Journal homepage
www.ajas.uoanbar.edu.iq
Anbar Journal of Agricultural Sciences
(University of Anbar – College of Agriculture)

EFFECT OF MUSHROOM RESIDUES, DATE RESIDUES AND BACTERIAL INOCULUM ON RHIZOSPHERIC SOIL PROPERTIES OF BROCCOLI PLANT

J. A. Al-Obidiy **H. J. Mohammed** **J. S. Alkobaisy ***

College of Agriculture, University of Anbar

***Correspondence to:** J. S. Alkobaisy, Department of Soil Science and Water Resources, College of Agriculture, University of Anbar, Iraq.
Email: ag.jamal.saleh@uoanbar.edu.iq

Article info

Received: 2023-09-07
Accepted: 2023-11-12
Published: 2025-06-30

DOI-Crossref:
10.32649/ajas.2025.188288

Cite as:
Al-Obidiy, J. A., Mohammed, H. J., and Alkobaisy, J. S. (2025). Effect of mushroom residues, date residues and bacterial inoculum on rhizospheric soil properties of broccoli plant. Anbar Journal of Agricultural Sciences, 23(1): 509-527.

Abstract

A field experiment was conducted in one of College of Agriculture fields, University of Anbar, Ramadi, Iraq, for autumn 2022-2023 to study the effect of each white fungus residue, date residues, and biofertilizer on some soil properties. The experiment included three factors: white mushroom residues at three levels of 0, 10, and 20 tons ha^{-1}, which was symbolized by (M0, M1, M2), and date waste in three levels of 0, 10, and 20 tons ha^{-1}. It was symbolized by (D0, D1, D2) and the bacterial inoculum consisting of (*Azotobacter chroococcum*+*Pseudomonas putida*) in two levels without adding and symbolizing, and it was symbolized (B0) and adding the inoculate and symbolizing it with (B1). A factorial experiment with three replications was designed with a randomized complete block design (RCBD). Broccoli seedlings were planted on 10/7/2022 after conducting land and crop service operations. The crop was harvested on 3/3/2023, and soil samples were analyzed before and after planting. The results of the statistical analysis showed that the triple interference with the highest levels (M2D2B1) showed a significant increase in the content of organic matter, microbial density, and concentrations of nitrogen, phosphorus, and potassium available in the soil, which recorded 12.15 g kg $^{-1}$ and 3.81710×cfu gm^{-1} soil and 154.40, 18.07, 287.54 mg kg^{-1}, the single treatments of white fungus residue, date residue, and bacterial inoculum recorded a significant decrease in each of the bulk density and saturated water conductivity, and a significant increase in the total porosity of the soil, which recorded bulk density rates of 1.30, 1.30 and 1.25 $Mg.m^{-3}$, respectively. The saturated water conductivity rates were 2.48, 2.55, and 2.56 cm h^{-1}, respectively, and the total porosity rates were 51.32, 51.26, and 51.12%, respectively. The comparison treatment without additions (M0D0B0) showed the lowest rates for all the studied soil characteristics, namely organic matter content, microbial density, concentrations of nitrogen, phosphorus, and potassium available in the soil, bulk density, saturated water conductivity, and total soil porosity, as it recorded 2.10 g kg $^{-1}$, 0.54 710×cfu. gm^{-1} soil, 32.13 mg kg^{-1}, 9.55 mg kg^{-1}, 206.55 mg kg^{-1}, 1.35 Mg. m^{-3}, 2.75 cm h^{-1}, 47.26%, respectively.

Keywords: Spent mushroom, Dates residues, Bio-Fertilizer, Organic residues.

تأثير مخلفات الفطر الابيض ومخلفات التمور واللقاح البكتيري في صفات تربة الرايزوسفير لنبات البروكلي

ثيان عادل العبيدي حذيفة جاسم محمد جمال صالح الكبيسي *

كلية الزراعة، جامعة الانبار

***المراسلة الى:** جمال صالح حمود الكبيسي، قسم علوم التربة والموارد المائية، كلية الزراعة، جامعة الانبار ، العراق.

البريد الالكتروني: ag.jamal.saleh@uoanbar.edu.iq

الخلاصة

اجريت تجربة حقلية في احد الحقول التابعة لكلية الزراعة، جامعة الانبار في الرمادي للموسم الخريفي 2022 – 2023 لدراسة تاثير كل من مخلفات الفطر الابيض ومخلفات التمور والمخصبات الحيوية على بعض صفات التربة ، ضمت التجربة ثلاث عوامل هي مخلفات الفطر الابيض بثلاث مستويات (0، 10، 20 طن هكتار$^{-1}$) ورمز لها بالرموز (M0، M1،M2)، مخلفات التمور بثلاث مستويات (0، 10، 20 طن هكتار$^{-1}$) ورمز لها بالرموز (D0، D1 ،D2) واللقاح البكتيري المتكون من (*Azotobacter chroococcum Pseudomonas putida*) بمستويين بدون أضافة لقاح ورمز له بالرمز(B0) وإضافة اللقاح ورمز له بالرمز (B1). صممت تجربة عاملية بتصميم القطاعات العشوائية الكاملة (RCBD) بثلاث مكررات. زرعت شتلات البروكلي بتاريخ

