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Interaction between calcium silicate, *Pseudomonas fluorescens* and irrigation intervals affecting soil microbial biomass and yield of wheat

Israa Saadi Mohammed **Salwan Al-Maliki***

Department of Soil and Water Resources, College of Agriculture, Al-Qasim Green University

Corresponding author: salwan85@agre.uoqasim.edu.iq

Abstract

Silicates can improve plant resistance to drought and enhance soil microbial communities. However, the relationship between bacterial inoculations, silicon and irrigation intervals in soil to enhance plant microbial biomass carbon (MBC) and plant resistance to drought remains unclear. This study aimed to find the interaction between calcium silicate, *Pseudomonas fluorescens* and irrigation intervals and its effect on soil microbial biomass (MBC) and availability of NPK for the wheat plant. The experiment included two factors, the first was the addition of calcium silicate and *Pseudomonas* (without addition, *Pseudomonas* 10 ml, calcium silicate, *Pseudomonas* 10 ml+ calcium silicate) (B0, B1, B2, B3) and the irrigation intervals (7, 14, 21) days (C0, C1, C2).The results showed that the combination of *Pseudomonas* + calcium silicate (B3) gave the highest soil respiration rate (24.83) mg/g, the highest MBC (701.33) mg.kg-1. The calcium silicate (B2) increased significantly the nitrogen content in the plant (25.66) mg / kg, grain yield (4.16) ton / ha. The results also declared that the 21 days (C2) irrigation interval raised significantly MBC (1040.12) mg/kg, nitrogen content in the plant (29.23) mg / kg, phosphorous content in the plant (20.66) mg / kg, potassium content in the plant (36.54) mg/kg, while the 14 days (C1) irrigation intervals increased soil respiration rate (24.75) mg/g, and the density of *Pseudomonas* in soil (25×10^7) CFU/ml. Furthermore, the combination of *Pseudomonas* with 21 days of irrigation

intervals (B1C2) significantly maximized MBC (1350.50) mg/g, phosphorous content in the plant (25.5) mg/kg, nitrogen content in the plant (37.05) mg/ kg, potassium content in the plant is 39.01 mg/kg suggesting an important role of *Pseudomonas* in plant tolerance for the highest extreme soil stress . More importantly, the combination of calcium silicate with 7 days irrigation intervals (B2C0) increased significantly the grain yield of wheat (4.26) tons/ha as compared with others. We concluded that both *Pseudomonas* and silicon combination improved the soil respiration and MBC as well as reduced the water stress for the wheat crop.

Keywords: calcium silicate, *Pseudomonas fluorescens*, irrigation intervals, drought, soil respiration, MBC, wheat.

1- Introduction

The wheat crop *Triticum aestivum* L. is one of the most important food grain crops in the world. It comes first in terms of the cultivation area, and third in terms of production (FAO, 2019). The decrease in the production of the wheat crop is due to several factors, the most important one is the salinity and drought deteriorations. The harvested area in 2017 was approximately (1.8) million hectares, giving a production of (2.5) million metric tons, at an average of (1.377) tons/ha (FAO, 2019). Iraq is currently suffering from low water levels in the Tigris and Euphrates rivers as a result of the construction of dams in Turkey, as well as the poor use of water sources in agriculture due to the inaccurate methods in managing the number of irrigations intervals during the growing season, which requires scientific solutions to use water properly in agriculture and discovering new technologies enable the crop to withstand 'water shortage.' One of the most important methods of good water management is to control the number of irrigations in each season by defining the period between one irrigation and another. The addition of silicon to the soil leads to the determination of water stress through the following mechanisms: (activating the enzymes of the metabolism process, increasing the efficiency of water use, the absorption of elements and the growth of roots (Yin et al., 2016). In a recent study, it was found that the addition of silicon increases the average of photosynthesis as well as carbohydrates in plant leaves and improves the absorption of elements (Etesami and Jeong 2018).The use of bacterial inoculation techniques in the cultivation of crops is one of the most effective and successful methods because these

organisms stimulate the growth of plants, regulate and increase the availability of nutrients to the roots of plants and increase soil fertility (Frietas et al., 2007). One of the most important microorganisms is *Pseudomonas spp* which has multiple mechanisms to stimulate growth in plants (Rana et al., 2011). Among the bacterial groups is plant growth-promoting rhizobacteria (PGPR), that stimulate the growth of wheat plants by raising the availability of the phosphorous to plant, and thus it is among the group of phosphorus-solubilizing bacteria in soil (Ahemd and Khan, 2011). The research aims to evaluate the effectiveness of silicon and of *Pseudomonas* bacteria in relieving water stress of wheat and its impact on the effectiveness of soil microbial biomass in soil.

