

## SOIL SUSTAINABILITY BY ADDING MOLASSES FACTORY RESIDUAL, SILICATE- SOLUBILIZING BACTERIA AND MINERAL FERTILIZER ON THE AVAILABILITY OF SOME NUTRIENTS IN THE SOIL

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### ABSTRACT

A field experiment was conducted in a loam soil at the research station of the College of Agricultural Engineering Sciences / University of Baghdad, during the autumn season 2023 to find out the effect of adding molasses residual, silicate- solubilizing bacteria, mineral fertilizers and their interactions on the availability of N, P, K, Si and organic matter in the soil after harvesting the cauliflower crop. The experiment was conducted in a factorial randomized complete block design (RCBD) with three replicates. The first factor included three levels; no addition mineral fertilizer  $M_0$  and adding 50% of the fertilizer recommendation ( $150 \text{ kg N ha}^{-1}$ ,  $65.5 \text{ kg P ha}^{-1}$  and  $124.5 \text{ kg K ha}^{-1}$ )  $M_1$  and adding 10 liters  $\text{ha}^{-1}$  of potassium silicate fertilizer  $M_2$  with adding 100% of the fertilizer recommendation for comparison. The second factor included adding biological and organic fertilizers at three levels the first level; no addition  $B_0$  and The second level included adding silicate- solubilizing bacteria (*Bacillus mucilaginosus*)  $B_1$ . The third level included adding date waste at a level of ( $10 \text{ Mg ha}^{-1}$ )  $B_2$ . The results showed the significant effect of adding molasses factory waste, silicate- solubilizing bacteria and mineral fertilizer to the soil. The interaction treatment  $M_1 B_2$  achieved the highest values in the availability of N, P and organic matter.

**Key words:** *Bacillus mucilaginosus*, Date waste.



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### INTRODUCTION

To maintain soil fertility, farmers resorted to adding large amounts of chemical fertilizers to provide nutrients for the plants, which led to an increase in the amount of pollutants due to the excessive use of these fertilizers. The use of chemical fertilizers has increased due to the increase in population and the increase in the need for food. Nitrogen, phosphorus, and potassium fertilizers are among the most commonly used fertilizers, including urea, triple superphosphate, and potassium sulfate. Iraq is famous for its many palm trees, and one of the main products of date factories is molasses, and date waste is a by-product of the date molasses industry. Date molasses

factories produce about 17-28% of date waste in the form of waste that is buried in the soil, causing environmental problems (Haris *et al.*, 2023). This waste can be used as organic fertilizer, and the bioconversion of these by-products of dates into valuable products instead of throwing them into drains and dumps to sustainable waste management (Musa and Elnour, 2024). *Bacillus mucilaginosus* is a silicate- solubilizing bacteria and an important biofertilizer due to its importance in improving plant growth, soil development, and increasing the availability of silicon, phosphorus and potassium in the soil (Zhao *et al.*, 2024). This bacteria is a biofertilizer used in sustainable agriculture due to the ability of this bacteria to

dissolve potassium and silicon compounds by the production of a group of enzymes, thus releasing potassium and silicon. Silicon is the second most abundant element in the earth's crust. Silicon was previously classified as a non-essential element, but now many recent studies have provided strong evidence of the positive effects of silicon in resisting biotic and abiotic stresses, and thus it is now recognized as a semi-essential element (Thakral *et al.*, 2024.). Silicon fertilizers improve the photosynthesis process, reduce the harmful effects of insects and pathogens, and improve the ability of plants to withstand salt and water stress (Liu *et al.*, 2024). Potassium silicate fertilizer is the main source of available silicon and potassium and is widely used in agricultural production. Cauliflower is one of the most important vegetables of the *Brassica oleracea*. In terms of nutrients, cauliflower ranks first among all the cruciferous family varieties. Cauliflower has a high nutritional value, as it contains phosphorus, calcium, iron, proteins and carbohydrates. It also contains a high percentage of antioxidants such as glucosinolates, which are of great importance in fighting cancer, and it also protects against many chronic human diseases (Zafar *et al.*, 2024). Therefore, the study aimed to determine how to maintain soil sustainability by adding molasses residual, silicate-solubilizing bacteria and mineral fertilizers.