2022/10/7 بعد اجراء عمليات خدمة الارض والمحصول. تم جني المحصول بتاريخ 2023/3/3، حللت نماذج التربة قبل وبعد الزراعة. اظهرت نتائج التحليل الإحصائي ان التداخل الثلاثي بأعلى المستويات الاضافة من عوامل الدراسة الثلاث (M2D2B1)، قد اعطى زيادة معنوية في محتوى المادة العضوية والكثافة الميكروبية وتراكيز النتروجين والفسفور والبوتاسيوم الجاهزة في التربة التي سجلت 12.15 غم كغم$^{-1}$ و $3.81^{7}10$ ×cfu غم على التتابع. اما بالنسبة للمعاملات المفردة لكل من $^{-1}$ملغم كغم 287.54 ،18.69 ،154.40 تربة و$^{-1}$ مخلفات الفطر الابيض ومخلفات التمور واللقاح البكتيري سجلت إنخفاض معنوي في كل من الكثافة الظاهرية والايصالية المائية المشبعة وزيادة معنوية في المسامية الكلية للتربة بلغت معدلات الكثافة الظاهرية 1.25 ،1.24، بالتتابع ومعدلات %51.12، 51.26، 51.32 بالتتابع، ومعدلات المسامية الكلية $^{-3}$ ميكا غرام م 1.25 بالتتابع. اعطت معاملة المقارنة بدون إضافات $^{-1}$سم ساعة 2.56، 2.55، 2.48 الايصالية المائية المشبعة اقل المعدلات لكل صفات التربة المدروسة وهي محتوى المادة العضوية والكثافة الميكروبية وتراكيز (M0D0B0) النتروجين والفسفور والبوتاسيوم الجاهزة في التربة و الكثافة الظاهرية والايصالية المائية المشبعة والمسامية الكلية غمتربة $^{-1}$ cfu× 10^{7} 0.54، $^{-1}$غم كغم 2.10 للتربة اذ سجلت 32.13 ملغم كغم$^{-1}$، 9.55 ملغم كغم$^{-1}$، 206.55 ملغم كغم$^{-1}$، 1.35 ميكا غرام م$^{-3}$، 47.26% و 2.75 سم ساعة$^{-1}$ بالتتابع.

كلمات مفتاحية: مخلفات الفطر الأبيض، مخلفات التمر ، سماد حيوي، مخلفات عضوية.

Introduction

Due to the vast population increase in recent decades, the urgent need for food has dramatically increased plant consumption, so farmers have started to support plants with nutrients to get the best production through chemical fertilizers. However, their frequent use seriously affects human, animal, and environmental health. Recently, alternatives or supplements to mineral fertilizers have been used, such as organic fertilizers and biofertilizers, which are safe and less expensive. One of the organic materials that has proven its worth in this field is white mushroom waste (spent mushroom compost). It is the remains of materials used in mushroom cultivation after harvesting, and it is considered one of the modern organic fertilizers that work to improve the physical, chemical, fertility, and biological properties of the soil due to its content of essential major elements, some minor elements, microorganisms, and growth regulators (6, 24 and 30). There is another type of organic material that can be used as organic fertilizer in agriculture, which is molasses factory waste (date waste), which is the remaining material from the molasses industry (the remainder of date fruits and date pits), which contains insoluble fibers consisting of cellulose, hemicellulose, lignin, and lignocellulose. Enzymes' fermentation transforms these materials into soluble compounds (1 and 2).

Using date waste significantly increased plant growth, yield, and leaf chlorophyll content (7 and 20). Date waste increases the percentage of NPK nutrients in the soil after decomposition by microorganisms present in the soil. Date waste improves soil structure by increasing the cohesive forces and bonding between particles and forming hydrophobic complexes that reduce soil structure breakdown during hydration (13 and

23). The bacterial inoculum contains beneficial microorganisms that secrete many enzymes, organic acids, growth regulators, and chelating materials, in addition to the ability of these organisms to dissolve phosphorus (P) and potassium (K) compounds and mineralize organic matter (OM) (31). Biofertilizers improve the soil's physical and chemical properties. They increase the soil's ability to retain water, reduce bulk density (BD), and increase soil aggregate stability (4, 21 and 31). Azotobacter bacteria can fix the atmospheric nitrogen (N) they need to build their bodies, and whatever is more than their need or when they decompose after their death is transferred to the soil, thus improving the soil properties (27). Pseudomonas bacteria convert insoluble P compounds into a soluble form, making it easier for the roots to absorb more P and increase their growth (3, 5 and 9). Pseudomonas bacteria have been used to play a major role in increasing the availability of major and minor nutrients for the plant and their effectiveness in improving soil structure (1 and 8).

