terrain. However, the improper use of DI raises the possibility of secondary salinization, which can seriously deteriorate soil and reduce production [7], [8]. The physical, chemical, and microbiological properties of saline soil were significantly improved after three years of drip irrigation [9]. According to the statement, it is an incredibly desired an alternative to standard techniques of eliminating pesticide chemicals because it permits contaminants to be destroyed Natural microbial activity, mediated by a variety of microbial strains [10]. The soil environment was considerably enhanced, with significant positive relationships between phosphate, bacteria and urea activities, as well as substantial inverse relationships with Ece and pH. Our research looked at how drip irrigation affected soil microbial properties. The goals of this research were to (1) examine the bacterial population's spatial distribution in the soil profile when drip irrigation is used. and (2) demonstrate the restorative impacts of soil microbial features on sandy soil under drip irrigation after two years.

2. Materials and Methods

2.1. Description of Study Site

Field work was done at the National Research Centre's experimental farm in El-Nubaria, Egypt (latitude 30^{o} 30' 1.4" N, longitude 30^{o} 9' 10.9" E, mean altitude 21 m above sea level) for two potato seasons, from November to March in 2019–2020 and 2020–2021. The climate of the experimental region is desert, with chilly winters and scorching, dry summers. For the El-Nubaria area, the monthly mean climate data for the two growing seasons are almost identical. The Central Laboratory for Agricultural Climate provided the maximum and lowest temperature, relative humidity, and wind speed data (CLAC).

2.2. Irrigation System Components

A 45 m^3/h centrifugal pump, a screen filter, a backflow prevention device, a pressure regulator, pressure gauges, control valves, and a flow meter were all part of the irrigation system. The primary line was a 110mm outer diameter (OD) polyvinyl chloride (PVC) pipe that carried water from the source to the field's key control stations. PVC pipes with a 75mm outside diameter were used to link the main line's sub-major lines. Polyethylene (PE) pipes with manifold lines a diameter of 63 mm, were linked to the sub-main line, as well as gauges for discharge and control valves. The emitters were made in 16 mm by 50 m lateral PE tubes in diameter. A 4 l/h emitter discharge occurred at an operating pressure of 1.0 bar., with a 30cm distance between the emitters.

2.3. Soil Properties and Irrigation Water Analysis

Samples of soil that were representative were collected at various soil layer levels (0-15, 15-30, 30-45, and 45-60 cm) to assess characteristics, both chemical and physical. Table 1 shows some soil chemical and physical parameters at the testing site, such as Soil pH and Ece were found in a soil-water ratio of 1:2.5 and a soil paste extract, respectively. The investigation was carried out using a drip irrigation method. Irrigation water was acquired from an irrigation canal (Nile water) that passed through the experimental location, as indicated in Table 2, with a pH of 8.3 and an electrical conductivity of 0.60 ds m^{-1}.

Table 1. A Few Physical and Chemical Properties of the Soil at the Experiment Site

Depth, (cm)	pH 1:2.5	EC, dS/m	Total (ppm)			
			Ca^{++}	N	P	K
0-15	8.3	0.35	0.50	0.16	0.25	0.23
15-30	8.2	0.36	0.51	0.20	0.29	0.24
30-45	8.3	0.34	0.55	0.18	0.30	0.23
45-60	8.4	0.73	0.57	0.20	0.28	0.25

Table 2. Chemical Properties of Irrigation Water at the Test Site

pH	EC, dS/m	Soluble cations, meg/L				Soluble anions, meg/L			
		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3	HCO_3-	SO_4-	Cl-
7.3	0.60	0.76	0.24	2.6	0.12	0	0.9	0.32	2.51

Note: pH: power of hydrogen; EC: electrical conductive; SAR: sodium absorption ratio

2.4. Soil Sample and Analysis

Soil samples were collected from each plot with 2.0 cm in diameter and 15 cm in height as an auger. Samples were collected on November 18, 2019, December 20, 2019, February 20, 2020, December 1, 2020, January 10, 2021, and March 5, 2021. On the X-axis, the sample positions were 0, 15, and -15 cm from the emitter. Soil samples were collected from each of these locations. Gathered at varied depths on the Y-axis of 0, 15, 30, and 45 cm from the soil surface. Using the

"contouring program Surfer version 8" Figure 1. The soil samples were used to determine the pH, soil enzyme activity, and electrical conductivity of saturated soil extract (ECe), and accessible N, P, and K. ECe was obtained using a conductivity meter, while a pH meter was used to measure the pH. The available N was measured using a spectrophotometer [11]. The available P was measured using the method of molybdenum-antimony anti-spectrophotometry, while the available K was determined using a flame photometer. Additional soil specimens were kept in a refrigerator at 4 degrees Celsius until the experiment with the microbe count was finished. Soil microorganisms' CFU were quantified using dilution plate counts. Bacteria were grown in Ashby medium.