#### MATERIALS AND METHODS

The experiment was conducted at the research station of the College of Agricultural Engineering Sciences / University of Baghdad in Al-Jadriya city, for the autumn season 2022-2023 in a Loam soil according to the modern American classification (Soil Survey Staff, 2006.). The soil was prepared for cultivation by plowing, smoothing and leveling the experimental land. Random samples were taken from the soil at a depth of 0-30 cm, then air-dried and ground using a wooden hammer and passed through a sieve with a hole diameter of 2 mm for the purpose of conducting some analyses (Page *et al.*, 1982) (Table 1). The area required for the experiment was divided into experimental units (plots) with dimensions of (2 x 3.5 m). Each terrace

was divided into three lines, the distance between a line and another is 80 cm and between plots was 40 cm. The experiment is factorial and was implemented according to a randomized complete block design (RCBD) with three replicates, each replicate containing 10 experimental units, and a distance of 2 meters was left between one replicate and the other. By applying the (Genstat) program to analyze the experimental data using the least significant difference (L.S.D) at the 0.05 level (Steel and Torrie, 1980). The experiment included two factors, the first factor is adding mineral fertilizers at three levels, all of which were added to the soil, the first level without adding (0), the second level is adding N, P and K fertilizer at a level of 50% of the fertilizer recommendation, the fertilizer recommendation is 150 kg N ha<sup>-1</sup> of urea fertilizer (46% N) and 65.5 P ha<sup>-1</sup> of concentrated superphosphate fertilizer (20% P) and 124.5 kg K ha<sup>-1</sup> of potassium sulfate fertilizer (42% K) (Ali *et al.*, 2014.), and the third level of mineral fertilizer is adding potassium silicate (5% Si) fertilizer at a level of 10 liters ha<sup>-1</sup>. The second factor was organic and biological fertilizers at three levels; the first without adding (0), the second level is adding biological fertilizer, which is silicate-solubilizing bacteria (*Bacillus mucilaginosus*), and the third level was adding date waste at a level of 10 tons ha<sup>-1</sup>. With the addition of 100% of the full fertilizer recommendation for comparison Three experimental units, thus the number of experimental units = 3\*3\*3= 27+3= 30. *Bacillus mucilaginosus* isolate was obtained from the Graduate Research Laboratory / Department of Soil science and Water Resources, and date waste (molasses factory waste) was obtained from one of the molasses factories in the Jamila city in the capital Baghdad from Al-Bayader Company, at a level of 100 kg. Date waste consists of date remains (without the seed). A sample was taken from the date remains for the purpose of estimating some acids, as shown in Table (2, 3).

#### Measurements

1- Calculating the concentrations of N, P, K, Si and organic matter in the soil after harvesting the crop

- Available nitrogen in the soil: Using the Micro Kieldahl device, available nitrogen in the soil was estimated as mentioned in (Bremner and Keeney, 1965.).
  - Available phosphorus in the soil: Using the spectrophotometer, available phosphorus in the soil was estimated as mentioned in (Page *et al.*, 1982).
  - Available potassium in the soil: The extracted potassium was estimated using the flame photometer after the soil potassium was extracted using ammonium acetate solution according to the method mentioned in (Black, 1965.).
  - Available silicon in the soil: It was estimated using the spectrophotometer and at a wavelength of (660 nm) according to method (Haynes, 2014.).
  - Organic matter in the soil: The organic matter was estimated according to the Walkly, Black method mentioned in (Page *et al.*, 1982) by the wet digestion method.
- 2- Estimation of acids in molasses factory waste (Date waste without pits)
- Estimation of fatty acids: 1- Extraction of fat from the sample: Fat was estimated based on method (AC, 1995.) using the fat extraction device (Soxholet).
  - 2- Fat esterification: The sample was prepared according to the method approved by (AC,1995.) and based on fat esterification by