Materials and Methods

A field experiment was conducted in one of the College of Agriculture research station fields in Ramadi City, Anbar Governorate, for the fall season of 2022 for a field with dimensions of 18×18 m. The study aims to know the effect of white mushroom waste, dates, and bacterial inoculum (Azotobacter chroococcum and Pseudomonas putida) on soil properties and broccoli plants. The field soil had a sandy clay loam texture. Agricultural operations such as plowing, leveling, and amendment prepare the soil before planting. Soil samples were taken randomly from a depth of (30-0 cm), and their chemical and physical properties were analyzed before planting Table 1.

Table 1: Pre-planting soil chemical and physical properties.

Soil Property	Value	Unit
EC	2.60	ds m^{-1}
pH	7.78	
Organic Matter O.M.	2.10	$g.kg^{-1}$
Microbial Density in Soil	0.54	$\times g^{-1} \times soil\ 10^7$ cfu
Available Nitrogen	32.13	$mg.kg^{-1}$
Available Phosphorus	9.55	$mg.kg^{-1}$
Available Potassium	206.55	$mg.kg^{-1}$
Bulk Density	1.35	$Mg.g^{-3}$
True Density	2.56	$Mg.g^{-3}$
Weighted Diameter	0.29	mm
Cation Exchange Capacity	35.95	Cmol.kg soil
Total Porosity	47.26	%
Saturated Water Conductivity	2.75	$h.cm^{-1}$
Accumulative Penetration	55.34	$Sec.cm^{-1}$
Sand	684	$g.kg^{-1}$
Silt	112	$g.kg^{-1}$
Clay	204	$g.kg^{-1}$
Soil Texture	Sandy Clay Loam	

Preparation of bacterial: Available isolates of bacteria (Azotobacter chroococcum+Pseudomonas putida) were taken from the Microbiology Laboratory of the College of Agriculture, University of Anbar. The isolates were multiplied and activated on the Nutrient Broth medium according to the method mentioned in (6).

Treatments and experiment design: The field was divided into three sectors representing replicates; each sector was divided into 18 plots, and each plot represented an experimental unit in which 11 plants were planted. The experiment was designed using a randomized complete block design (R.C.B.D) with three replicates, so the total number of treatments was 54. Agricultural operations were carried out, including plowing, amendment, and leveling. Broccoli seedlings were planted on 10/7/2022 under the drip irrigation system, and harvesting was carried out in two batches, the first on 12/30/2022 and the second on 1/16/2023. The results of the experiment were statistically analyzed using the analysis of variance method, and the (F) value and (LSD) value were tested under a significance level 0.05 as stated in SAS 2003. The experimental treatments included the following:

1. White mushroom waste at three levels (0, 10, and 20 tons ha^{-1}) symbolized by (M0, M1, M2)
2. Date waste at three levels (0, 10, and 20 tons ha^{-1}) symbolized by (D0, D1, D2)
3. Bacterial inoculum (Azotobacter+Pseudomonas) without addition and adding the inoculum symbolized by (B0, B1).

Studied characteristics: The soil characteristics were studied and analyzed: organic matter, microbial density, concentrations of available N, available P, available K in the soil, BD, total porosity, and saturated water conductivity.

Results and Discussion

The effect of white mushroom waste, dates, and bacterial inoculum on the soil organic matter content: Table 2 shows the effect of adding white mushroom waste, date waste, and bacterial inoculum on the soil's OM content (g kg^{-1}). There is a significant difference for adding white mushroom waste at a level of 20 t ha^{-1} (M2) compared to a level of 10 t ha^{-1} (M1) and without adding (M0), as the rates were 8.73, 5.61, and 3.48 g kg^{-1}, respectively, with an increased rate of 55.61 and 150.86%, respectively. There were significant differences for adding date waste at a level of 20 t ha^{-1} (D2) compared to a level of 10 t ha^{-1} (D1) and without adding (D0), recording rates of 7.21, 5.98, and 4.63 g kg^{-1}, respectively, with an increased rate of 20.57 and 55.72%, respectively. The treatment of bacterial inoculum (B1) to the OM had a significant difference compared to the treatment without adding the inoculum (B0), recording rates of 6.77 and 5.11 g kg^{-1}, respectively, with an increased rate of 32.49%. The dual interaction of adding white mushroom waste and date waste at the levels of 20 tons ha-1 (M2D2) showed a significant difference compared to not adding organic waste (M0D0) and recorded rates of 10.55 and 3.02 g kg^{-1}, respectively, with an increase rate of 249.33%. The dual interaction of adding white mushroom waste at the level of 20 tons ha-1 and bacterial inoculum (M2B1) recorded a significant difference compared to the treatment without adding (M0B0), recording rates of 9.92 and 2.77g kg^{-1}, respectively, with an increased rate of 258.12%.

There were significant differences in the binary interaction between date residues at the level of 20 t ha^{-1} and bacterial inoculum (D2B1) compared to the control treatment

(D0B0) recording 8.32 and 4.17 g kg^{-1}, respectively, with an increased rate of 99.52%. The triple interaction represented by adding white fungus residues and date residues at the levels of 20 t ha^{-1} and bacterial inoculum (M2D2B1) showed the highest rate of OM content in the soil with significant differences compared to the control treatment in which no organic residues and no bacterial inoculum were added (M0D0B0) recording 12.15 and 2.10 g kg^{-1}, respectively, with an increase rate of 478.57%.

