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The Effect of Adding Spent Mushroom, Biological and Mineral Fertilizers on Some Plant Growth Indicators

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Abstract

This field experiment was conducted to examine the effect of Spent Mushroom, biological and mineral fertilizers and their effect on some plant indicators in a field planted with Zea Mays L. at harvesting. The results of the experiment indicated that the use of Spent Mushroom, the application of mineral fertilizer at different levels and both types of biofertilizer, which Mentioned like (O, B and M) resulted in a significant increase in Some plant growth indicators. The highest average plant height was 297.3 (cm) for the treatment (O1B1M3), for dry weight 11.97 (mg ha-1) for treatment (O1B2M3), the grain yield was 11.32 (mg ha-1) for the treatment (O1B1M3), the biological yield was 26.37 (mg ha-1) for the treatment (O1B1M3) and the chlorophyll content was 114.30 (SPAD). Compared to the comparison treatment. It can be concluded from the above that the use of Spent Mushroom farm waste as organic fertilizer, as well as biological of both types and mineral fertilizers, and despite the varying results of the fertilizers used, they led to plant growth indicators which is reflected in their quality.

Keywords:

Bacillus mehaterium, chromobacterium violaceum, spent mushroom, zea Mays L. growth indicators.

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Introduction

Crop production faces challenges due to the increase in population, climate change, as well as increased demand for production, but large parts of the soil produced are used for other requirements due to increasing urbanization, which results in high pressure to reduce arable land (Mustapha et al., 2017; Veerasamy & Fredrik, 2023). Most fertile soils in urban environments are converted to other uses. Crop production cannot be increased beyond this, due to poor agricultural management and farmers' use of artificial fertilizers more than recommended, and this has led to a negative impact on human health and soil health and to an increase in economic costs (Bhat et al., 2017; Veerasamy & Fredrik, 2023; Mohammed & Hasan, 2022).

Hence, this study was launched to contribute to the reduce of problems that the country suffers from by adopting sustainable, safe and renewable agriculture (Paul et al., 2020). Therefore, modern methods of soil and crop management must be followed, and among these methods is the addition of various organic and biological fertilizers (Balavandi, 2017). Utilizing Mushroom waste is one of the used and promising technologies that contributes as a nutrient-rich (Al-Hilfy & Al-Temimi, 2017) organic fertilizer, including carbon and nitrogen, which is an important indicator of the availability of nitrogen as an organic fertilizer (Peksem et al., 2011).

Recently, interest in the production of food fungi has increased globally due to their high nutritional value, especially their containment of most of the essential amino acids that are important in human nutrition. It also contains zinc, iron, potassium, copper and sodium (USDA, 2006; Nejad et al., 2010), As Mushroom waste retains most of the nutrients during the Mushroom production cycles, and the remains of the cultivation media after the end of the Mushroom cultivation cycle are called Mushroom waste or Spent Mushroom media (Landschoot & McNitt, 2013; Acar & Yüksekdağ, 2023).

Biofertilizers are natural materials that contain a compatible group of beneficial microorganisms, and they can be defined as biological fertilizers that are added to the soil to provide the plant with its nutritional needs. Through its vital activities, it transforms unready nutrients into a ready form that can be absorbed by the plant. Some of these organisms work to fix atmospheric nitrogen in its symbiotic and non-symbiotic forms and reduce the use of chemical fertilizers (Javid et al., 2011; Mohammed & Hasan, 2023).

Corn is used in the production of Corn oil, starch, Corn flour, in addition to being used as animal feed and used in many industries and fields of energy and biofuel production. Corn is a rich source not only of carbohydrates and calories, but also of many vitamins, minerals, and is rich in dietary fiber that is useful in promoting the health of the digestive system. To prevent some of its problems, in addition to antioxidants, which may play a role in preventing some diseases and some types of cancer (Mahmoud et al., 2018). Therefore, this research aimed to study the effect of Spent Mushroom residues on some Zea maize L. growth indicators.