reacting it with methanolic potassium hydroxide and prepared by dissolving 11.2 g of potassium hydroxide and dissolving it in 100 ml of methanol, then 1 g of fat was taken and 8 ml of methanolic potassium hydroxide was added to it with 5 ml of hexane and shaken quickly for 30 seconds and then left to separate into two layers, taken from the upper layer (hexane layer) which contains the esterified fat and injected into the device.

#### 3- Chromatographic analysis of the sample:

- Fatty acid compounds were analyzed using a gas chromatography device (GC-2010) Shimadzu model, made in Japan, where a flame ionization detector (FID) was used and a capillary separation column type (SE-30) with lengths of (30m \* 0.25 mm) was used.
- Amino acids estimation: They were estimated using the Amino acid analyzer device.

#### 4- Biological analysis:

- Total number of bacteria in the soil: The total number of bacteria in the soil was estimated according to the method mentioned in (Page *et al.*, 1982) by dilution and plate counting in sterile plates and on Nutrient Agar medium.
- Total number of fungi in the soil: The total number of fungi in the soil was estimated before planting according to the method mentioned in (Black, 1965.) by dilution and plate counting using PDA medium

**Table 1. Some physical, chemical, fertility and biological properties of soil before planting**

Character	Value	Unit
pH	7.3	-
EC	1.3	ds m <sup>-1</sup>
O.M	12.0	g kg <sup>-1</sup> soil
Available N	28.0	
Available P	8.0	
Available K	113.81	mg kg <sup>-1</sup>
Available Si	0.12	
Cations	Ca <sup>+2</sup>	3.42
	Mg <sup>+2</sup>	1.98
	Na <sup>+</sup>	2.01
	K <sup>+</sup>	0.90
Anions	SO <sub>4</sub> <sup>-2</sup>	0.88
	CO <sub>3</sub> <sup>-2</sup>	Nil
	HCO <sub>3</sub> <sup>-</sup>	1.00
	Cl <sup>-</sup>	4.12
Soil Texture	Sand	392
	Clay	108
	Silt	500
	Loam	
Total bacteria	10 <sup>6</sup> ×4.4	Cfu g <sup>-1</sup> dry soil
Total fungus	10 <sup>3</sup> ×1.6	Cfu g <sup>-1</sup> dry soil

Laboratory analyses were conducted at the University of Baghdad/College of Agricultural Engineering Sciences/Laboratories of the

Department of Soil Sciences and Water Resources.

**Table 2. Some fatty acids in molasses factory residual (date waste without seed).**

No	Name	Concentration %
1	Palmitic	6.14
2	Oleic	17.25
3	Lenolic	52.92
4	Linolenic	2.98
5	Stearic	8.66

Laboratory analyses were performed at the Ministry of Science and Technology/GC mass laboratories.