Table 2: Effect of white mushroom waste, date waste, and bacterial inoculum on the soil organic matter content (g kg^{-1}).

White Mushroom Waste M	Date Waste D	Bacterial Inoculum B		M×D
		B0	B1	
M0	D0	2.10	3.94	3.02
	D1	2.96	4.08	3.52
	D2	3.25	4.55	3.90
M1	D0	3.96	4.55	4.25
	D1	5.01	5.77	5.39
	D2	6.11	8.26	7.19
M2	D0	6.44	6.79	6.62
	D1	7.21	10.83	9.02
	D2	8.95	12.15	10.55
LSD $_{M*D*B}$	0.65		LSD$_{m*D}$	0.46

M * B

White Mushroom Waste	B0	B1	White Mushroom Waste Means	
M0	2.77	4.19	3.48	
M1	5.03	6.19	5.61	
M2	7.53	9.92	8.73	
LSD $_{M*B}$	0.37		LSD$_{m}$	0.27

B×D

Date Waste	B0	B1	Date Waste Means	
D0	4.17	5.09	4.63	
D1	5.06	6.89	5.98	
D2	6.10	8.32	7.21	
Lsd $_{D*B}$	0.37		LSD$_{d}$	0.27

B

Bacterial Inoculum	B0	B1
Means of Bacterial Inoculum	5.11	6.77
LSD $_{B}$	0.22	

White mushroom waste at three levels (0, 10, and 20 tons ha^{-1}) was symbolized by M0, M1, and M2. Date waste at three levels (0, 10, and 20 tons ha^{-1}) and symbolized by (D0, D1, D2) and bacterial inoculum. It consists of (*Azotobacter chroococcum*+*Pseudomonas putida*) at two levels without adding the inoculum and marked with the symbol (B0) and adding the inoculum and marked with the symbol (B1).

The effect of white mushroom waste, date waste, and bacterial inoculum on soil microbial density: Table 3 shows the effect of white mushroom waste, date waste, and bacterial inoculum on soil microbial density (710×cfu g^{-1} soil). There are significant differences for adding white mushroom waste at the level of 20 t ha^{-1} (M2), compared to the level of 10 t ha^{-1} (M1) and without addition (M0) recording 2.61, 1.67 and 1.27 710×cfu g^{-1} soil respectively, with an increase rate of 56.28 and 105.51%. There was a significant difference in adding date waste at the level of 20 tons ha-1 (D2) compared to the level of 10 tons ha^{-1} (D1) and without adding (D0), and the rates reached 2.21, 1.80, and 1.54 $^{7}10 \times cfu\ g^{-1}$ soil, respectively, with an increased rate of 22.77 and 43.50%. There is a significant difference for the treatment of adding bacterial inoculum (B1) in increasing the soil microbial density compared to not adding inoculum (B0), recording 2.42 and 1.28 710×cfu g^{-1} soil, respectively, with an increase rate of 89.06%. The binary interaction of adding white fungus waste and date waste at the level of 20 t ha^{-1} (M2D2) recorded significant rates in soil microbial density (710×cfu g-1 soil) compared to not adding (M0D0) by 3.06 and 0.95 710×cfu g^{-1} soil, respectively, with an increase rate of 222.10%. The binary interaction of adding white mushroom waste at the level of 20 $t.ha^{-1}$ and bacterial inoculum (M2B1) showed a significant difference compared to not adding mushroom waste and bacterial inoculum (M0B0), recording rates of 3.28 and 0.83 710×cfu g^{-1} soil, respectively, with an increase rate of 295.18%. There was a significant difference in the binary interaction between date waste at the level of 20 $t.ha^{-1}$ with the addition of bacterial inoculum (D2B1) compared to not adding both (D0B0), recording rates of 2.85 and 0.99 710×cfu g^{-1} soil, respectively, with an increase rate of 187.87%. The triple interaction (M2D2B1) showed the highest value of soil microbial density, which reached 3.81 710×cfu g^{-1} soil, compared to without addition, which recorded 0.54 710×cfu g^{-1} soil, with an increased rate of 605.55%, to outperform all binary interactions and single treatments significantly.

Table 3: Effect of white mushroom waste, date waste, and bacterial inoculum on microbial density in soil (710×cfu g^{-1} soil).