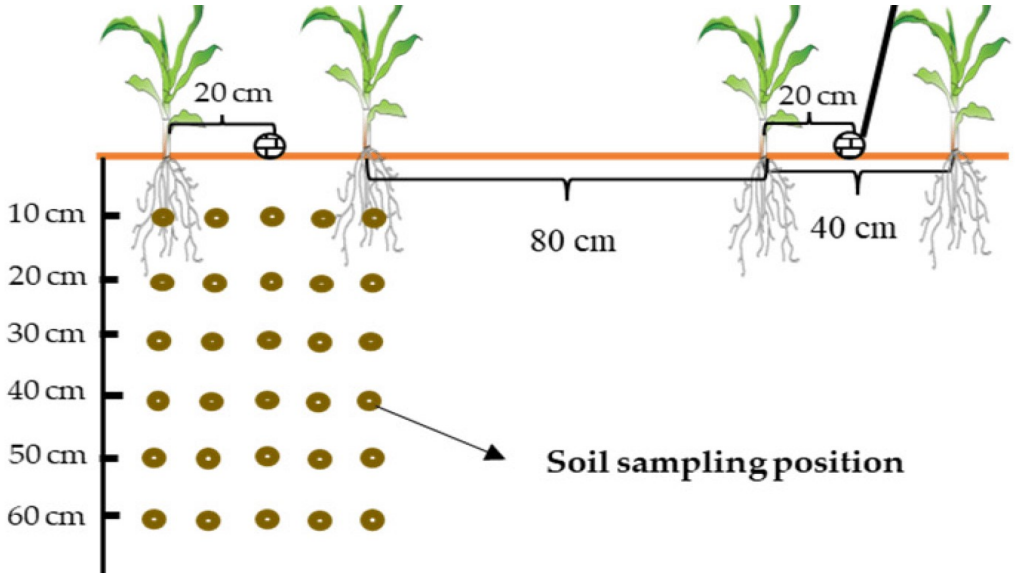

Figure 1. Layout of the Position of Soil Samples

2.5. Crop Type

A single crop type has been selected: Spunta Dutch potatoes. The plot was handled using agronomic practices and fertilization recommendations found in official agricultural bulletins. The experimental areas were planted in the 2019–2020 and 2020–2021 growing seasons (5–Nov.:5–Mar.). For the four growth phases of the potato crop (starting stage, crop development stage, mid-season stage, and late season stage), Table 3 displays the growing stage lengths, crop coefficients (Kc), crop height (h), and root depth (Zr) based on single-Kc.

Table 3. Reference Values for Lengths, Crop Height (h), Root Depth (Zr), and Single Crop Coefficient (Kc) for Each of the Four Stages of Potato Growth [12]

Stage	Period	Da		H, m	Zr
		Ys	Kc	mm	
Initial stage	1 Dec. – 30 Dec.	30	0.77	0.36	0.49
Development stage	1 Jan. – 30 Jan.	30	1.15	0.60	0.60
Mid-season stage	1 Feb. – 5 Mar.	35	0.75	0.51	0.60
Late season stage	5 Nov. – 30 Nov.	25	0.50	0.14	0.20

2.6. Bio-Fertilizer

The National Research Centre's Microbiology Department, Agricultural and Biological Research Division, provided support for the biofertilizer. It contained a combination of Bacillus megaterium and *Azotobacter chroococcum* are examples of N2-fixing bacteria for phosphate mobilization and (*Bacillus circulance*) for potassium dissolution. The bio-fertilizers were cultivated independently in batch cultures until the late exponential phase of each microorganism [13]. The *Azotobacter* bacterial strain was employed, with the bacterial isolate planted on a liquid *Azotobacter* Agar environment for 1:2 days at 28°:30°C to produce a cell suspension of $4x10^5$ cell/g soil. The *Baccilus megaterium* phosphate-degrading bacterial strain was employed, with the bacterial isolate being seeded on a liquid Nutrient Ashby environment for 5 days at a temperature of 28°:30° C to produce a cell suspension of $6x10^6$ cell/g soil. The bacterial strain *Baccilus circulans* was tested for phosphate, and the bacterial isolate was planted on a liquid Nutrient Ashby environment for 5 days at a temperature of 28°:30° C to produce a cell suspension of $4x10^6$ cell/g soil. Bio-fertilization treatments were administered via injection into the irrigation water.