**Table 3. Some amino acids in molasses factory residual (date waste without seed).**

No	Reten. Time [min]	Area [mAU.s]	Height [mAU]	Amount ( $\mu\text{g/gm}$ )	Calculation	Peak type	Compound Name
1	2.06	825.98	631.4	10.58	Calibration curve	Order	Aspartic acid
2	2.81	914.45	223.6	12.66	Calibration curve	Order	Asparagine
3	3.76	132.65	511.5	10.65	Calibration curve	Order	Lysine
4	4.05	921.44	635.0	8.98	Calibration curve	Order	Serine
5	5.08	632.65	364.1	9.22	Calibration curve	Order	Threonine
6	5.85	332.65	633.2	13.65	Calibration curve	Order	Isoleucine
7	6.28	632.14	342.5	12.80	Calibration curve	Order	Alanine
8	6.82	926.65	511.2	10.88	Calibration curve	Order	Valine
9	7.93	832.11	231.4	9.80	Calibration curve	Order	Tyrosine
10	8.58	825.65	533.6	6.58	Calibration curve	Order	Arginine
11	9.38	312.66	578.0	10.47	Calibration curve	Order	Cysteine
12	10.22	514.66	381.5	13.55	Calibration curve	Order	Methionine
13	11.48	932.65	595.9	12.08	Calibration curve	Order	Proline
14	11.96	525.66	280.8	10.54	Calibration curve	Order	Histidine
15	12.39	610.22	582.6	8.77	Calibration curve	Order	Lucien
16	13.12	832.00	361.4	9.25	Calibration curve	Order	Phenylalanine
17	13.91	542.45	605.9	7.98	Calibration curve	Order	Glycine
	Total						

Laboratory analyses were conducted at the Ministry of Science and Technology/GC mass laboratories

**Table 4. Effect of adding date residual, silicate- solubilizing bacteria and mineral fertilizer on soil organic matter ( $\text{g.kg}^{-1}$  soil) after harvest.**

M	B			Mean of M
	B <sub>0</sub>	B <sub>1</sub>	B <sub>2</sub>	
M <sub>0</sub>	11.130	13.330	20.230	14.897
M <sub>1</sub>	11.930	13.400	23.300	16.210
M <sub>2</sub>	10.270	12.530	19.670	14.157
L.S.D <sub>0.05</sub>		0.978		0.565
Mean of B	11.110	13.087	21.067	
L.S.D <sub>0.05</sub>		0.565		

## RESULTS AND DISCUSSIONS

Organic matter:

Table (4) shows that adding M<sub>1</sub> (N, P, K) at a level of 50% of the fertilizer recommendation had a significant effect on increasing the

organic matter in the soil, which amounted to 16.210 ( $\text{g.kg}^{-1}$  soil), with an increase rate of 8.81% compared to the treatment of without adding M<sub>0</sub>, which amounted to 14.897. The second factor is that adding B<sub>2</sub> (date residual)

at a level of 10 Mg ha<sup>-1</sup> achieved 21.067 (g. kg<sup>-1</sup> soil) in the organic matter in the soil, with an increase rate of 89.62% compared to the treatment of non- addition B<sub>0</sub>, which mean 11.110 (g. kg<sup>-1</sup> soil). The treatment of B<sub>1</sub>, which dissolves silicates (*Bacillus mucilaginosus*), amounting to 13.087 (g. kg<sup>-1</sup> soil), achieved an increase rate of 17.79% when compared to the treatment of not adding B<sub>0</sub>. The results of the statistical analysis

indicated the significant effect of the interaction of B and M levels, as the M<sub>1</sub> B<sub>2</sub> treatment (50% of the fertilizer recommendation with date residual) achieved the highest content of organic matter, which recorded to 23.300 (g. kg<sup>-1</sup> soil), with an increase rate of 109.34%. When compared to the no-addition treatment M<sub>0</sub> B<sub>0</sub> which was 11.130 (g. kg<sup>-1</sup> soil).

**Table 5. Effect of adding date residual, silicate- solubilizing bacteria and mineral fertilizer on the concentration of available nitrogen in the soil (mg N kg<sup>-1</sup>) after harvest**

M	B			Mean of M
	B <sub>0</sub>	B <sub>1</sub>	B <sub>2</sub>	
M <sub>0</sub>	18.260	23.860	28.090	23.403
M <sub>1</sub>	25.040	34.160	35.850	31.683
M <sub>2</sub>	25.240	31.850	28.280	28.457
L.S.D <sub>0.05</sub>		2.965		1.712
Mean of B	22.847	29.957	30.740	
L.S.D <sub>0.05</sub>		1.712		

Available nitrogen:

Table (5) shows that adding M<sub>1</sub> at a level of 50% of the fertilizer recommendation had a significant effect on increasing the concentration of available nitrogen in the soil, which reached 31.683 (mg N kg<sup>-1</sup>) and an increase rate of 35.38% compared to the treatment of without adding M<sub>0</sub>, which recorded to 23.403 (mg N kg<sup>-1</sup>), while adding M<sub>2</sub> potassium silicate achieved a lower increase rate than M<sub>1</sub> and reached 21.59% (mg N kg<sup>-1</sup>) compared to the treatment of not adding M<sub>0</sub>. The results of the statistical analysis showed that the addition of B<sub>2</sub> (date residual) at a level of 10 tons ha<sup>-1</sup> had a significant effect on the available nitrogen content in the soil at a rate of 30.740 (mg N kg<sup>-1</sup>) and an increase rate of 34.55% compared to the treatment without addition, which recorded to 22.847 (mg N kg<sup>-1</sup>), but the

addition of silicate- solubilizing bacteria B<sub>1</sub> (*Bacillus mucilaginosus*) achieved 29.957 (mg N kg<sup>-1</sup>) and an increase rate of 31.12% compared to the treatment without addition. The results of the statistical analysis of the interaction of B and M levels showed that the M<sub>1</sub> B<sub>2</sub> treatment (50% of the fertilizer recommendation with date residual) outperformed the other treatments in achieving the highest rate of available nitrogen in the soil, which amounted to 35.850 (mg N kg<sup>-1</sup>) and an increase rate of 96.33% compared to the non-addition treatment, which gave the lowest concentration of available nitrogen, which recorded to 18.260 (mg N kg<sup>-1</sup>), but this treatment did not differ significantly of M<sub>1</sub> B<sub>1</sub>, which amounted to 34.160 (mg N kg<sup>-1</sup>) and an increase rate of 87.08% compared to the non-addition treatment.

**Table 6. Effect of adding date residual, silicate- solubilizing bacteria and mineral fertilizer on the concentration of available phosphorus in the soil (mg P kg<sup>-1</sup>) after harvest**

M	B			Mean of M
	B <sub>0</sub>	B <sub>1</sub>	B <sub>2</sub>	
M <sub>0</sub>	7.640	8.770	10.270	8.893
M <sub>1</sub>	12.270	14.590	15.890	14.250
M <sub>2</sub>	11.090	12.460	12.760	12.103
L.S.D <sub>0.05</sub>		0.911		0.526
Mean of B	10.333	11.940	12.973	
L.S.D <sub>0.05</sub>		0.526		

Available phosphorus:

The results of the statistical analysis of Table (6) indicate that adding M<sub>1</sub> at a level of 50% of

the fertilizer recommendation significantly increased the available phosphorus in the soil at a rate of 14.250 (mg P kg<sup>-1</sup>) and an increase

rate of 60.24% compared to the treatment of without adding M<sub>0</sub>, which recorded to 8.893 (mg P kg<sup>-1</sup>), while adding M<sub>2</sub> potassium silicate achieved 12.103 (mg P kg<sup>-1</sup>) and an increase rate of 36.10% compared to the treatment of not adding. The second factor is that adding B<sub>2</sub> (date residual) achieved a significant increase in available phosphorus in the soil, reaching 12.973 (mg P kg<sup>-1</sup>) and an increase rate of 25.55% compared to the treatment without addition, which achieved 10.333 (mg P kg<sup>-1</sup>). The B<sub>1</sub> treatment of silicate-solubilizing bacteria (*Bacillus mucilaginosus*) achieved a significant increase of 11.940 (mg P kg<sup>-1</sup>) and an increase rate of 15.55% compared to the treatment without

addition. This rate shows that adding date residual or silicate- solubilizing bacteria achieves an increase in available phosphorus. The results of statistical analysis showed that the di interaction of B and M levels was significant, as the M<sub>1</sub> B<sub>2</sub> treatment (50% of the fertilizer recommendation with date residual) gave the highest rate of available phosphorus in the soil, reaching 15.890 (mg P kg<sup>-1</sup>) and an increase rate of 107.98% compared to the non-addition treatment, which achieved the lowest concentration of available phosphorus, reaching 7.640 (mg P kg<sup>-1</sup>). This treatment did not differ significantly from M<sub>1</sub> B<sub>1</sub>, which achieved 14.590 (mg P kg<sup>-1</sup>) and an increase rate of 90.97%.