White Mushroom Waste M	Date Waste D	Bacterial Inoculum B		M×D
		B0	B1	
M0	D0	0.54	1.37	0.95
	D1	0.92	1.77	1.34
	D2	1.03	1.99	1.51
M1	D0	0.89	1.97	1.43
	D1	1.02	2.06	1.54
	D2	1.33	2.76	2.04
M2	D0	1.53	2.95	2.24
	D1	1.97	3.07	2.52
	D2	2.31	3.81	3.06
LSD $_{M*D*B}$	0.04		LSD_{m*D}	0.03
M * B				
White Mushroom Waste	B0	B1	White Mushroom Waste Means	
M0	0.83	1.71	1.27	
M1	1.08	2.26	1.67	
M2	1.94	3.28	2.61	
LSD $_{M*B}$	0.02		LSD_m	0.02
B×D				
Date Waste	B0	B1	Date Waste Means	
D0	0.99	2.10	1.54	
D1	1.30	2.30	1.80	
D2	1.56	2.85	2.21	
Lsd $_{D*B}$	0.02		LSD_d	0.02
B				
Bacterial Inoculum	B0	B1		
Means of Bacterial Inoculum	1.28	2.42		
LSD $_B$	0.01			

M0, M1, M2: White mushroom waste at three levels (0, 10 and 20 tons ha^{-1}). D0, D1, D2: Date waste at three levels of 0, 10 and 20 tons ha^{-1}. B0, B1: without adding inoculum and adding the inoculum. The triple intervention (M2D2B1) showed the highest value for microbial density in the soil, amounting to

3.81×710 cfug^{-1} soil, compared to without a recorded addition of 0.54×710 cfug-1 soil, with an increase rate of 605.55%.

The effect of white mushroom waste, date waste, and bacterial inoculum on the concentration of available soil nitrogen: Table 4 shows the effect of adding white mushroom waste, date waste, and bacterial inoculum on the available N concentration in the soil (mg kg^{-1}). There are significant differences for adding white mushroom waste at a level of 20 tons ha^{-1} (M2) compared to a level of 10 tons ha^{-1} (M1) and without adding (M0) recording 136.50, 83.27 and 44.64 mg kg^{-1}, respectively, with a percentage of 63.92 and 205.77%. Adding date waste at a level of 20 tons ha^{-1} (D2) recorded a significant difference compared to a level of 10 tons ha^{-1} (D1) and without adding (D0), recording rates of 97.63, 87.98 and 78.80 mg kg^{-1}, respectively, with a percentage of 10.97 and 23.90%, respectively. The treatment of adding bacterial inoculum (B1) had a significant difference from that of not adding inoculum (B0), recording 100.31 and 75.96 mg kg^{-1}, respectively, and by 32%. The two-way interaction of white mushroom waste at a level of 20 tons ha-1 and adding bacterial inoculum (M2B1) showed a significant difference compared to the control treatment (M0B0) by 150.02 and 37.79 mg kg^{-1}, respectively, and by 296.98%, but the two-way interaction of adding white mushroom waste and date waste and the two-way interaction of adding date waste and adding bacterial inoculum did not give significant differences. The triple interaction of adding white mushroom waste and date waste at the levels of 20 tons ha^{-1} and adding bacterial inoculum (M2D2B1) recorded the highest significant rate of N content in the soil compared to the control treatment (M0D0B0), recording 154.40 and 32.13 mg kg^{-1}, respectively, at a rate of 380.55%.

Table 4: Effect of white mushroom waste, date waste, and bacterial inoculum on the concentration of available soil nitrogen (mg kg^{-1}).

White Mushroom Waste M	Date Waste D	Bacterial Inoculum B		M×D
		B0	B1	
M0	D0	32.13	42.50	37.31
	D1	36.58	51.65	44.11
	D2	44.68	60.29	52.49
M1	D0	53.78	89.87	71.82
	D1	69.58	98.37	83.98
	D2	77.97	110.04	94.01
M2	D0	109.22	145.29	127.25
	D1	121.32	150.36	135.84
	D2	138.39	154.40	146.40
LSD $_{M*D*B}$	7.25		LSD$_{m*D}$	0.03
M * B				
White Mushroom Waste	B0	B1	White Mushroom Waste Means	
M0	37.79	51.48	44.64	
M1	67.11	99.43	83.27	
M2	122.98	150.02	136.50	
LSD $_{M*B}$	4.19		LSD$_m$	2.96
B×D				
Date Waste	B0	B1	Date Waste Means	
D0	0.99	2.10	1.54	
D1	1.30	2.30	1.80	
D2	1.56	2.85	2.21	
Lsd $_{D*B}$	0.02		LSD$_d$	0.02
B				
Bacterial Inoculum	B0	B1		
Means of Bacterial Inoculum	75.96	100.31		
LSD $_B$	2.42			

M0, M1, M2: White mushroom waste at three levels (0, 10 and 20 tons ha^{-1}). D0, D1, D2: Date waste at three levels (0, 10 and 20 tons ha^{-1}). B0, B1: without adding inoculum and adding the inoculum. The triple intervention (M2D2B1) recorded the highest significant rate for the percentage of N in the soil compared to the control treatment.