2- Materials and Method

2.1.Experimental site

The experiment was conducted in one of the farms belongs to Al-Fayhaa Company for the production of the table eggs in the province of Babylon in the village of Sinjar, which is 3 km from the center of the city towards the north-east of the province during the winter agricultural season 2020/2021. Cultivation was conducted in silty loamy soil classified as *Typic Torrifuvent* according to the modern American classification (2006). Several soil samples were taken at a depth of 0-30 cm and mixed to form a representative sample of the entire field. Then the soil was dried and passed through a sieve with a diameter of 2 mm to conduct physical and chemical analyzes of the soil before cultivation. The analysis was conducted in the laboratories of the Faculty of Science, University of Babylon. The results of the analysis are shown in Table (1).

Table (1) Physical and chemical properties of field soil

Traits		units	vales	References
pH		**_**	**7.8**	**Richards,1954**
EC		**Ds.m^{-1}**	**2.77**	**Page et al., 1982**
Macro nutrients	nitrogen	**ppm**	**30.35**	**Page et al., 1982**
	phosphorous		**6**	
	potassium		**205**	
texture	**sand**	**%**	**14.4**	**Black,1965**
	silt		**51.01**	
	clay		**34.59**	
(silt clay loam)				
Moisture at field capacity		**32**	**%**	**Black,1965**
Moisture at wilting point		**17.02**	**%**	
moisture content		**39**	**%**	

The agricultural land was prepared by performing two orthogonal plowing using moldboard plows and then the field soil was levelled, and divided into three plots, leaving a space of 2 m between one plot and another. Each plot was divided into 12 experimental units with an area of (2×3 m^2). The study units were randomly distributed into each plot. Also, the experimental unit included 6 lines with a length of 3 meters and a planting distance of 20 cm between each plant was created. The wheat crop was planted on 4/12/2021 with seeds of the cultivar IPA seeds. Treatments were irrigated every 7, 14 and 21 days. The diammonium phosphate (DAP) (P 23%, N 21% were used

in a single dose before planting at a rate of 100 kg hectares. Urea (N 46%) and potassium fertilizers (K 42%) were added in three doses at a rate of 100 kg hectares, the first after a week of germination and the second after a month from the first dose and the third a month after the second dose. The wheat plant was cultivated on 29/5/2021.

2.2.*Pseudomonas fluorescens* inoculation

A broth inoculant for *Pseudomonas* bacteria was obtained from the Agricultural Research Department at the Ministry of Science and Technology, which contains a number of bacterial cells as much as 1×10^8. The method of the preparation of the inoculation was achieved as below:

The inoculant was prepared at the soil biological laboratories of the Ministry of Science and Technology, Baghdad, as described in Wollum (1982). Soil samples were collected from the agricultural fields containing a wheat plant and placed in tight bags and taken to the laboratory. The soil was also sieved with a 2 mm sieve. 50 g of soil was weighed and then a distilled water was added to a 250 ml flask to prepare a soil suspension. 1 ml of soil suspension was placed into petri dishes containing nutrient agar and *Pseudomonas* agar base. The petri dishes were incubated at a temperature of 27 °C for 2 - 3 days until the bacterial colonies were formed. Later on, *Pseudomonas* was diagnosed using a gram dye test and the light microscope. Bacteria were purified after observing the colonies and a gram dye test was performed. A stain was taken from the colonies and a dilution method was proceeded (Buchanan & Gibbon, 1974) by taking a 1 ml of dilution No. 6 and cultured into a *Pseudomonas agar* base dishes containing nutritional medium and then incubated at 27 °C for two days.

The process was repeated several times until the pure colonies were recorded. After that, the bacterial suspension was prepared by taking a stain of the pure colonies and placed in tubes containing 10 ml of N. agar broth culture medium and incubated for two days at a temperature of 27°C. Then, the bacterial suspension was placed in centrifugation for 5 minutes at a speed of 300 rpm, then the precipitate was suspended in a normal saline solution, then the volume was completed to 100 ml and added to the soil and seeds.