Materials and Methods

A field experiment was conducted at a College of Agriculture in Baghdad, Iraq. The experiment was conducted in soil whose chemical, physical and biological properties are shown in Table (1). The purpose of this study was to understand the extent of the effect of organic fertilizerSpent mushroom farm waste (O0: control and O1: Spent mushroom), biofertilizer of both types (B0: control and B1: Bacillus megaterium and B2: Chromobacterium violaceum) and mineral fertilizer at different levels (M0: control and M1: 50% of recommendation and M2:75% of recomm. and M3: 100% of recomm.) on the growth indicators of corn (Zea mays L.) during the flowering and harvest periods of the spring season 2022-2023.

Table 1. Before planting the study soil had many physical chemical properties

Adjective	Value	Unit	source
pH $_{1:1}$	7.34	-	(Page et al., 1982)
EC $_{1:1}$	1.50	ds m^{-1}	
Organic matter	12.15	g kg^{-1}	
CEC	20.24	Centi mole $^{+}$ kg^{-1}	
Available Nitrogen	35.00	g kg^{-1}	(Salem & Ali, 2017)
Available phosphorus	8.80	g kg^{-1}	
Available Potassium	121.00	g kg^{-1}	
Available Zinc	3.06	g kg^{-1}	(Hassan et al., 2013)
Total bacteria	$14*10^6$	Cfu g^{-1} soil	(Black, 1965_b)
Total fungi	$6.3*10^3$	Cfu g^{-1} soil	
Soil Texture	Silty Clay Loam	-	(Black, 1965a)

The field was divided into three sectors and each sector contains 24 experimental units. Each experimental unit consists of three lines, each measuring 3 meters in length. The distance between the lines is 75 centimeters, and the spacing between individual (AL-Joburi, 2016) plants is 25 centimeters. The area of each experimental unit is 5 square meters, with a 1-meter gap separating different experimental units. The treatments were assigned randomly within a single sector (Al-Sahuki, 1990).

The growth indices of corn were estimated as reported in (Al-Sahouki, 1990; Salem and Ali, 2017; Kakhia, 2006).

Results

Corn (Zea maize L.) plant Indicators

- ***Plant Chlorophyll Content (SPAD unit)***

Table 2 showed the effect of Spent Mushroom farm waste fertilizer, biofertilizer, and mineral fertilizer on the plant's chlorophyll content. The highest average for adding Spent Mushroom farm waste fertilizer was 109.69 (SPAD), an increase of 13.08% compared to the comparison treatment, which was 97 (SPAD) at the flowering time. Adding biofertilizer didn't give any significant effect on the flowering period on the chlorophyll content for plant.

Table 2 showed that the highest average for adding mineral fertilizer was 106.59 (SPAD) in the (M_3) treatment, which didn't differ significantly from the (M_1) and (M_2) treatments, with an increase of 9.66% compared to the comparison treatment, which amounted to 97.20 (SPAD) at the flowering time.

Table 2 also showed that all binary interactions of added fertilizers (organic, bio and mineral) significantly affected the plant's chlorophyll content. The interaction of Spent Mushroom waste and biofertilizer achieved the highest chlorophyll content in the treatment (O_1B_0), And represented with the second level of organic fertilizer and the comparison treatment amounted to112.34 (SPAD), which didn't differ from the treatment (O_1B_2) which was 110.73, with an increase of 21.84% compared to the comparison treatment (O_0B_0), which was 92.20 (SPAD). The highest content of chlorophyll was achieved in the treatment (O_1M_3) And represented with the second level of organic fertilizer and the third level of mineral fertilizers, which amounted to 112.95 (SPAD), with an increase rate of 21.63% compared to the comparison treatment (O_0B_0), which amounted to 92.86 (SPAD) and didn't differ significantly from the treatment (O_1M_1) and (O_1M_2). The interaction between biofertilizer and mineral fertilizer achieved the highest chlorophyll content, reaching 106.98 (SPAD) in the treatment (B_2M_3), And represented with the second level of biofertilizer and the third level of mineral fertilizers with an increase rate of 12.56% compared to the comparison treatment (O_0B_0), which amounted to 95.04 (SPAD), and which didn't differ significantly from the treatment (B_2M_1), (B_2M_2), (B_1M_1), (B_1M_2), (B_1M_3), (B_0M_1), (B_0M_2) and (B_0M_3).