The effect of white mushroom waste, date waste, and bacterial inoculum on the concentration of available soil phosphorus: Table 5 shows the effect of white mushroom waste, date waste, and bacterial inoculum on the concentration of available P in the soil (mg kg^{-1}). There is a clear significant difference for adding white mushroom waste at a level of 20 t ha^{-1} (M2) compared to a level of 10 t ha^{-1} (M1) and without adding (M0), recording rates of 16.89, 13.54, and 10.97 mg kg^{-1}, respectively, with a percentage of 24.74 and 53.97%, respectively. There were significant differences for treating date waste at a level of 20 t ha^{-1} (D2) compared to a level of 10 t ha^{-1} (D1) and without adding (D0), recording rates of 14.41, 13.83, and 13.16 mg kg^{-1}, respectively, with a percentage of 4.19 and 9.49%, respectively. There was a significant difference between the treatment of bacterial inoculum (B1) and the treatment without adding (B0), and the rate of the two treatments was 14.81 and 12.79 mg kg^{-1}, respectively, with a percentage of 15.79%. However, the double and triple interactions between adding white mushroom waste, date waste, and bacterial inoculum did not show significant differences between their treatments regarding the concentration of available P in the soil (mg kg^{-1}).

Table 5: Effect of white mushroom waste, date waste, and bacterial inoculum on the concentration of available soil phosphorus (mg kg^{-1}).

White Mushroom Waste M	Date Waste D	Bacterial Inoculum B		M×D
		B0	B1	
M0	D0	9.55	11.25	10.40
	D1	9.91	11.98	10.94
	D2	10.65	12.47	11.56
M1	D0	11.89	13.89	12.89
	D1	12.87	14.46	13.67
	D2	13.12	15.01	14.07
M2	D0	14.88	17.48	16.18
	D1	15.69	18.04	16.87
	D2	16.55	18.69	17.62
LSD $_{M*D*B}$	NS		LSD$_{m*D}$	NS
M * B				
White Mushroom Waste	B0	B1	White Mushroom Waste Means	
M0	10.04	11.90	10.97	
M1	12.63	14.45	13.54	
M2	15.70	18.07	16.89	
LSD $_{M*B}$	NS		LSD$_m$	0.73
B×D				
Date Waste	B0	B1	Date Waste Means	
D0	12.10	14.21	13.16	
D1	12.82	14.83	13.83	
D2	13.44	15.39	14.41	
Lsd $_{D*B}$	NS		LSD$_d$	0.73
B				
Bacterial Inoculum	B0	B1		
Means of Bacterial Inoculum	12.79	14.81		
LSD $_B$	0.59			

M0, M1, M2: White mushroom waste at three levels (0, 10 and 20 tons ha^{-1}). D0, D1, D2: Date waste at three levels (0, 10 and 20 tons ha^{-1}). B0, B1: without adding inoculum and adding the inoculum. There is a clear significant difference in adding white mushroom waste at a level of 20 tons ha^{-1} (M2) compared to a level of 10 tons ha^{-1} (M1) and without adding (M0).

The effect of white mushroom waste, date waste, and bacterial inoculum on the concentration of available soil potassium: Table 6 shows the effect of adding white mushroom waste, date waste, and bacterial inoculum on the available K concentration in the soil (mg kg^{-1}). There is a significant difference for adding white mushroom waste at the level of 20 t ha^{-1} (M2) compared to the level of 10 t ha^{-1} (M1) and without adding (M0), recording 272.10, 248.15 and 222.10 mg kg^{-1}, respectively, with a percentage of 9.65 and 22.51%. Date waste at the level of 20 t ha^{-1} (D2) showed significant differences in K concentration compared to the level of 10 t ha^{-1} (D1) and with treatment without adding (D0), as K concentration rates in the soil were recorded at 254.01, 246.80 and 241.53 mg kg^{-1}, respectively, with a percentage of 2.92 and 5.16%. There was a significant difference between adding bacterial inoculum (B1) and without inoculum (B0), recording 255.98 and 238.92 mg kg^{-1}, respectively, with a percentage of 7.14%. However, the binary and triple interactions between adding white mushroom waste, date waste, and bacterial inoculum showed no significant differences in their treatments concerning the soil K concentration (mg kg^{-1}).

Table 6: Effect of white mushroom waste, date waste, and bacterial inoculum on available soil K (mg kg^{-1}) concentration.

White Mushroom Waste M	Date Waste D	Bacterial Inoculum B		M×D
		B0	B1	
M0	D0	206.55	226.69	216.62
	D1	211.94	231.55	221.75
	D2	220.18	235.67	227.93
M1	D0	233.42	251.11	242.26
	D1	240.63	253.40	247.02
	D2	249.92	260.43	255.18
M2	D0	255.45	275.99	265.72
	D1	261.87	281.43	271.65
	D2	270.32	287.54	278.93
LSD $_{M*D*B}$	NS		LSD$_{m*D}$	NS
M * B				
White Mushroom Waste	B0	B1	White Mushroom Waste Means	
M0	212.89	231.30	222.10	
M1	241.32	254.98	248.15	
M2	262.55	281.65	272.10	
LSD $_{M* B}$	NS		LSD$_m$	3.19
B×D				
Date Waste	B0	B1	Date Waste Means	
D0	231.80	251.26	241.53	
D1	238.14	255.46	246.80	
D2	246.81	261.21	254.01	
Lsd $_{D*B}$	NS		LSD$_d$	3.19
B				
Bacterial Inoculum	B0	B1		
Means of Bacterial Inoculum	238.92	255.98		
LSD $_B$	2.60			

M0, M1, M2: White mushroom waste at three levels (0, 10 and 20 tons ha^{-1}). D0, D1, D2: Date waste at three levels (0, 10 and 20 tons ha^{-1}). B0, B1: without adding inoculum and adding the inoculum. Date waste at the level of 20 tons ha^{-1} (D2) showed significant differences in K concentration compared to the level of 10 tons ha^{-1} (D1) and with the treatment without addition (D0).