2.3.Method of the inoculation and calcium silicate application

Pseudomonas bacteria were also added to the seeds at an average of 150 ml with an inoculant density of about 10^8 cells to 150 g of seeds. The wheat seeds were contaminated with bacteria 4 hours before planting and then planted directly in the targeted treatments. The inoculant was also added to the soil of about (5 ml) near seeds. Calcium silicate Ca_2O_4Si was mixed with the soil at an amount of 240 g per plot at an average of (400 kg/ha).

2.4. Studied parameters:

2.4.1. Soil respiration

The released (CO_2) was measured using the alkali trap method (Anderson, 1983).

2.4.2. Microbial biomass carbon (MBC)

The measurement of MBC was conducted according to the method described by Horwath et al. (1996) by finding the amount of the mineralized CO_2 during 10 days by incubating the soil with chloroform fumigation (CFI) and then the amount of the mineralized carbon dioxide was subtracted from the samples not exposed to chloroform according to the details below:

2.4.2.1 Fumigation method

5 g of each soil was placed in a small container inside a wide desiccator, then a small beaker containing 10 ml of chloroform acid $CH Cl_3$ was placed inside the desiccator following a water bath for (30) seconds for the evaporation purpose and then the desiccator was well vacuumed and sealed. The samples were left for 3 days until the acid completely evaporated, then the samples were left open for another 2 days to volatilize the smell of the acid.

2.4.2.2 Calculate the CO_2 released from both sterilized and non-sterilized samples

The CO_2 released from the soil was subjected to chloroform was estimated according to the alkali trap method (Anderson, 1983) mentioned above by incubating the base with a standard NaOH of 1 molar with the soil for 10 days, then some of the drops of phenolphthalein were placed and then the solution was titrated with the acid of HCl of standard 0.5 M and the amount of CO_2 was estimated.

The microbial biomass carbon (µg g^{-1} soil) was calculated according to the method described by Horwath et al. (1996).

Microbial biomass C (ug C g^{-1} soil) = $(0.71 \times CO_2F - 0.23 \times CO_2C)/Kc$

Where:

MBC: microbial biomass carbon

Kc = 0.41 at 25°C

F: Quantity of mineralized carbon dioxide in fumigated samples

C: Amount of mineralized carbon dioxide in not fumigated samples

0.71 and 0.23: Horth constants have been suggested as derivational links between microscopic and chemical methods.

2.4.3 Counting *Pseudomonas* in the soil

Pseudomonas bacteria were calculated at the laboratory of the College of Science, University of Babylon according to the method described by Wollum (1982). 10 g of the soil was added to 90 ml of peptone water consisting of a 5 g peptone, 5 g tripton and 5 g sodium chloride. The mixture was subjected to shaking with an electric vibrator at a speed of 120 RPM for 30 minutes. 1 ml was added to 9 ml of water to be the second decimal dilution and so on to obtain the sixth decimal dilution. Then, 1 ml of the sixth decimal dilution was placed on the nutrient medium nutrient agar and media particular *Pseudomonas* agar base to grow bacteria on culture media. The petri-dishes were incubated at 30 °C to isolate bacteria (Buchanan & Gibbon, 1974). The bacterial genera were investigated based on the cultivar characteristics of the bacterial colonies on the selected media, such as color, shape, luster, viscosity, cell shape and their response to the gram dye. The samples were investigated under the light microscope. The media particular *Pseudomonas* agar base contains magnesium anhydrous 1.4g and Pancreaic digest of gelatin 16 g consisting of 11 g agar, potassium sulphate 10g and Casein enymic hydrolysate 10g and 500ml water (Wollum, 1982). The numbers of colonies were calculated by multiplying the average number of colonies by the reciprocal of the dilution.

2.4.4 . Determination of the elements in the leaves

The nitrogen, potassium and phosphorous content of the leaves was estimated during the flowering stage according to the described method by Labetowicz, (1988).

2.4.5 . Grain yield

It was calculated from the harvest of three lines from each experimental unit and converted on the basis of ton/ha and according to the following equation:

The yield was estimated by multiplying the grain rate of the plant by the plant density used per hectare

2.5. Experimental design

The data were analyzed using the Genstat program for statistical analysis using a complete randomized block design (RCBD) with two factors. The first factor was irrigation intervals (C0, C1, C2) and the second factor was the biological factor *(*control treatment b0, *pseudomonas* bacteria b1, calcium silicate b2, and *pseudomonas* + calcium silicate b3. The least significant difference test (LSD) was used at the level of the less than 0.05.