It is noted from Table 2 that there is a significant three-way interaction. The treatment ($O_1B_2M_3$) achieved the highest rate of plant chlorophyll content, which amounted to 114.30 (SPAD), which didn't differ significantly from the treatment ($O_1B_2M_1$), ($O_1B_2M_2$), ($O_1B_1M_3$), ($O_1B_1M_2$), and ($O_1B_1M_1$), with an increase rate of 26.43% compared to the comparison treatment ($O_0B_0M_0$) which amounted 90.40 (SPAD).

Table 2. Effect of spent mushroom farm waste fertilizer biofertilizer and Mineral fertilizer on the chlorophyll content in the leaves of Corn plants (SPAD unit)

45 days after Planting							
Organic Fertilizers (O)	**Biofertilizers (B)**	**Mineral Fertilizers (M)**				O * B	
		M_0	M_1	M_2	M_3		
O_0	B_0	90.40	90.78	91.85	95.75	92.20	
	B_1	91.63	100.55	105.20	105.28	100.67	
	B_2	96.55	97.80	98.53	99.66	98.14	
O_1	B_0	99.68	117.78	115.13	116.77	112.34	
	B_1	103.23	106.42	106.60	107.79	106.01	
	B_2	101.71	112.67	114.24	114.30	110.73	
L.S.D $_{0.05}$ (O*B*M)		4.929*				L.S.D $_{0.05}$ (O*B)	9.858*
Organic Fertilizers (O)		**M*O**				**Mean (O)**	
O_0		92.86	96.38	98.53	100.23	97.00	
O_1		101.54	112.29	111.99	112.95	109.69	
L.S.D $_{0.05}$ (M*O)		5.691*				L.S.D $_{0.05}$ (O)	2.846*
Biofertilizers (B)		M*B				Mean (B)	
B_0		95.04	104.28	103.49	106.26	102.27	
B_1		97.43	103.48	105.90	106.54	103.34	
B_2		99.13	105.23	106.39	106.98	104.43	
L.S.D $_{0.05}$ (M*B)		6.970*				L.S.D $_{0.05}$ (B)	N.S
Mean (M)		97.20	104.33	105.26	106.59		
L.S.D $_{0.05}$ (M)		4.024*					

(O0: Without organic fertilizer, O1: Spent Mushroom farm waste fertilizer, Bo: Without adding biological fertilizer, B1: Bacillus Mrgaterium, B2: Chromobacterium violaceum, M0: Without adding mineral fertilizer, M1: Recommendation of 50% of mineral fertilizer, M2: Recommendation 75% of mineral fertilizer, M3: Recommendation 100% of mineral fertilizer)

- ***Plant Height (cm)***

Table (3) showed the effect of Spent Mushroom farm waste fertilizer, Biofertilizer, and Mineral fertilizer on plant height, and the height value for adding Spent Mushroom waste fertilizer was 241.2 (cm), an increase of 6.63% compared to the comparison treatment, which amounted to 226.2 (cm) at harvest.

Table (3) showed the effect of Spent Mushroom farm waste fertilizer, biofertilizer, and mineral fertilizer on plant height. The treatment of adding biofertilizer (B_1) was superior in achieving the highest value in the plant height index over biofertilizer (B_2), which reached 255 (cm), an increase of 15.43% compared to the comparison treatment, which amounted to 220.9 (cm) at the harvest time.

Table 3. Effect of spent mushroom farm waste fertilizer, biofertilizer, and mineral fertilizer on the height of Corn plants (cm)

110 days after Planting							
Organic Fertilizers (O)	**Biofertilizers (B)**	**Mineral Fertilizers (M)**				O * B	
		M_0	M_1	M_2	M_3		
O_0	B_0	204.0	218.7	222.7	226.7	218.0	
	B_1	221.0	235.0	242.7	250.3	237.3	
	B_2	219.0	220.7	225.0	228.3	223.3	
O_1	B_0	211.7	222.7	226.0	226.7	221.8	
	B_1	215.7	282.3	296.0	297.3	272.8	
	B_2	218.7	224.0	229.3	244.7	229.2	
L.S.D $_{0.05}$ (O*B*M)		14.73*				L.S.D $_{0.05}$ (O*B)	7.36*
Organic Fertilizers (O)		**M*O**				**Mean (O)**	
O_0		214.7	224.8	229.1	235.1	226.2	
O_1		215.3	243.0	250.4	256.2	241.2	
L.S.D $_{0.05}$ (M*O)		8.50*				L.S.D $_{0.05}$ (O)	4.25*
Biofertilizers (B)		M*B				Mean (B)	
B_0		207.8	220.7	224.3	226.7	220.9	
B_1		218.3	258.7	269.3	273.8	255.0	
B_2		218.8	222.3	227.2	236.5	225.2	
L.S.D $_{0.05}$ (M*B)		10.41*				L.S.D $_{0.05}$ (B)	5.21*
Mean (M)		215.0	233.9	240.9	245.7		
L.S.D $_{0.05}$ (M)		6.01*					