The effect of white fungus waste, date waste, and bacterial inoculum on the soil bulk density: Table 7 shows the effect of adding white mushroom waste, date waste, and bacterial inoculum on the soil BD (Mg m3-). There is a significant difference for adding white mushroom waste, especially at the level of 20 tons ha^{-1} (M2) compared to the level of 10 tons ha^{-1} (M1) and without adding (M0), recording rates of 1.25, 1.27, and 1.30 Mg m3- respectively, with a decrease rate of 2.30 and 3.84% respectively. Adding date waste showed a significant difference at the level of 20 tons ha^{-1} (D2) compared to the level of 10 tons ha^{-1}- and without adding (D0), recording 1.24, 1.28, and 1.30 Mg m3- respectively, with a decrease rate of 1.53 and 4.61%. There is a significant difference in the bacterial inoculum (B1) treatment compared to the treatment without addition (B0). The rate of the two treatments was recorded at 1.25 and 1.29 µg m3-

respectively, with a decrease rate of 3.10%. However, the binary and triple interactions of white mushroom waste, dates, and bacterial inoculum showed no significant differences.

Table 7: Effect of white mushroom waste, date waste, and bacterial inoculum on the soil bulk density (Mg m^{-3}).

White Mushroom Waste M	Date Waste D	Bacterial Inoculum B		M×D
		B0	B1	
M0	D0	1.35	1.30	1.32
	D1	1.33	1.27	1.30
	D2	1.29	1.25	1.27
M1	D0	1.32	1.26	1.29
	D1	1.29	1.25	1.27
	D2	1.27	1.24	1.25
M2	D0	1.30	1.25	1.27
	D1	1.26	1.23	1.24
	D2	1.24	1.21	1.22
LSD $_{M*D*B}$	NS		LSD$_{m*D}$	NS
M * B				
White Mushroom Waste	B0	B1	White Mushroom Waste Means	
M0	1.32	1.27	1.30	
M1	1.29	1.25	1.27	
M2	1.27	1.23	1.25	
LSD $_{M*B}$	NS		LSD$_{m}$	0.01
B×D				
Date Waste	B0	B1	Date Waste Means	
D0	1.32	1.27	1.30	
D1	1.30	1.26	1.28	
D2	1.26	1.22	1.24	
Lsd $_{D*B}$	NS		LSD$_{d}$	0.01
B				
Bacterial Inoculum	B0	B1		
Means of Bacterial Inoculum	1.29	1.25		
LSD $_{B}$	0.01			

M0, M1, M2: White mushroom waste at three levels (0, 10 and 20 tons ha^{-1}). D0, D1, D2: Date waste at three levels (0, 10 and 20 tons ha^{-1}). B0, B1: without adding inoculum and adding the inoculum. There is a significant difference in adding the bacterial inoculum (B1) compared to without adding (B0). The average rates for the two treatments were 1.25 and 1.29 mg/m3, respectively, with a decrease rate of 3.10%.

The effect of white fungus waste, date waste, and bacterial inoculum on soil porosity: Table 8 shows the effect of adding white mushroom waste, date waste, and bacterial inoculum on soil porosity (%). There are significant differences in soil porosity for the treatment of white mushroom waste at a level of 20 tons ha^{-1} (M2) compared to a level of 10 tons ha^{-1} (M1) and without adding (M0), recording 51.32, 50.32 and 49.28% respectively, and at a rate of 1.98 and 4.13% respectively. There are significant differences for adding date waste at a level of 20 tons ha^{-1} (D2) compared to a level of 10 tons ha^{-1} and without adding (D0), and their rates were 51.26, 50.32 and 49.34%, respectively, and at an increased rate of 1.86 and 3.89% respectively. There is a significant difference between adding bacterial inoculum (B1) and not adding (B0), as the two treatments recorded 51.12 and 49.49%, respectively, with an increase rate of 3.29%. The binary interaction of date waste at a level of 20 t ha^{-1} and adding bacterial inoculum (D2B1) showed a significant difference compared to without adding (D0B0), recording 51.82 and 48.30%, with an increased rate of 7.28%. However, the binary interactions between white fungus waste and date waste and the interaction between white fungus waste and bacterial inoculum did not show significant differences, nor did the triple interactions.

Table 8: Effect of white mushroom waste, date waste, and bacterial inoculum on soil porosity (%).