4- Results and discussion

4.1. Soil respiration (mg/g)

The results in Table (2) showed that bio fertilization had significant effects on the soil respiration (mg/g). Pseudomonas + calcium silicate (B3) significantly had the highest soil respiration 24.83 mg/g, followed by the calcium silicate treatment. (B2) 19.93 mg/g. The control treatment B0 recorded the lowest soil respiration 15.2 mg/g. The results also showed that the irrigation periods had a significant effect on the soil respiration. Irrigation treatment at 24 days (C1) had higher soil respiration than the rest of the other treatments 24.75 (mg/g), followed by treatment of a 21 day irrigation interval C2 (23.75 mg/g). While the 7 days irrigation intervals (C0) recorded the lowest soil respiration (9.33 mg/g). The interaction treatment (B2C1) had higher soil respiration than the rest of the other treatments (33 mg/g).

Table 2: Effect of bio fertilization and irrigation intervals on soil respiration (mg/g).

Bio Fertilization	irrigation periods			Mean
	C 0	C 1	C 2	
B 0	3.1	22.5	20	15.2
B1	2.4	17	32	17.13
B2	2.8	33	24	19.93
B3	29	26.5	19	24.83
irrigation intervals	9.33	24.75	23.75	
LSD 0.05	C= 0.4328	B= 0.2184		CB= 0.4760

B0 = control, B1 = pseudomonas Bacteria, B2 = calcium silicate, B3 = interaction of pseudomonas Bacteria + calcium silicate, C0 = 7 days, C1 = 14 days, C2 = 21 days

4.2. Density of *Pseudomonas* in soil (CFU/ml)

Bio fertilization had a significant effect on the density of *Pseudomonas* in the soil (CFU/ml), the results showed in Table (3) that the treatment B1 had significantly higher density of *pseudomonas* in the soil than others reached 65×10^7 CFU/ml. The results also showed that the irrigation periods had a significant effect on the density of *pseudomonas* in the soil, the irrigation treatment (C1) had significantly higher density than the other treatments 25×10^7 CFU/ml. The interaction treatment (B1C1) had significantly higher density than the rest of the others 93×10^7CFU/ml.

Table 3: Effect of bio fertilization and irrigation intervals on the density of *pseudomonas* in soil (CFU/ml)

Bio Fertilization	irrigation periods			Bio Fertilization average
	C 0	C 1	C 2	
B 0	3×10^2	4×10^4	8×10^2	1×10^4
B1	31×10^7	93×10^7	73×10^7	65×10^7
B2	31×10^6	85×10^6	74×10^6	63×10^6
B3	95×10^5	84×10^5	73×10^5	84×10^5
irrigation periods	87×10^6	25×10^7	20×10^7	
LSD 0.05	C= 77×10^6	B= 49×10^6		CB= 94×10^6

B0 = control, B1 = pseudomonas Bacteria, B2 = calcium silicate, B3 = interaction of pseudomonas Bacteria + calcium silicate, C0 = 7 days, C1 = 14 days, C2 = 21 days

4.3. Microbial Biomass Carbon (MBC) (mg.kg-1)

The results in Table (4) showed *pseudomonas* + calcium silicate (B3) significantly had the highest MBC 701.33 mg.kg-1, followed by the treatment calcium silicate (B2) 553.66 mg.kg-1, while the control treatment B0 recorded the lowest MBC 315.3 mg.kg-1. The irrigation treatment (C2) had significantly higher MBC than the rest of the other treatments 1040.12 mg.kg-1, followed by C1 treatment 455.25 mg.kg-1, while the control treatment recorded (C0) the lowest MBC 124.88 mg.kg-1. The highest interaction affect (B1C2) for MBC was 1350.5 mg.kg-1.