Table 3 also showed that the effect of Spent Mushroom farm waste fertilizer, biofertilizer, and mineral fertilizer on plant height. The highest average addition of mineral fertilizer was 245.7 (cm) in the treatment (M_3), which didnt differ significantly from the treatment (M_2), with an increase of 14.27% compared to the comparison treatment, which amounted to 215 (cm) at harvest.

Table 3 also showed the significant bilateral interactions in plant height. The interaction of Spent Mushroom waste and biofertilizer achieved the highest increase in the treatment (O_1B_1), And represented with the second level of organic fertilizer and the second level of biofertilizers which amounted to 272.8 (cm), with an increase of 25.13% compared to the comparison treatment (O_0B_0), which amounted to 218 (cm). and a value amounted to of 256.2 (cm) in the treatment (O_1M_3), And represented with the second level of organic fertilizer and the third level of mineral fertilizers which didn't differ significantly from the treatment (O_1M_2), with an increase rate of 19.32% compared to the comparison treatment of 214.7. (cm) at treatment (O_0M_0). And the highest reached 273.8 cm in the treatment (B_1M_3), And represented with the first level of biofertilizer and the third level of mineral fertilizers which didn't differ significantly from the treatment (B_1M_2), and the lowest height reached 207.8 in the treatment (B_0M_0), with an increase rate of 31.76% at the harvest time.

It is noted from Tables 3 the triple interactions and their effect on plant height. The treatment ($O_1B_1M_3$) achieved the highest rate of plant height, reaching 297.3 (cm), which didn't differ significantly from the treatments ($O_1B_1M_1$) and ($O_1B_1M_2$), with an increase rate of 45.73% over the comparison treatment, which amounted to 204 (cm).

- ***Dry Weight (mega gram ha-1)***

Table 4 showed the effect of Spent Mushroom farm waste fertilizer, biofertilizer and mineral fertilizer on dry weight, and the highest dry weight for adding Spent Mushroom waste fertilizer (O_1) was 10.14 (Mg ha^{-1}), with an increase of 24.26% compared to the comparison treatment, which amounted to 8.16 (Mg ha^{-1}). At harvest.

As Table 4 showed the highest average of biofertilizer addition was in treatment (B_2) and amounted to 9.83 (Mg ha^{-1}), with an increase of 21.96% compared to the comparison treatment, which amounted to 8.06 (Mg ha^{-1}) at the harvest time.

Table 4 showed that the highest average of mineral fertilizer addition was 9.82 (Mg ha^{-1}) at treatment (M_3), an increase of 15.93% compared to the comparison treatment, which amounted to 8.47 (Mg ha^{-1}) at the harvest time.

Table 4. Effect of spent mushroom farm waste fertilizer biofertilizer and Mineral fertilizer on the dry weight of Corn plants (Mg ha-1)