**Table 7. Effect of adding date residual, silicate- solubilizing bacteria and mineral fertilizer on the concentration of available potassium in the soil (mg K kg<sup>-1</sup>) after harvest**

M	B			Mean of M
	B <sub>0</sub>	B <sub>1</sub>	B <sub>2</sub>	
M <sub>0</sub>	109.780	224.330	219.570	184.560
M <sub>1</sub>	203.940	235.740	233.600	224.427
M <sub>2</sub>	165.380	225.980	223.010	204.790
L.S.D <sub>0.05</sub>		5.014		2.895
Mean of B	159.700	228.683	225.393	
L.S.D <sub>0.05</sub>		2.895		

Available potassium:

Table (7) shows that adding M<sub>1</sub> at a level of 50% of the fertilizer recommendation had a significant effect on increasing the available potassium in the soil at a rate of 224.427 (mg K kg<sup>-1</sup>) and an increase rate of 21.60% compared to the non-addition treatment, which achieved 184.560 (mg K kg<sup>-1</sup>), while adding M<sub>2</sub> potassium silicate reached 204.790 (mg K kg<sup>-1</sup>) and an increase rate of 10.961% compared to the no-add treatment. The second factor B<sub>1</sub> bacteria (*Bacillus mucilaginosus*) had a significant effect on the available potassium in the soil, as it reached 228.683 (mg K kg<sup>-1</sup>) and an increase rate of 43.20% compared to the treatment non addition, which reached 159.700 (mg K kg<sup>-1</sup>). The addition of

B<sub>2</sub> date residual (at a level of 10 tons ha<sup>-1</sup>) had a significant effect on the available potassium in the soil, as it reached 225.393 (mg K kg<sup>-1</sup>) and an increase rate of 41.14%. The results of the statistical analysis of the interaction of B and M levels showed that the M<sub>1</sub> B<sub>1</sub> treatment (50% N, P and K with bacteria) gave the highest rate of available potassium in the soil, reaching 235.740 (mg K kg<sup>-1</sup>) and an increase rate of 114.74% compared to the non-addition treatment, which gave the lowest concentration of available potassium, reaching 109.780 (mg K kg<sup>-1</sup>), but this treatment did not differ significantly from M<sub>1</sub> B<sub>1</sub>, which achieved 233.600 (mg K kg<sup>-1</sup>) and an increase rate of 112.79%.

**Table 8. Effect of adding date residual, silicate- solubilizing bacteria and mineral fertilizer on the concentration of ready silicon in the soil (mg Si g<sup>-1</sup>) after harvest.**

Mean of M	B			M
	B <sub>0</sub>	B <sub>1</sub>	B <sub>2</sub>	
M <sub>0</sub>	0.106	0.290	0.249	0.215
M <sub>1</sub>	0.251	0.299	0.267	0.272
M <sub>2</sub>	0.363	0.381	0.359	0.368
L.S.D <sub>0.05</sub>		0.023		0.013
Mean of B	0.240	0.323	0.292	
L.S.D <sub>0.05</sub>		0.013		

Available silicone:

Table (8) shows that adding  $M_2$  potassium silicate had a significant effect on increasing the available silicon in the soil at a rate of  $0.368 \text{ (mg Si g}^{-1}\text{)}$  and an increase rate of 71.16% compared to the non-addition treatment, which achieved  $0.215 \text{ (mg Si g}^{-1}\text{)}$ , while adding  $M_1$  at a level of 50% of the fertilizer recommendation reached  $0.272 \text{ (mg Si g}^{-1}\text{)}$  and an increase rate of 26.51% compared to the non-addition treatment. The second factor is that adding bacteria (*Bacillus mucilaginosus*) had a significant effect on the available silicon in the soil, as it reached  $0.323 \text{ (mg Si g}^{-1}\text{)}$  and an increase rate of 34.58% compared to the treatment without addition, which reached  $0.240 \text{ (mg Si g}^{-1}\text{)}$ , and adding B2 date waste achieved a significant effect on the available silicon in the soil, as it reached  $0.292 \text{ (mg Si g}^{-1}\text{)}$  and an increase rate of 21.67%. The results of the statistical analysis of the interaction of B and M levels showed the superiority of the  $M_2 B_1$  treatment (potassium silicate with bacteria), which achieved the highest rate of available silicon in the soil, reaching  $0.381 \text{ (mg Si g}^{-1}\text{)}$  and an increase rate of 259.43% compared to the non-addition treatment, which gave the lowest concentration of available potassium, reaching  $0.106 \text{ (mg Si g}^{-1}\text{)}$ . Tables (4, 5, 6, 7, 8) shows that the addition of date waste, silicate-solubilizing bacteria and mineral fertilizer led to an increase in organic matter, nitrogen, phosphorus, potassium and silicon in the soil. The interaction treatment (adding 50% of the fertilizer recommendation with date residual) symbolized by  $M_1 B_2$  achieved the highest values in availability (N, P and organic matter), and the interaction treatment (adding 50% of the fertilizer recommendation with silicate-solubilizing bacteria) symbolized by  $M_1 B_1$  achieved the highest significant increase in potassium availability (K), and the interaction treatment (potassium silicate with silicate-solubilizing bacteria) symbolized by  $M_2 B_1$  achieved the highest values in silicon concentration (Si). The reason for the superiority of the interaction  $M_1 B_2$  (50% of the fertilizer recommendation with date residual) significantly in organic matter, nitrogen and phosphorus in the soil may be

due to the fact that the added mineral fertilizer of urea and concentrated superphosphate led to an increase in available nitrogen and phosphorus in the soil (Al Bahrani, 2022), and the reason may be due to the secretion of date waste of organic acids that affect the soil environment and release more nutrients date residues are rich in phenolic compounds such as carotenoids, sterols, phenolic acids and anthocyanins (Ahmad *et al.*, 2021). Date residues also contain a percentage of amino acids including Isoleucine and Methionine Table (3) in addition to fatty acids including Palmatic, Oleic, Lenolnic, Linolenic and Stearic Table (2), which led to a reduction in soil pH and an increase in the solubility of compounds containing nutrients in a available form for absorption by the plant, thus increasing its availability in the soil solution, These residues contain carbon and nutrients and are rich in sugar, as they mainly contain fructose and glucose, in addition to fats, proteins and water-soluble vitamins (Oladzad *et al.*, 2021). They also contain a high percentage of potassium, magnesium, calcium and phosphorus (Al-Hamdani, 2019). These residues improve the physical and chemical properties of the soil and its ability to retain water and increase its porosity and aeration, which enhances the health and productivity of the soil and thus increases the activity and effectiveness of these organisms in decomposing organic matter (Al-Obidiy, *et al.*, 2023; Kavvadias *et al.* 2024). Nutrient availability increases when fertilizing with half a mineral fertilizer and half organic fertilizer compared to whole organic one (Devkota *et al.*, 2021). The reason for the superiority of the  $M_1 B_1$  dual interaction treatment may be due to the ability of these bacteria to secrete enzymes that play an important role in the mechanism of potassium release, including nuclease, protease, phosphomono esterase, endoglucanase, ribonuclease and cellobiase. They also secrete acids organic facilitates the process of potassium release from fixation sites. These bacteria produce polysaccharides that strongly adsorb organic acids and bind them together on the metal surface, This leads to an increase in the concentration of organic acids, which leads to the release of potassium