Table 4: Effect of biofertilization and irrigation intervals on MBC (mg.kg-1)

Bio Fertilization	irrigation periods			Mean
	C 0	C 1	C 2	
B 0	95.5	207	643.5	315.3
B1	101.5	209	1350.5	553.66
B2	96.5	622.5	1051	590
B3	206	782.5	1115.5	701.33
irrigation intervals	124.88	455.25	1040.12	
LSD 0.05	C= 0. 1636	B= 0.2610		CB= 0.4066

B0 = control, B1 = pseudomonas Bacteria, B2 = calcium silicate, B3 = interaction of pseudomonas Bacteria + calcium silicate, C0 = 7 days, C1 = 14 days, C2 = 21 days

4.4. Nitrogen, phosphorous and potassium content in the plant (mg.kg-1)

The results in Table 5 showed that treatment (B2) had significantly the highest nitrogen content in the plant 25.66 mg/g. The irrigation treatment (C2) had significantly higher nitrogen content than the rest of the others 29.23 mg.kg-1. The results in Table (5) showed that there was an interaction affect between silicate and 21 irrigation intervals (B1C2) 37.05 mg.kg-1 suggesting an important role for the silicate in enhancing nitrogen content during the drought phase.

The results in Table (6) showed that the treatments of B3 had significantly the highest phosphorous content in the plant 16.46 and 16.13 mg.kg-1. The irrigation treatment (C2) had significantly higher phosphorous content than the rest of the other treatments 20.66 (mg.kg-1), followed by the treatment of C1 which gave the phosphorous content of 13.15 mg.kg-1. The results in Table (6) showed that the interaction between B1 c2 was significant suggesting a direct effect on increasing the phosphorous content in the plant.

Table (7) showed that treatment (B3) had significantly the highest potassium content in the plant 35.25 (mg.kg-1). The irrigation treatment (C2) significantly outperformed the rest of the other treatments giving the highest rate of potassium content in the plant 36.54 mg $.g^{-1}$. The interaction affect (B1C2) was significant giving the highest potassium content in the plant 39.01 mg.kg-1.

Table 5: Effect of biofertilization and irrigation intervals on N content in plant (mg.kg-1)

Bio Fertilization	irrigation periods			Mean
	C 0	C 1	C 2	
B 0	16.823	19.657	23.15	19.88
B1	19.32	19.037	37.05	25.14
B2	17.827	30.133	29.01	25.66
B3	23.05	23.563	27.69	24.77
irrigation intervals	19.26	23.09	29.23	
LSD 0.05	C= 0.3463		B= 0.2736	CB= 0.4829

B0 = control, B1 = pseudomonas Bacteria, B2 = calcium silicate, B3 = interaction of pseudomonas Bacteria + calcium silicate, C0 = 7 days, C1 = 14 days, C2 = 21 days

Table 6: Effect of biofertilization and irrigation intervals on the phosphorous content in plants (mg.kg-1)

Bio Fertilization	irrigation intervals			Mean
	C 0	C 1	C 2	
B 0	6.65	9.527	15.52	10.57
B1	7.89	10.03	25.5	14.47
B2	9.81	19.03	19.55	16.13
B3	13.33	14.01	22.05	16.46
irrigation intervals	9.42	13.15	20.66	
LSD 0.05	C= 0.1628	B= 0.4169		CB= 0.6343

B0 = control, B1 = pseudomonas Bacteria, B2 = calcium silicate, B3 = interaction of pseudomonas Bacteria + calcium silicate, C0 = 7 days, C1 = 14 days, C2 = 21 days

Table 7: The effect of bio fertilization irrigation periods and the interaction between them on potassium content in plants mg.gm^{-1}

Bio Fertilization	irrigation periods			Mean
	C 0	C 1	C 2	
B 0	25.62	32.01	32.05	29.89
B1	28.32	29.51	39.01	32.28
B2	27.15	35.763	38.05	33.65
B3	33.71	35.00	37.05	35.25
irrigation intervals	28.7	24.32	36.54	
LSD 0.05	C= 0.3277		B= 0.2340	CB= 0.4281

B0 = control, B1 = pseudomonas Bacteria, B2 = calcium silicate, B3 = interaction of pseudomonas Bacteria + calcium silicate, C0 = 7 days, C1 = 14 days, C2 = 21 days

4.5. Grain yield (tons/ha)

The results in table (8) showed that treatment (B2) had significantly the highest grain yield 4.16 tons/ha. Irrigation intervals (C0) recorded the highest grain yield 3.73 tons/ha. The results in Table (8) showed that the interaction between B2 and c0 was significant suggesting an efficient strategy for silicate in increasing the grain yield.