110 days after Planting							
Organic Fertilizers (O)	**Biofertilizers (B)**	**Mineral Fertilizers (M)**				O * B	
		M_0	**M_1**	**M_2**	**M_3**		
O_0	B_0	6.26	7.12	7.81	7.92	7.28	
	B_1	7.86	8.18	8.34	8.40	8.20	
	B_2	8.44	8.71	9.40	9.45	9.00	
O_1	B_0	8.00	8.27	8.88	10.28	8.85	
	B_1	10.80	10.82	10.89	11.08	10.90	
	B_2	9.48	10.18	11.22	11.79	10.67	
L.S.D $_{0.05}$ (O*B*M)		0.750*				L.S.D $_{0.05}$ (O*B)	0.375*
Organic Fertilizers (O)		**M*O**				**Mean (O)**	
O_0		7.52	8.00	8.52	8.59	8.16	
O_1		9.42	9.76	10.33	11.05	10.14	
L.S.D $_{0.05}$ (M*O)		0.433*				L.S.D $_{0.05}$ (O)	0.217*
Biofertilizers (B)		M*B				Mean (B)	
B_0		7.11	7.69	8.35	9.10	8.06	
B_1		9.33	9.50	9.61	9.74	9.55	
B_2		8.96	9.44	10.31	10.62	9.83	
L.S.D $_{0.05}$ (M*B)		0.531*				L.S.D $_{0.05}$ (B)	0.265*
Mean (M)		8.47	8.88	9.42	9.82		
L.S.D $_{0.05}$ (M)		0.306*					

Table 4 also showed that the binary interaction was a significant for dry weight, and the highest rate amounted to 10.90 (Mg ha-1) the treatment (O1B1), And represented with the first level of organic fertilizer and the second level of biofertilizers with an increase rate of 49.72% compared to the comparison treatment (O0B0), which amounted to 7.28 (Mg ha-1). And the highest dry weight of the plant was 11.05 (Mg ha-1) in the (O1M3) treatment and represented with the second level of organic fertilizer and the third level of mineral fertilizers, which didn't differ significantly from the (O1M2) treatment, with an increase rate of 46.94%. Compared to the comparison treatment (O0M0), which amounts to 7.52 (Mg ha-1). And that the highest dry weight reached 10.62 (Mg ha-1) in the (B2M3) treatment, which didn't differ significantly from the (B2M2) treatment and represented with the second level of biofertilizer and the Second level of mineral fertilizers with an increase rate of 49.36% Compared to the comparison treatment (O0M0) of 7.11 (Mg ha-1) at the harvest time.

It is noted from Table (4) that the triple interactions are significant for Mushroom waste (O), biofertilizer (B) and mineral fertilizer (M), and the treatment (O1B2M3) achieved the highest rate of dry plant weight, reaching 11.79 (Mg ha-1), which didn't differ significantly from (O1B2M2) and (O1B1M3), with an increase rate of 88.33% compared to the comparison treatment of 6.26 (Mg ha-1).

- ***Grain Yield (mega gram ha-1)***

Table 5 showed the effect of Spent Mushroom farm waste fertilizer, biofertilizer, and mineral fertilizer on grain yield, and the highest average for adding Spent Mushroom waste fertilizer was 8.55 (Mg ha^{-1}), an increase of 53.77% compared to the comparison treatment, which amounted to 5.56 (Mg ha^{-1}) at the harvest time.

Table 5 also showed that the highest average for adding biofertilizer was for the fertilizer treatment (B_1), which amounted to 7.54 (Mg ha^{-1}), an increase of 17.99% compared to the comparison treatment, which amounted to 6.39 (Mg ha^{-1}) at the harvest time.

Table 5 showed that adding mineral fertilizer (M) had a significant effect on increasing grain yield, and this was achieved in the treatment (M_3), with an increase rate of 30.29% compared to the comparison treatment, which amounted to 6.14 (Mg ha^{-1}) at the harvest time.

Table 5 also showed that all binary interactions of added fertilizers (organic, bio-mineral) were significant, as Spent Mushroom residues (O) and bio-fertilizers (B) achieved the highest grain yield when treated (O_1B_1), And represented with the second level of organic fertilizer and the Second level of biofertilizers, which amounting to 9.13 (Mg ha^{-1}), with a percentage increase 80.07% compared to the comparison treatment (O_0B_0), which amounted to 5.07 (Mg ha^{-1}) and didn't differ significantly from the treatment (O_1B_2). And reaching 9.72 (Mg ha^{-1}) in the treatment (O_1M_3), And represented with the second level of organic fertilizer and the third level of mineral fertilizers with an increase rate of 94.4% compared to the comparison treatment (O_0M_0) which amounted to 5 (Mg ha^{-1}).And reaching 8.93 (Mg ha^{-1}) in the treatment (B_1M_3), And represented with the second level of biofertilizer and the third level of mineral fertilizers with an increase rate of 55.03% compared to the comparison treatment (B_0M_0), which amounted to 5.76 (Mg ha^{-1}).

