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Evaluation of the effect of Azospirillum biofertilizer and banana peel organic fertilizer on sunflower production parameters and active chemicals

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Abstract

This study is to assess the efficiency of organic fertilization using banana peels and biofertilization using Azospirillum spp. bacteria in enhancing sunflower plant performance in light of the growing need to create sustainable agricultural systems. The seeds were then sown in holes on 2024/3/3. The experiment was carried out using a randomized complete block design (RCBD) with three replications and a factorial layout. There were two components in the experiment: The first component is the concentrations of banana peel (0, 50, 75, and 100 g\kg). The second factor included Azospirillum fertilizer at concentrations (0 ,50,75,100 mL. L^{-1}) , The studied traits Included The number of seeds in the disk (seed $disk^{-1}$), Weight of 100 seed (g), Biological yield (Mgha. L^{-1}), the active compounds oleic acid and thymol. The results indicate a significant effect between the banana peel treatments and *Azospirillum* biofertilizer, with the (100 g/kg), and the (100 mL. L^{-1}) treatment outperforming the others, yielding the highest average of number of seeds in the disk seed $disk^{-1}$ were (1736.8 and 1813.25 seed $disk^{-1}$) respectively, Weight of 100 seed (57.17 and 57.85 seed g), Biological yield (74.76 and 77.24 Mgha. L^{-1}) , oleic acid (7.59 and 8.36 %), thymol (7.46 and 9.45%).

Keywords: *Azospirillum biofertilizer*, organic banana peel, sunflowers, active compounds , thymol.

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Introduction

The sunflower plant (*Helianthus annuus* L.) One of the strategic oilseed crops belonging to the Asteraceae family, it is characterized by its high economic and nutritional value. Sunflower is widely cultivated in many countries around the world due to its tolerance to harsh environmental conditions, its ability to grow in various types of soil, and its high productivity of oil rich in unsaturated fatty acids, especially linoleic acid [1]. Organic fertilization is one of the fundamental pillars of sustainable agriculture, as it aims to improve soil fertility, increase its organic matter content, and enhance microbial activity, without harming the environment or polluting groundwater as chemical fertilizers do when used excessively. Organic fertilizer consists of partially or fully decomposed natural materials, such as banana peels [2], Banana peels contain a high percentage of potassium (K), which is essential for strengthening roots, promoting flowering, and increasing the plant's resistance to diseases. They also contain significant amounts of phosphorus (P), calcium (Ca), and magnesium (Mg) which are elements that contribute improving plant growth and development [3]. The use of banana peels in composting also contributes to reducing organic waste and achieving the principle of environmental recycling, which enhances the concept of sustainable agriculture and maintains the balance of the agricultural ecosystem [4]. Biofertilization is a type of fertilization that uses beneficial microorganisms – such as bacteria and fungi – to improve soil fertility and stimulate plant growth. This technique is considered part of sustainable agriculture, as it helps reduce reliance on chemical fertilizers and preserves the environment and soil health [5]. *Azospirillum* is a genus of beneficial bacteria widely used in biofertilization, especially with non-leguminous plants such as wheat, corn, rice, barley, and millet. These bacteria belong to the group of "free-living nitrogen fixers," where they live in the soil near plant roots (the rhizosphere) and fix atmospheric nitrogen, converting it into a form that the plant can absorb and utilize [6].The main benefits of *Azospirillum* for plants Biological nitrogen fixation: Plants help meet a large part of their nitrogen needs, reducing the need for chemical fertilizers Root growth stimulation: Bacteria secrete natural plant hormones such as an auxins and gibberellins, which stimulate root growth and increase the plant's ability to absorb water and nutrients [7]. Improving stress resistance: such as drought or salinity, where it enhances the plant's physiology under harsh environmental conditions[8]. Increasing in yield: Many studies have shown that inoculation with *Azospirillum*

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bacteria leads to an increase in production by up to 30% in some crops such as corn and wheat [9]. The aim of this study is to understand the importance of bio-fertilization and banana peels on productive traits and active compounds for sunflower.