Table 8: The effect of bio fertilization irrigation periods and the interaction between them on the grain yield (tons/ha)

Bio Fertilization	irrigation periods			Mean
	C 0	C 1	C 2	
B 0	3.05	3.2	3.137	3.13
B1	3.683	3.55	3.763	3.67
B2	4.260	4.118	4.112	4.16
B3	3.91	3.763	3.41	3.69
irrigation intervals	3.73	3.66	3.61	
LSD 0.05	C= 0.1245	B= 0.1590		CB= 0.2403

B0 = control, B1 = pseudomonas Bacteria, B2 = calcium silicate, B3 = interaction of pseudomonas Bacteria + calcium silicate, C0 = 7 days, C1 = 14 days, C2 = 21 days

5. Discussion

5-1- Effect of interaction between bacteria, calcium silicates and irrigation periods on biological parameters in the soil

The combination of *pseudomonas* with the calcium silicate (B3) had significantly the highest values of soil respiration (Table 2). This status is attributed to the active role played by *pseudomonas* in dissolving organic phosphorous by secreting organic acids such as lactic, acetic and other acids that dissolve complex compounds in the rhizosphere by secreting enzymes (phosphatase) that affect the growth of the roots and their development, which is reflected on the microbial activity and soil respiration. Moreover, the role of silicon in soil is not forgettable as it stimulates the plant to develop some of the mechanisms that enable it to resist various stress

conditions, such as biotic or abiotic factors (Liang et al., 2006). Silicon also works to chelate the micro-elements and increases their absorption leading to more development of roots system and soil microbiology activity. The reason for the increase in the density of pseudomonas bacteria in treatment (B1) (Table 3) is due to the role of pseudomonas inoculants, where the inoculation of bacteria increased and supported their density in the soil and this was indicated by Meena et al. (2014), Renuk et al. (2015). It is clear that the interaction between pseudomonas and calcium silicate led to a clear improvement in MBC and this is directly due to the role of pseudomonas through vital secretions such as acids and proteins that raise the proportion of carbon in the soil and improve soil properties. Besides, calcium silicate may reduce pH and increase the availability of phosphorous and potassium since they play an important role in increasing the area of root spread and their secretions (Ahmed and Khan 2011), as the dense roots have an important strategy in increasing the carbon of biomass.

The results also showed a significant increase in the soil respiration, pseudomonas and MBC with the 14-day irrigation intervals compared to the 7-day irrigation intervals. Bacteria have an ability to survive and ideally grow in the soil under conditions of water stress, as these bacteria possess some mechanisms at the molecular level of the bacterial cell that enable them to respond and survive during periods of soil drought, and this includes having the ability to modify the composition of the external structure of the cell through the production of exogenous polysaccharides (EPS) and thus the ability to promote plant growth and increase its efficiency to resist water stress conditions (Marasco et al., 2012). The secreted exopolysaccharides may accumulate outside the cell to act as a protective barrier against dehydration between cells and the surrounding environment through its ability to store a high water content (Naseem et al., 2018), which maintains the moisture content in the root zone and thus had to be reflected positively on plant growth and production under water stress conditions (Khan et al., 2017). This (EPS) compound can maintains the moisture content of the soil, especially in the areas close to the roots of the plant, being the area of interaction between bacteria and plants. (EPS) compound has an ability of swelling and contraction and remains saturated with moisture and is not affected by changes that occur in the water level of the soil and as a result, the organisms associated with this compound remain able to grow and move towards the dissolved components (Or et al., 2007). More importantly, another mechanism which could help microbes to cope with certain conditions is the formation of soil aggregates with small pores cussed by EPS that control the movement and

retention of water (Castellane et al., 2014). Furthermore, exopolysaccharides can bind with some cations such as Ca^{+2} resulting in the formation of a polymeric structure that has a high water-holding capacity by hydrogen bonds, leading to the increased levels of water stress (Roberson and Firestone, 1992). These findings have similar approaches with Chandra et al. (2018) when used pseudomonas bacteria to reduce the effect of water stress resulting from secreting different concentrations of polyethylene glycol that control the plant growth.