Table 5. Effect of spent mushroom farm waste fertilizer biofertilizer and mineral fertilizer on the total grain yield of Corn plants (Mg ha^{-1})

110 days after Planting							
Organic Fertilizers (O)	**Biofertilizers (B)**	**Mineral Fertilizers (M)**				**O * B**	
		M_0	**M_1**	**M_2**	**M_3**		
O_0	B_0	4.66	4.77	5.25	5.58	5.07	
	B_1	5.12	5.49	6.68	6.54	5.95	
	B_2	5.21	5.19	5.60	6.71	5.68	
O_1	B_0	6.85	7.85	7.92	8.26	7.72	
	B_1	7.26	8.15	9.80	11.32	9.13	
	B_2	7.71	8.40	9.45	9.59	8.79	
L.S.D $_{0.05}$ (O*B*M)		0.815*				L.S.D $_{0.05}$ (O*B)	0.407*
Organic Fertilizers (O)		M*O				Mean (O)	
O_0		5.00	5.15	5.83	6.28	5.56	
O_1		7.28	8.13	9.05	9.72	8.55	
L.S.D $_{0.05}$ (M*O)		0.470*				L.S.D $_{0.05}$ (O)	0.235*
Biofertilizers (B)		M*B				Mean (B)	
B_0		5.76	6.31	6.58	6.92	6.39	
B_1		6.19	6.82	8.22	8.93	7.54	
B_2		6.46	6.79	7.53	8.15	7.23	
L.S.D $_{0.05}$ (M*B)		0.576*				L.S.D $_{0.05}$ (B)	0.288*
Mean (M)		6.14	6.64	7.44	8.00		
L.S.D $_{0.05}$ (M)		0.333*					

It is noted from Tables (5) that there are significant triple interactions in grain yield. The treatment ($O_1B_1M_3$) achieved the highest rate of grain yield, which amounted to 11.32 (Mg ha^{-1}), with an increase of 142.91% compared to the comparison treatment (O0B0), which amounted to 4.66 (Mg ha^{-1}).

- ***Biological Yield (Mg ha-1)***

Table 6 showed the effect of Spent Mushroom farm waste fertilizer, biofertilizer, and mineral fertilizer on the biological yield, and the highest average for adding Spent Mushroom waste fertilizer was 24.56 (Mg ha^{-1}), with an increase of 14.92% compared to the comparison treatment, which amounted to 21.37 (Mg ha^{-1}). At the harvest time.

Table 6. Effect of spent mushroom farm waste fertilizer biofertilizer and mineral fertilizer on the biological yield of Corn plants (Mg ha-1)

110 days after Planting							
Organic Fertilizers (O)	**Biofertilizers (B)**	**Mineral Fertilizers (M)**				**O * B**	
		M_0	**M_1**	**M_2**	**M_3**		
O_0	B_0	17.79	19.43	20.28	21.47	19.74	
	B_1	20.47	21.36	23.64	24.72	22.55	
	B_2	20.75	21.83	22.35	22.37	21.83	
O_1	B_0	22.24	23.54	24.59	24.76	23.78	
	B_1	24.12	25.03	25.23	26.37	25.19	
	B_2	23.61	24.73	25.11	25.35	24.70	
L.S.D $_{0.05}$ (O*B*M)		2.969*				L.S.D $_{0.05}$ (O*B)	1.484*
Organic Fertilizers (O)		M*O				Mean (O)	
O_0		19.67	20.87	22.09	22.85	21.37	
O_1		23.32	24.44	24.98	25.49	24.56	
L.S.D $_{0.05}$ (M*O)		1.714*				L.S.D $_{0.05}$ (O)	0.857*
Biofertilizers (B)		M*B				Mean (B)	
B_0		20.01	21.48	22.44	23.11	21.76	
B_1		22.30	23.19	24.43	25.54	23.87	
B_2		22.18	23.28	23.73	23.86	23.26	
L.S.D $_{0.05}$ (M*B)		2.099*				L.S.D $_{0.05}$ (B)	1.050*
Mean (M)		21.50	22.65	23.53	24.17		
L.S.D $_{0.05}$ (M)		1.212*					

Table 6 showed that the highest average addition of biofertilizer was in treatment (B_1) amounted to 23.87 (Mg ha^{-1}), with an increase of 9.69% compared to the comparison treatment, which amounted to 21.76 (Mg ha^{-1}) at the harvest time.