Material and method

This research was conducted on the seeds type Agway XL-10 (chine) were planted on 2024/3/3 in holes alhindia \kerbala\Iraq , the type of soil (Sandy clay) A reversible moldboard plow was used for plowing, disc harrows were used for leveling, and the soil was then divided into multiple experimental units. Because the experimental unit area was 5 x 3 m, it was 15 m². To guarantee that there was no effect transfer between them, 75 cm and 1 m intervals were left between the replicates. Then in holes at the upper third of the row, with a distance of 50 cm between each hole, alternating on both sides of the row with 3 seeds per hole and a depth of 3-5 cm. Afterwards, the plants were thinned to one plant per hole. Additionally, all crop maintenance operations were carried out, including weeding at a rate of 4 times during the crop growth period, and the plants were irrigated periodically based on soil moisture and plant condition. The soil was also fertilized according to the fertilization recommendation with nitrogen fertilizer in the form of urea 200 kg ha^{-1} (N46%) in two doses, the first one month after planting and the second before reaching the flowering stage. As for the phosphate fertilizer, Diammonium Phosphate (DAP) 160 kg ha^{-1} [10]. The experiment was conducted in a factorial arrangement and with a randomized complete block design (RCBD) with three replications, including two factors in the experiment: The first factor: concentrations from banana peel (0,50,75,100 g\kg). The second factor: concentrations from *Azospirillum* (0, 50, 75, 100 $ml.L^{-1}$) [11,12].

Preparing banana peels as fertilizer

The bananas were collected from local markets and washed with distilled water to remove dirt, then exposed to the open air to dry. The ground bananas were then prepared according to the concentrations mentioned above and mixed with the soil [13].

Preparing *Azospirillum* as fertilizer

100 g of *Azospirillum* powder were taken for every 1 kg of sunflower seeds,the vaccine was mixed with a little less than 500 mL of water. The seeds were well mixed until they are fully

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coated. It was left to dry in the shade (not direct sunlight) for 20–30 minutes. Then the seeds were planted on the same day to enhance nitrogen fixation in the root zone immediately after germination [14,15].

The studied traits

The number of seeds in the disk (seed disk^{-1}), Weight of 100 seed (g), Biological yield (Mgha.L^{-1}). The active compounds oleic acid and thymol were estimated in sunflower seeds using Gas chromatography-mass spectrometry at a column temperature of 50°C and an injector temperature of 150°C [16,17].

statistically analyzed

The collected data were statistically analyzed according to the experimental design. Treatment means were compared using the Least Significant Difference (LSD) test at a 0.05 probability level. Statistical analysis was performed using the SAS software [18].

Results :

The number of seeds seed disk^{-1} in the disk

The results in Table (1) show a significant effect between the banana peel treatments, with the (100 g/kg) treatment outperforming the others, **on the number of seeds seed disk^{-1} in the disk** yielding the highest average of 1736.8 seed disk^{-1}, followed by the (75 and 50 g/kg) treatments with an average of 1655.5 and 1520.5 seed disk^{-1} , compared to the control treatment, which yielded the lowest average of 1513 seed disk^{-1}, while *Azospirillum* biofertilizer treatments show a significant effect, with the (100 mL.L^{-1}) treatment outperforming the others, yielding the highest average of 1813.25 seed disk^{-1}, followed by the (75 and 50 mL.L^{-1}) treatments with an average of 1672.56 and 1492.25 seed disk^{-1}, compared to the control treatment, which yielded the lowest average of 1325.75 seed disk^{-1}. The interaction between banana peel (100 g/kg) and *Azospirillum* biofertilizer (100 mL.L^{-1}) shows a substantial effect and produced the greatest average interaction with 1945 seed disk^{-1}. But interaction the control treatment recorded the lowest average with 1176 seed disk^{-1}.

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Table 1. Effect of *Azospirillum* biofertilizer and organic banana peel fertilizers on The number of seeds seed disk^{-1} in the disk.

Azospirillum biofertilizer (mL.L^{-1})	banana peel (g\kg)				
0	0	50	75	100	Mean
	1176	1287	1367	1473	1325.75
50	1285	1465	1584	1635	1492.25
75	1435	1574	1785	1894	1672.56
100	1656	1756	1896	1945	1813.25
LSD 0.05 for interaction	2.95				
Mean	1513	1520.5	1655.5	1736.8	
LSD $_{0.05}$ for *banana peel*(g\kg) = 1.86 LSD$_{0.05}$ *Azospirillum biofertilizer (* mL.L^{-1}) = 1.94					

Weight of 100 seed

Based on the results in Table (2) show a significant effect between the banana peel treatments, with the (100 g/kg) treatment outperforming the others, on **weight of 100 seed** yielding the highest average of 57.17 seed g, followed by the (75 and 50 g/kg) treatments with an average of 56.41 and 55.205 seed g, compared to the control treatment, which yielded the lowest average of 53.61 seed g., while *Azospirillum* biofertilizer treatments show a significant effect, with the (100 mL.L^{-1}) treatment outperforming the others, yielding the highest average of 57.85 seed g followed by the (75 and 50 mL .L^{-1}) treatments with an average of 56.98 and 54.53 seed g compared to the control treatment, which yielded the lowest average of 53.17 seed g. The interaction between banana peel (100 g/kg) and *Azospirillum* biofertilizer (100 mL.L^{-1}) shows a substantial effect and produced the greatest average interaction with 59.48 seed. g. But interaction the control treatment recorded the lowest average with 51.86seed. g.