5-2 The effect of the bacteria, calcium silicates and irrigation periods on the content of the plant elements and wheat yield

The application of calcium silicate with bacteria had significantly the highest increase in the (N, P) in the plant. Silicone promotes plant roots growth and encouraging nutrient absorption. Bacteria also dissolved of organic phosphorous compounds and then converted them into available forms into the soil solution and consequent pass to the plant. Moreover, bacteria can convert the calcium phosphate to the available-made form for the plant by secreting some organic acids such as acetic, formic, citric and lactic acid, and enzymes such as phosphatase, which have the ability to decompose phosphorous bonds with calcium and releases then to the soil solution to be available for uptake by the plant (Nahas, 2007). Thus, increasing the phosphorous content in the leaves. The combination of *pseudomonas* bacteria with silicates at the 21 days irrigation intervals led to an increase in the phosphorous content in the plant, and the reason for this is due to the role of bacteria in the secretion of organic acids, hormones and growth regulators that lower soil pH and increase the availability of nutrients in the soil. *Pseudomonas* bacteria secrete enzymes such as nitrogenase, phosphatase and organic acids with low molecular weights such as lactic acid, citric acid, and gluconic acids, which have a role in reducing the degree of soil reaction pH by increasing the concentration of hydrogen ion H^{+} in the rhizosphere, which accelerates the dissolution of minerals which contains these nutrients (Khan et al., 2009).

The results showed a significant superiority of calcium silicate (B2) on increasing plant yield, and this is attributed to the role of silicon in many physiological processes, the most important of which is improving the efficiency of photosynthesis, increasing the effectiveness of roots to absorb nutrients necessary for plant growth and development, reducing toxicity Na ions and an increase in the ratio of K:Na and increasing the effectiveness of antioxidant enzymes, reducing the toxicity of heavy metals. It stimulates the plant to develop some of the mechanisms that enable it to resist

or withstand various stress conditions (Liang et al., 2006). It was found in a number of studies that silicon regulates the content of proline under water stress conditions (Ahmed et al., 2009). A positive effect of adding silicon is to improve the availability of phosphorous and then increase the uptake of P by plants, which has an important role in the physiological processes in the plant (Rotaru et al. 2010) and thus increasing the plant yield.

6. Conclusions

We can conclude from this study that the interaction between *pseudomonas* bacteria and calcium silicate B3 achieved significant improvements in soil respiration, microbial biomass carbon (MBC), potassium and phosphorous content in the plant. Furthermore, the treatment of the irrigation intervals every 21 days (C2) significantly improved MBC and the content of nitrogen, phosphorous and potassium in the plant, and this is associated with the clear enhancements in growth indicators that occurred with the irrigation intervals at 14 and 21 days. Moreover, the interaction between *pseudomonas* b1 and C2 irrigation intervals of 21 days showed a significant effect on N, P, and K content in the leaves. More importantly, the wheat plant was positively maximized by all the added treatments and especially by the silicate. This study reflects a novel interest regarding the importance of *pseudomonas* and calcium silicate in alleviating water stress during drought conditions and the considerations for microbe's developments.

7. References

Ahemad M.,& Khan M.S.(2011). *Pseudomonas aeruginosa* strain PS1 enhances growth parameters of greengram [Vigna radiata(L.) Wilczek] in insecticide-stressed soil. J.Pest.Sci., 84:123-131.

Ahmed, M., Qadeer, U., & Aslam, M. A. (2011). Silicon application and drought tolerance mechanism of sorghum. African Journal of Agricultural Research, 6(3), 594-607.

Anderson, J. P. (1983). Soil respiration. Methods of soil analysis: part 2 chemical and microbiological properties, 9, 831-871.

Buchanan, R. E. &Gibbons, N. E. 1974. bergey's Manual Of Determinative Bacteriology, 8th Edn. Baltimore: Williams & Wilkins.

Castellane , T. C. L., M. V. F. Lemos, and E. G. de Macedo Lemos.2014. Evaluation of the biotechnological potential of rhizobium tropici strains for exopolysaccharide production. Carbohydr. Polym. 111, 191–197.

Chandra, S., Askari, K., & Kumari, M. (2018). Optimization of indole acetic acid production by isolated bacteria from Stevia rebaudiana rhizosphere and its effects on plant growth. *Journal of Genetic Engineering and Biotechnology*, *16*(2), 581-586.