While the highest average for adding mineral fertilizer (Table 6) was 24.17 (Mg ha^{-1}) at treatment (M_3), with an increase of 12.41% compared to the comparison treatment, which amounted to 21.50 (Mg ha^{-1}) at the harvest time.

Table 6 showed that all binary interactions of added fertilizers are significantly affected on biological yield indicates. The interaction of Spent Mushroom waste and biofertilizer achieved the highest biological yield in the treatment (O_1B_1), And represented with the second level of organic fertilizer and the second level of bio fertilizers amounting to 25.19 (Mg ha^{-1}), with an increase rate of 27.60%. Compared to the comparison treatment (O_0B_0), which amounted to 19.74 (Mg ha^{-1}) and didn't differ from the treatment (O_1B_2). And reaching 25.49 (Mg ha^{-1}) in the treatment (O_1M_3), And represented with the second level of organic fertilizer and the third level of mineral fertilizers with an increase rate of 29.58% compared to the comparison treatment (O_0B_0), which amounted to 19.67 (Mg ha^{-1}), which didn't differ significantly from the (O_1M_3), (O_1M_1) and (O_1M_2). And the highest biological yield achieved to 25.54 (Mg ha^{-1}) in the treatment (B_1M_3), And represented with the second level of biofertilizer and the third level of mineral fertilizers which didn't differ significantly from the treatment (B_1M_2), (B_2M_2) and (B_2M_3), with an increase rate of 27.63% when compared with the lowest average, which is 20.01 (Mg ha^{-1}) for treatment (O_0B_0) at the harvest time.

It is noted from Table (6) that the triple interactions are significant and the treatment ($O_1B_1M_3$) achieved the highest rate of biological yield, amounting to 26.37 (Mg ha^{-1}), which didn't differ significantly from the treatment ($O_1B_1M_0$), ($O_1B_1M_1$), ($O_1B_2M_0$), ($O_1B_1M_3$), ($O_1B_1M_3$), ($O_1B_2M_1$), ($O_1B_2M_2$) and ($O_1B_2M_3$), with an increase rate of 48.22% compared to the comparison treatment ($O_0B_0M_0$), which amounts to 17.79 (Mg ha^{-1}).

Discussion

Tables (2, 3, 4, 5, and 6) shows that the adding organic fertilizers (Spent Mushroom farm waste) to the soil caused an increase in Zea maize L. plant growth indicators (plant height, dry weight, grain yield, and biological yield and chlorophyll), and the reason may be due to its high content of nutrients necessary for plant growth, which has a positive impact on the characteristics and indicators of plant growth(Wang et al., 2021). This result is in line with (Alves et al., 2022), who concluded that the use of spent Mushroom culture waste (SMS) improves maize growth indicators. The use of organic fertilizers has significantly enhanced the growth and productivity of corn plants, both under normal irrigation and during severe drought. Additionally, these fertilizers improve the quality of corn by enhancing nutrient absorption (Shah et al., 2023).

As Tables (2, 3, 4, 5, and 6) shows that the adding of biofertilizers to the soil increased the zea maize *L.* plant growth indicators (plant height, dry weight, grain yield and biological yield), but the biofertilizers had no effect on the character of chlorophyll. And the (B_1) excelled in the indicators of plant growth, because it's one of the types of bacteria active in preparing the important element phosphorus, which plays a direct role in influencing most of the physiological processes that take place within the plant. It also encourages the absorption of Nitrogen, which is important in building cell membranes such as the plasma membrane, mitochondria, chloroplast, and vacuole membrane. Phosphorus is also involved in the formation of some rich compounds. With energy that acts as cofactors for enzymes in plants (AL-Joburi, 2016), The biofertilizer treatment (B2) excelled in indicators (dry weight), Because it is a potassium-dissolving bacterium, it has many effects on plants, including its effect on the rate of carbon metabolism. Fertilization with potassium also improves the quality of crops, as it works to increase the weight of grains (Sharma et al., 2005). The use of biofertilizers significantly enhances the diversity of microorganisms in the soil. They improve plants' absorption of essential nutrients like nitrogen (N), phosphorus (P), and potassium (K), thereby increasing productivity and quality. Additionally, biofertilizers compete with pathogens and boost plants' resistance to stress, leading to improved disease resistance. This underscores the potential and importance of biofertilizers in promoting sustainable agricultural development (Wei et al., 2024). These results were consistent with (Mohammed & Hassan, 2023; Hassan, 2013) and Mohammed & Hasan, 2022).