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Table 2. Effect of *Azospirillum* biofertilizer and organic banana peel fertilizers on Weight of 100 seed g.

Azospirillum biofertilizer (mL.L^{-1})	banana peel (g\kg)				
0	0	50	75	100	Mean
	51.86	52.56	53.86	54.38	53.17
50	52.56	53.87	55.35	56.37	54.53
75	54.56	56.45	57.44	58.46	56.98
100	55.48	57.94	58.48	59.48	57.85
LSD 0.05 for interaction	2.67				
Mean	53.61	55.205	56.41	57.17	
LSD $_{0.05}$ for *banana peel* (g\kg) = 1.56 LSD$_{0.05}$ *Azospirillum biofertilizer* (mL.L^{-1}) = 1.64					

Biological yield

Indicate the results in Table (3) show a significant effect between the banana peel treatments, with the (100 g/kg) treatment outperforming the others **on Biological yield**, yielding the highest average of 74.76 Mgha^{-1} followed by the (75 and 50 g/kg) treatments with an average of 73.86 and 71.63 Mgha^{-1}, compared to the control treatment, which yielded the lowest average of 69.67Mgha^{-1}. while *Azospirillum* biofertilizer treatments show a significant effect, with the (100 mL.L^{-1}) treatment outperforming the others, yielding the highest average of 77.24 Mgha^{-1}, followed by the (75 and 50 mL.L^{-1}) treatments with an average of 73.73 and 70.79 Mgha^{-1}, compared to the control treatment, which yielded the lowest average of 68.16 Mgha^{-1}., The interaction between banana peel (100 g/kg) and *Azospirillum* biofertilizer (100 mL.L^{-1}) shows a substantial effect and produced the greatest average interaction with 79.45 Mgha^{-1}. But interaction the control treatment recorded the lowest average with 66.87Mgha^{-1}.

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Table 3. Effect of *Azospirillum* biofertilizer and organic banana peel fertilizers on Biological yield (Mgha^{-1}) .

Azospirillum biofertilizer (mL.L^{-1})	banana peel (g\kg)				
0	0	50	75	100	Mean
	66.87	67.34	68.96	69.45	68.16
50	67.97	69.56	71.96	73.67	70.79
75	69.95	72.67	75.85	76.46	73.73
100	73.87	76.98	78.67	79.45	77.24
LSD 0.05 for interaction	2.78				
Mean	69.67	71.63	73.86	74.76	
LSD $_{0.05}$ for *banana peel* (g\kg) = 1.45 LSD$_{0.05}$ *Azospirillum biofertilizer* (mL.L^{-1}) = 1.56					

Seed Oleic acid

Based on the results in Table (4) show a significant effect between the banana peel treatments, with the (100 g/kg) treatment outperforming the others **on seed Oleic acid**, yielding the highest average of 7.59% , followed by the (75 and 50 g/kg) treatments with an average of 6.77 and 5.60%, compared to the control treatment, which yielded the lowest average of 4.68%. while *Azospirillum* biofertilizer treatments show a significant effect, with the (100 mL.L^{-1}) treatment outperforming the others, yielding the highest average of 8.36% followed by the (75 and 50 mL.L^{-1}) treatments with an average of 7.25 and 5.11% compared to the control treatment, which yielded the lowest average of 4.18%. The nteraction between banana peel (100 g/kg) and *Azospirillum* biofertilizer (100 mL.L^{-1}) shows a substantial effect and produced the greatest average interaction with 9.98%. But interaction the control treatment recorded the lowest average with 2.67%.

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Table 4. Effect of *Azospirillum* biofertilizer and organic banana peel fertilizers on Oleic acid%.