3. Results and Discussion

3.1. Distribution of Soil Enzyme Activity during Various Cultivation Periods

Using drip irrigation for two years significantly enhanced urease, alkaline phosphatase, and potassium activity compared to the commencement of agriculture. Figure 2a shows the distribution of urease activities. There was no discernible change in urease activity horizontally at the commencement of agriculture. Urease activity near the emitter increased significantly after drip irrigation at the end of the season but reduced as the separation between the source and the emitter grew. The amount of urease was 1.6 times higher under the emitter compared to the 40 cm distance. Urease activity was higher in the surface layer compared to deeper soil.

Figure 2b depicts the horizontal distribution of alkaline phosphatase activity on irrigated ground. The activity was consistently greater close to the source than farther away. After drip irrigation at the end of the season, alkaline phosphatase activity was 2.24 times higher close to the emitter than on the field before irrigation, and this climbed to five times after two years of irrigation. In one and two-year-old irrigated field, alkaline phosphatase activities were higher under the emitter and 10 cm distant than at 15, 30, and 45 cm. All treatments, including the land before drip irrigation and those after one or two years of the surface layer having good water and nutrient conditions, showed a decrease in alkaline phosphatase activity with higher soil depth in a vertical orientation, while alkaline phosphatase activity in the surface layers varied significantly depending on irrigation time.