Tables (2, 3, 4, 5, and 6) shows that adding mineral fertilizers to the soil increased the growth indicators of Corn plants. The reason for this may be that adding readily available fertilizers to the soil allows plants to absorb nutrients directly. Additionally, potassium plays a crucial role during the grain formation stage. It activates many enzymes, contributes to the synthesis of amino acids and proteins, and aids in the transportation of carbohydrates. This process ultimately enhances the efficiency of carbon metabolism. Then it leads to an increase in chlorophyll and grain yield or the increase is due to the role of potassium in increasing the number of grains in the row, which was reflected positively on grain yield (Najad, 2010). These results were consistent with (Al-Halafi & Al-Tamimi, 2017). And the results of the study (Faraj, 2007) showed that adding the full fertilizer recommendation to ground fertilization gave the highest weight to grain yield, biological yield, weight of a thousand grains and plant height compared to all other ground fertilization treatments for corm plant.

Tables (2, 3, 4, 5, and 6) shows that all binary interactions were significant in their effect on the studied indicates. This may be due to the role of organic fertilizers in reducing the degree of soil reaction (pH) to the rhizosphere zone and because of this, most of the soil nutrients are prepared and are considered as an indicator of soil health, fertility and plant nutrition factors from the soil, such as total nitrogen (TN), available phosphorus (P) and micronutrients (Fe^2, Cu, Zn) and soil organic carbon (Hafez et al., 2021). And this is consistent with the study of (Ewais et al., 2015) which indicated that N, P and K fertilizers + compost (organic fertilizer) led to a significant increase in all studied parameters of corn plants. The results of the study (Mahmood et al., 2010) showed that the effect of organic and mineral fertilizers and foliar spraying with humic acid on the growth and yield of corn (Zea mays L.) was significant in all studied plant growth indicators. And the use of biofertilizers also leads to high production in corn grains when combined with two doses of the recommended nitrogenous mineral fertilizer 210 (kg N ha^{-1}), and this is consistent with what was stated in the study (Mohammed & Alkobaisy, 2024) that the interaction between biofertilizer and mineral fertilizer increased the growth indicators of the corn plant.

Tables (2, 3, 4, 5, and 6) indicate that the triple interaction between bio-organic and mineral fertilizers added to the soil increased the growth indicators of Corn plants. This is due to the interaction between the three fertilizers increasing the availability of most nutrients in the soil. As the Mushroom cultivation waste, which contains a variety of microscopic soil organisms, which promotes the acceleration of decomposition processes, the availability of nutrients, and the decomposition of organic materials, results in sugar aggregates that are a raw material for feeding the microorganisms and providing them with the energy necessary to carry out their activities through mineralization processes as well as the formation of soil aggregates. Also, the different levels of mineral fertilizers increased the readiness of nutrients in the soil, which reflected positively on some plant growth indicators and increased the activity of microorganisms in the soil (Webster & Buckerfield, 2003).

Conclusion

The study demonstrates that integrating spent mushroom, biofertilizers, and mineral fertilizers significantly improves the safety of plant growth indicators. The combination of spent mushroom at 8 Mg ha^{-1}, biofertilizer (*Bacillus megaterium*), and 100% of the recommended NPK dose ($O_0B_1M_3$) achieved the highest growth indicators at both flowering and maturity stages. This approach improved soil fertility by enhancing organic matter content, microbial biomass, and diversity while increasing the bioavailability of nitrogen and phosphorus. Furthermore, it promoted sustainable fertilization by reducing reliance on mineral fertilizers Enhancing plant growth indicators and improving quality. The findings highlight the potential of mixed fertilizer strategies for sustainable soil management, improved crop productivity, and environmental conservation.

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