(Han *et al.*, 2024). In addition to the added mineral fertilizer M<sub>1</sub> of potassium sulfate, which increased the percentage of available potassium in the soil. The reason for the superiority of the dual interaction treatment M<sub>2</sub> B<sub>1</sub> in increasing the concentration of available silicon in the soil may be due to the fact that these bacteria have a fundamental role in the release of silicon from its fixation sites through the secretion of organic and inorganic acids that work to release silicon from silicate minerals, which increases the concentration of silicon in the soil (Etesami, and Jeong, 2022; Mounir *et al.*, 2020; Naji *et al.*, 2024). In addition, the added mineral fertilizer M<sub>2</sub> of potassium silicate increased the percentage of available silicon in the soil (Solanki *et al.*, 2023).

### CONCLUSION

The field experiment showed that combining organic amendments, beneficial bacteria, and mineral fertilizers significantly improved soil fertility after cauliflower harvest. The integration of silicate-solubilizing bacteria and organic residues enhanced nutrient availability and increased organic matter content in the soil. The combined application of reduced mineral fertilization with organic inputs proved most effective in improving nitrogen, phosphorus, and overall soil quality.

### CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

### DECLARATION OF FUND

The authors declare that they have not received a fund.

### AUTHOR/S DECLARATION

-We confirm that all Figures and Tables in the manuscript are original to us. Additionally, any Figures and images that do not belong to us have been incorporated with the required permissions for re-publication, which are included with the manuscript.-Author/s signature on Ethical Approval Statement

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## استدامة التربة بأضافة مخلفات معمل الدبس والبكتريا المذيبة للسليكات والسماد المعدني في جاهزية

### بعض المغذيات في التربة

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### المستخلص

اجريت تجربة حقلية في تربة مزيجة في احد حقول كلية علوم الهندسة الزراعية جامعة بغداد في منطقة الجادرية خلال الموسم الخريفي 2023 لمعرفة تأثير مخلفات معمل الدبس والبكتريا المذيبة للسليكات والأسمدة المعدنية وتداخلاتها في جاهزية N و P و K و Si ومحتوى المادة العضوية في التربة بعد جني محصول القرنابيط، طبقت تجربة عاملية بتصميم القطاعات الكاملة المعشاة (RCBD) بثلاث مكررات. تضمن العامل الأول ثلاث مستويات من دون اضافة السماد المعدني  $M_0$  و اضافة 50% من التوصية السمادية (150 كغم N هـ<sup>-1</sup> و 65.5 P هـ<sup>-1</sup> و 124.5 K هـ<sup>-1</sup>)  $M_1$  و اضافة 10 لتر هـ<sup>-1</sup> من سماد سليكات البوتاسيوم  $M_2$  مع اضافة 100% من التوصية السمادية لأجل المقارنة. وشمل العامل الثاني اضافة السمادين الحيوي والعضوي وبثلاث مستويات المستوى الأول: بدون اضافة  $B_0$  والمستوى الثاني اضافة البكتريا المذيبة للسليكات (*Bacillus mucilaginosus*)  $B_1$  والمستوى الثالث اضافة مخلفات التمر بمستوى (10 ميكاغرام هـ<sup>-1</sup>)  $B_2$ ، اظهرت النتائج التأثير المعنوي لأضافة مخلفات معمل الدبس والبكتريا المذيبة للسليكات والسماد المعدني في التربة. وحققت معاملة التداخل الثنائي  $M_1 B_2$  اعلى القيم في جاهزية N و P والمادة العضوية.

الكلمات المفتاحية: مخلفات التمر، *Bacillus mucilaginosus*، الاسمدة المعدنية.