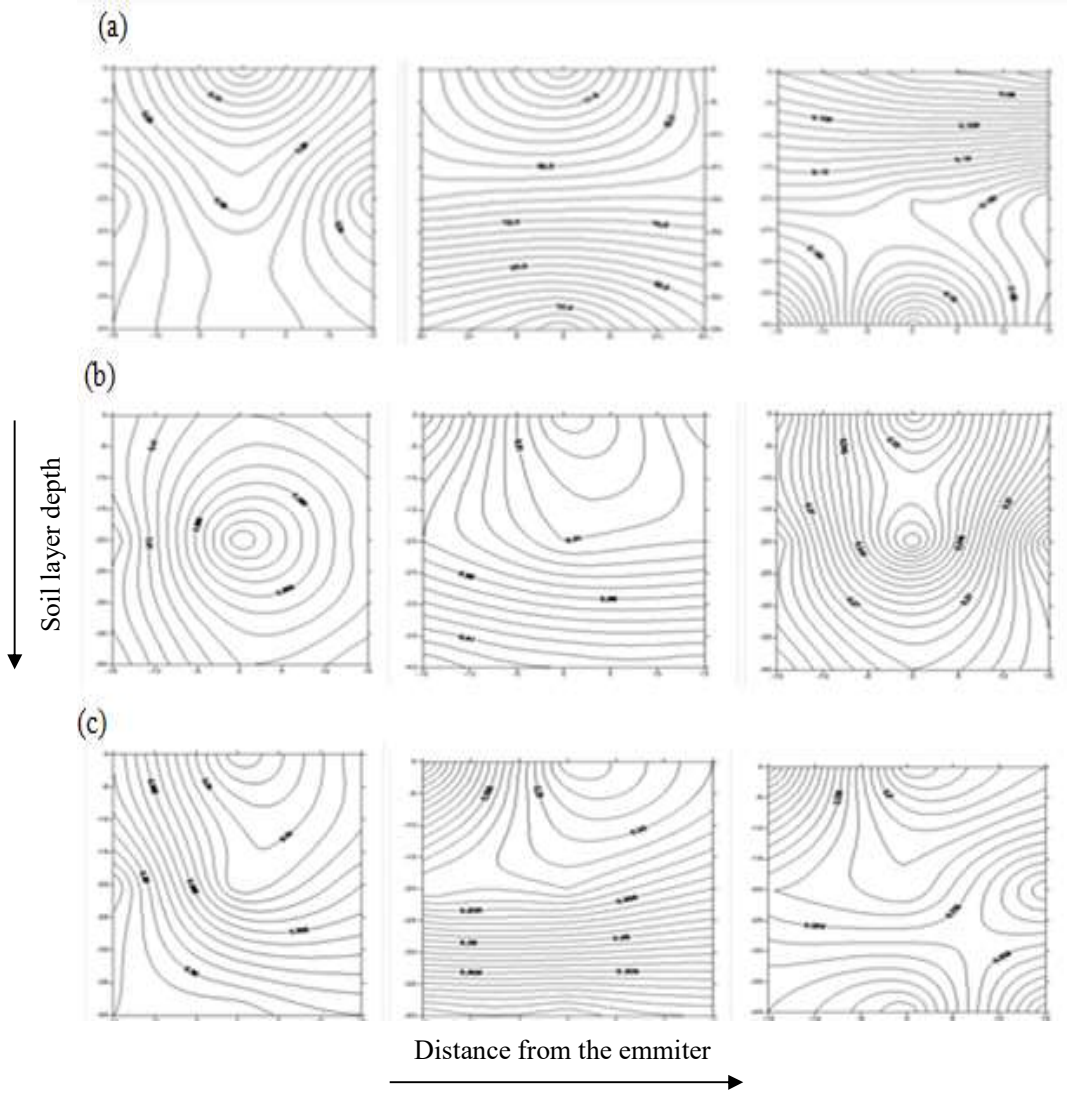

Figure 2. Soil Enzyme Activity Distribution for Various Planting Growth Stages

3.2. Dispersal of Bacteria by Cultivation Period

The CFU (colony forming unit) of bacteria rose in tandem with the length of drip irrigation, particularly under bio-fertilizer method in contrast to mineral fertilizers. Bacterial CFUs in Low soil layers ranged from 0 to 40 cm on uncultivated terrain. In the 0–40 cm soil strata, the average CFU of bacteria increased 112 times. Following two years of drip irrigation, the bacterial CFU rose to almost 78 × 10^6 CFU g-1 dry soil in the strata of 0–10 cm, indicating enhanced soil conditions for the growth of microorganisms. When looking vertically, Bacterial CFU levels were greater in soil strata at the surface than in subsoil on uncultivated land. This is due to the fact that soil physical and chemical properties, as well as soil nutritional status, limit the vertical spread of soil microorganisms. As depth increases, soil temperature, organic matter, and nitrogen levels fall, making it unsuitable for the growth of most bacteria. The origins were primarily dispersed in 0-10 cm soil layers, therefore the soil in this layer is well-nourished. There are large disparities in the impacts on the removal of total nitrogen (TN) by various plant species; Ginkgo biloba has an

average TN removal rate of 41%, while Miscanthus sinensis has an average TN removal rate of 91% [14]. In the horizontal direction, bacteria activity on irrigated land was usually closer to the emitter than it is from a distance. The bacteria activity close to the emitter was 2.24 times higher after cultivation ended than it was before watering. Activities under the emitter and 10 cm distance were higher in the irrigated land than those at 15, 20, and 30 cm distance.

3.3. Dispersal of Bacteria by Cultivation Period

Potato growing conditions improved significantly after watering. The soil salinity dropped dramatically, and in soil strata 0-45 cm, the average ECe was 0.33 ds m-1. Figure 3, with an average pH of 7.8. soil fertility increased significantly.