Etesami, H.; Jeong, B.R.2018. Silicon (Si) Review and Future Prospects on the Action Mechanisms in Alleviating Biotic and Abiotic Stresses in Plants. *Ecotoxicol*. *Environ*. *Saf*. 2018, *147*, 881–896,

FAO. FAO Cereal Supply and Demand Brief. Retrieved on December 20, 2019, from http://www.fao.org/worl dfoodsituation/csdb/en/

Frietas ,ADS .;Vieira ,CL.; Santos ,CERS.; Stamford ,NP., and Lyra ,MCCP. (2007).Characterization of rhizobateria isolated from L.Pachyrhyzus erosus cultivated in saline soil of the state of Pernambuco ,Brazil . Braganta , 66:497-504.

Ganeshan, G., & Manoj Kumar, A. (2005). Pseudomonas fluorescens, a potential bacterial antagonist to control plant diseases. Journal of Plant Interactions, 1(3), 123-134.

Horwath, W. R., Paul, E. A., Harris, D., Norton, J., Jagger, L., & Horton, K. A. (1996). Defining a realistic control for the chloroform fumigation-incubation method using microscopic counting and 14C-substrates. Canadian Journal of Soil Science, 76(4), 459-467.

Khan , N, A. Bano and M.A. Babar . 2017. The root growth of wheat plants, the water conservation and fertility status of sandy soils influenced by plant growth promoting rhizobacteria. Symbiosis :72: 195–205.

Labetowicz, J. (1988). The Chosen of analyzed Method of Soil, Plant and Fertilizer. Editor: SGGW-AR Warszawa, Poland, 119-123.

Labetowicz, J. (1988). The Chosen of analyzed Method of Soil, Plant and Fertilizer. Editor: SGGW-AR Warszawa, Poland, 119-123.

Liang, Y., Zhang, W., Chen, Q., Liu, Y., & Ding, R. (2006). Effect of exogenous silicon (Si) on H+-ATPase activity, phospholipids and fluidity of plasma membrane in leaves of salt-stressed barley (Hordeum vulgare L.). *Environmental and Experimental Botany*, *57*(3), 212-219.

Marasco , R., E. Rolli, B. Ettoumi, G. Vigani, F. Mapelli, S. Borin. 2012. A drought resistance-promoting microbiome is selected by root system under desert farming. PloS one, 7(10).

Meena, V. S., Maurya, B. R., & Bahadur, I. (2014). Potassium solubilization by bacterial strain in waste mica. *Bangladesh Journal of Botany*, *43*(2), 235-237.

Nahas, E. (2007). Phosphate solubilizing microorganisms: Effect of carbon, nitrogen, and phosphorus sources. In *First international meeting on microbial phosphate solubilization* (pp. 111-115). Springer, Dordrecht.

Naseem , H., M. Ahsan, M. A. Shahid and N. Khan .2018. Exopolysaccharides producing rhizobacteria and their role in plant growth and drought tolerance. Journal of basic microbiology, 58(12), 1009-1022.

Or , D., S. Phutane, and A. Dechesne.2007. Extracellular polymeric substances affecting pore-scale hydrologic conditions for bacterial activity in unsaturated soils. Vadose Zone J. 6, 298–298.

Rana, A.;Saharan,B.;Joshi,M.;Prasanna,R.;Kumar,K.,&Nain.(2011). Identification of multitrail(PGPR) isolates and evaluating their potential as inoculants for wheat. Ann. Microbiol., 68:893-90.

Renuk N, Prasanna R, Sood A, Ahluwalia AS, Bansal R, Babu S, Singh R, Shivay YS and Nain L 2015. Exploring the efficacy of wastewater-grown microalgal biomass as a biofertilizer for wheat. Environment Science Pollution Research 10.1007/s11356-015-5884-6

Roberson , E.B., M.K. Firestone. 1992. Relationship between desiccation and exopolysaccharide production in a soil Pseudomonas sp. Appl Environ Microbiol :58:1284–91.

Rotaru, V. (2010). The effects of phosphorus application on soybean plants under suboptimal moisture conditions. *Lucrări Ştiinţifice*, *53*(2), 27-30.

Wollum, A. G. (1982). Cultural methods for soil microorganisms. In: PageAL (ed) Methods of soil analysis, part 2. American Society of Agronomy, Madison, Wisconsin, p 781-802

Yin, L., Wang, S., Tanaka, K., Fujihara, S., Itai, A., Den, X., & Zhang, S. (2016). Silicon-mediated changes in polyamines participate in silicon-induced salt tolerance in S orghum bicolor L. *Plant, cell & environment*, *39*(2), 245-258.