Azospirillum biofertilizer (mL.L^{-1})	banana peel (g\kg)				
0	0	50	75	100	Mean
	2.67	3.65	4.84	5.56	4.18
50	3.75	4.86	5.45	6.37	5.11
75	5.74	6.45	7.34	8.45	7.25
100	6.56	7.45	9.45	9.98	8.36
LSD 0.05 for interaction	2.87				
Mean	4.68	5.60	6.77	7.59	
LSD $_{0.05}$ for *banana peel* (g\kg)=1.45 LSD$_{0.05}$ *Azospirillum biofertilizer* (mL.L^{-1}) =1.75					

seed thymol

Indicate the results in Table (5) show a significant effect between the banana peel treatments, with the (100 g/kg) treatment outperforming the others **on seed thymol**, yielding the highest average of 7.46% , followed by the (75 and 50 g/kg) treatments with an average of 6.60and 4.93%, compared to the control treatment, which yielded the lowest average of 4.20%. while *Azospirillum* biofertilizer treatments show a significant effect, with the (100 mL.L^{-1}) treatment outperforming the others, yielding the highest average of 9.45% followed by the (75 and 50 mL.L^{-1}) treatments with an average of 6.50and 5.60% compared to the control treatment, which yielded the lowest average of 4.13%. The interaction between banana peel (100 g/kg) and *Azospirillum* biofertilizer (100 mL.L^{-1}) shows a substantial effect and produced the greatest average interaction with 8.56%. But interaction the control treatment recorded the lowest average with 2.64%.

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Table 5. Effect of *Azospirillum* biofertilizer and organic banana peel fertilizers on thymol %.

Azospirillum biofertilizer ($mL.L^{-1}$)	banana peel (g\kg)				
0	0	50	75	100	Mean
	2.64	3.76	4.85	5.35	4.13
50	3.75	4.74	6.45	7.45	5.60
75	4.64	5.46	7.45	8.46	6.50
100	5.75	5.75	7.65	8.56	9.45
LSD 0.05 for interaction	2.86				
Mean	4.20	4.93	6.60	7.46	
LSD $_{0.05}$ for *banana peel* (g\kg) = 1.67 $LSD_{0.05}$ *Azospirillum biofertilizer* ($mL.L^{-1}$) = 1.83					

Discussion :

This study aims to evaluate the impact of using banana peels as an organic additive to the soil on the productive traits and active compounds of the sunflower plant (*Helianthus annuus*), due to the beneficial nutrients found in banana peels such as potassium, calcium, and magnesium, in addition to phenolic compounds. The results showed that treatments involving the addition of banana peels in moderate amounts (such as 10-15% of the dry soil weight) contributed to the improvement of a range of productive traits, such as: Increase in plant height. Increase in the number of branches and flowers. increase in the diameter of the flower disc and the number of seeds. improvement in seed weight and oil yield [19]. These results can be explained by the fact that banana peels are a rich source of potassium, which promotes vegetative growth and flowering in sunflower plants. Additionally, the high organic content in banana peels contributes to improving soil structure and increasing the activity of beneficial microorganisms, thereby enhancing nutrient absorption [20].

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Active compounds: it was also observed that there was an increase in the concentration of some active compounds in the seeds or parts of the sunflower plant treated with banana peels, such as: total phenols. Flavonoids. the content of volatile or fixed oil (depending on the type of analysis used). It is believed that the stimulation of these compounds is due to the plant's response to mild stress caused by the slow decomposition of banana peels and the release of certain organic acids and secondary compounds, which triggers plant defense mechanisms and increases the accumulation of these compounds[21]. Using banana peels is considered an environmentally friendly practice that contributes to recycling organic waste and reduces reliance on chemical fertilizers. However, attention should be paid to the quantity used to avoid any negative effects on the soil, such as increased salinity or soil pH disturbance in case of excessive use [22]. Evaluate the impact of biofertilization using *Azospirillum* spp. on the productive traits and active compounds in sunflower (*Helianthus annuus* L.), in light of modern trends towards sustainable agriculture and reducing reliance on chemical fertilizers[23]. These increases can be explained by the role of *Azospirillum* in fixing atmospheric nitrogen in the soil and enhancing its availability to plants, which improves vegetative growth and photosynthesis[24].In addition, these bacteria produce natural plant growth regulators such as auxins and cytokinins, which contribute to the activation of cell division and increase branching and biomass Secondly: The effect of *Azospirillum* on active compounds These results support the hypothesis that active soil microorganisms, such as *Azospirillum*, stimulate metabolic responses in the plant that lead to the accumulation of secondary compounds with medical and industrial value, such as antioxidants[25].

Conclusion

The study demonstrated the effectiveness of biofertilization using *Azospirillum* and banana peels in enhancing the growth, productivity, and effective chemical content of sunflower plants. It is recommended to use this type of fertilization as part of integrated plant nutrition management programs, especially in sustainable and organic farming systems.

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