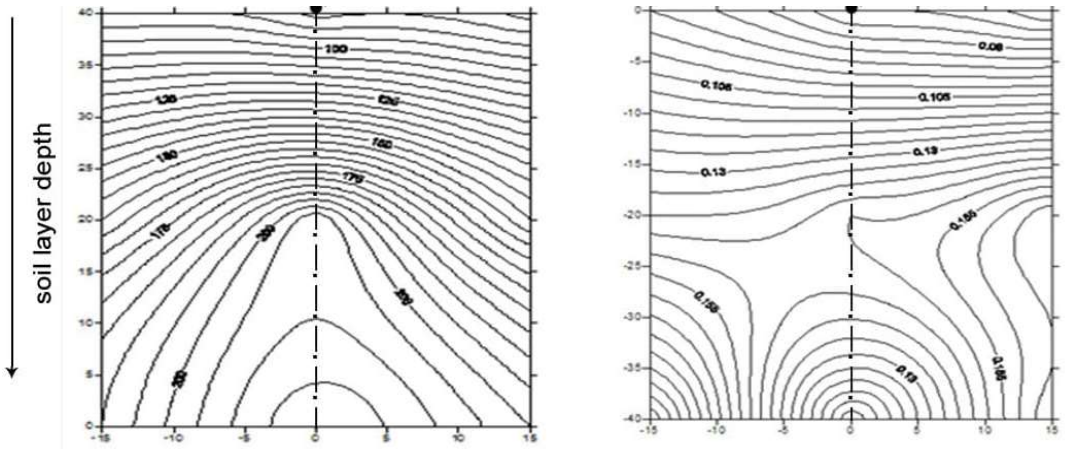

Figure 3. Patterns of Salt Distribution and Total Count for Biogate-fert Technique

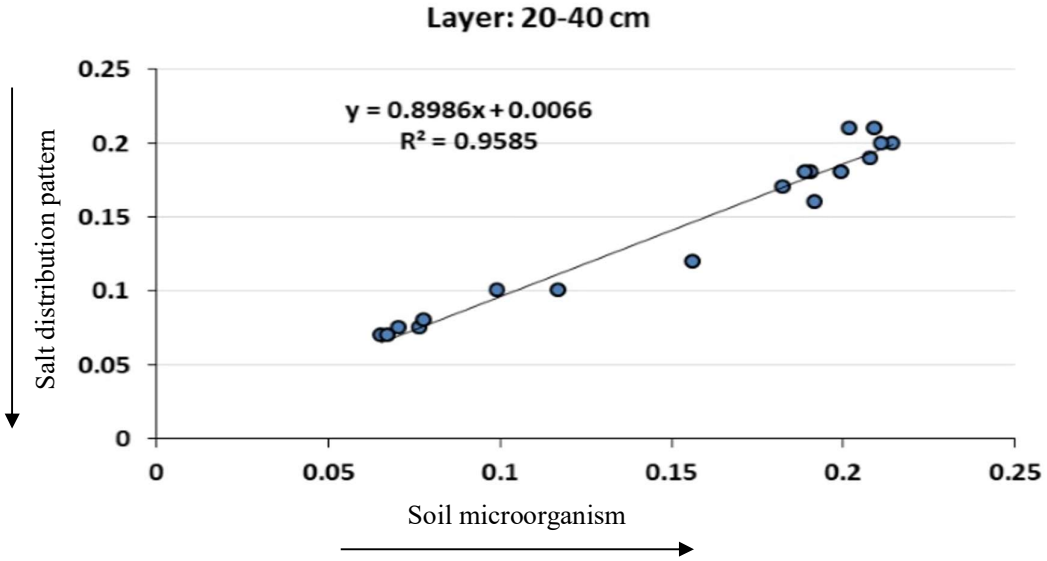

Figure 4. Correlations Between Soil Microorganisms and Salt Distribution Patterns

The findings were comparable to those of Wang et al. [15], who discovered Achnatherum splendens (Trin) Nevski should be planted enhanced alkali soil, and that the total amount of bacteria rose with extended cultivation time. Soil microbial parameters are key indicators for assessing soil conditions [16]. In addition, soil physicochemical parameters increased after two

years of growth in the present investigation. Additional study will be conducted later on. The bacterial CFU oriented vertically dropped as soil depth increased. This is due to the fact that soil physical and chemical properties, as well as soil nutritional status, limit the vertical spread of soil microorganisms. As depth increases, soil temperature and nitrogen levels decrease, making it unsuitable for the growth of most bacteria. The roots were primarily dispersed in layers of 0–10 cm of earth, which have good aeration and robust nourishment; as a result, CFU of soil bacteria were higher in this layer than in subsoil [15]. This showed that drip irrigation increases the microbiological properties of sandy soil.

4. Conclusion and Recommendation

Planting potatoes under drip irrigation had a significant effect on bacteria levels, and as the number of farmed years rose under the drip irrigation system, the biological qualities improved dramatically. Following two years of culture, the bacterial levels increased by 114 times more than that of untamed soil. The bacterial CFU oriented vertically dropped as soil depth increased. Only two years' worth of data were used to draw the study's conclusions, so there may be some limitations, necessitating additional studies conducted in the coming years. More research is needed to evaluate the actual requirements and other relevant management parameters for the biogation approach under various physical field circumstances, such as soil salinity, low water quality, and stress.

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