White Mushroom Waste M	Date Waste D	Bacterial Inoculum B		M×D
		B0	B1	
M0	D0	47.26	49.21	48.24
	D1	48.04	50.39	49.22
	D2	49.60	51.17	50.39
M1	D0	48.43	50.78	49.60
	D1	49.60	51.17	50.39
	D2	50.39	51.56	50.98
M2	D0	49.21	51.17	50.19
	D1	50.87	51.95	51.37
	D2	52.12	52.73	52.43
LSD $_{M*D*B}$	NS		LSD$_{m*D}$	NS
M * B				
White Mushroom Waste	B0	B1	White Mushroom Waste Means	
M0	48.30	50.39	49.28	
M1	49.47	51.17	50.32	
M2	50.70	51.82	51.32	
LSD $_{M*B}$	NS		LSD$_m$	0.475
B×D				
Date Waste	B0	B1	Date Waste Means	
D0	48.30	50.39	49.34	
D1	49.47	51.17	50.32	
D2	50.70	51.82	51.26	
Lsd $_{D*B}$	0.672		LSD$_d$	0.475
B				
Bacterial Inoculum	B0	B1		
Means of Bacterial Inoculum	49.49	51.12		
LSD $_B$	0.388			

M0, M1, M2: White mushroom waste at three levels (0, 10 and 20 tons ha^{-1}). D0, D1, D2: Date waste at three levels (0, 10 and 20 tons ha^{-1}). B0, B1: without adding inoculum and adding the inoculum. Significant differences in soil porosity for the treatment of adding white mushroom waste at a level of 20 tons ha^{-1} (M2) compared to a level of 10 tons ha^{-1} (M1) and without adding (M0), recorded as 51.32, 50.32 and 49.28%, respectively.

The effect of white mushroom waste, date waste, and bacterial inoculum on soil water conductivity: Table 9 shows the effect of white mushroom waste, date waste, and bacterial inoculum on the soil-saturated water conductivity (cm h^{-1}). There are significant differences in the treatment of white mushroom waste on the saturated water conductivity value at the level of 20 tons ha^{-1} (M2) compared to the level of 10 tons ha^{-1} (M1) and without adding (M0) recording 2.48, 2.62, and 2.69 cm h^{-1}, respectively, with a decrease rate of 2.60 and 7.80%. There is a significant difference for adding bacterial inoculum (B1) compared to without adding (B0), recording 2.56 and 2.63 cm h^{-1}, respectively, with a decrease rate of 2.66%, and adding date waste did not give any significant differences in the saturated water conductivity value. The binary interaction of white mushroom waste and date waste at the levels of 20 $t.ha^{-1}$ (M2D2) showed a significant difference compared to the absence of (M0D0) addition, recording rates of 2.43 and 2.74 $cm.h^{-1}$, respectively, with a decrease rate of 4.37%. However, the binary interactions between adding white mushroom waste and adding bacterial inoculum and between adding date waste and bacterial inoculum did not give any results, nor did the triple interactions.

Table 9: Effect of white mushroom waste, date waste, and bacterial inoculum on saturated soil water conductivity (cm^{-1} h).

White Mushroom Waste M	Date Waste D	Bacterial Inoculum B		M×D
		B0	B1	
M0	D0	2.75	2.73	2.74
	D1	2.70	2.65	2.68
	D2	2.66	2.62	2.64
M1	D0	2.70	2.58	2.64
	D1	2.67	2.56	2.62
	D2	2.63	2.55	2.59
M2	D0	2.57	2.45	2.51
	D1	2.54	2.44	2.49
	D2	2.45	2.41	2.43
LSD_{M*D*B}	NS		LSD_{m*D}	0.15
M * B				
White Mushroom Waste	B0	B1	White Mushroom Waste Means	
M0	2.70	2.67	2.69	
M1	2.67	2.56	2.62	
M2	2.52	2.43	2.48	
LSD_{M*B}	NS		LSD_m	0.09
B×D				
Date Waste	B0	B1	Date Waste Means	
D0	2.67	2.59	2.63	
D1	2.64	2.55	2.59	
D2	2.58	2.53	2.55	
Lsd_{D*B}	0.672		LSD_d	0.475
B				
Bacterial Inoculum	B0	B1		
Means of Bacterial Inoculum	2.63	2.56		
LSD_B	0.07			

It is clear from Tables 2, 3, 4, 5, 6, 7, 8, and 9 that the addition of white fungus residues Agaricus bisporus and date residues to the molasses and bacterial inoculum consisting of (Azotobacter chroococcum+Pseudomonas putida) each individually and some of their binary and triple interactions led to an increase in both OM and microbial density in the soil, and the concentrations of available N, available P and available K in the soil, and in the porosity and saturated water conductivity of the soil and a decrease in the soil BD. The triple interaction treatment of the highest level of 20 tons ha^{-1} of fungus residues and date residues in the presence of the bacterial inoculum of Azotobacter and Pseudomonas (B1D2M2) outperformed by showing the highest rates of OM content, microbial density, and available N concentration in the soil. Many studies have indicated the critical role of white mushroom waste, as it improves the soil's fertile and physical properties and increases the necessary elements in it, such as N, P, and K, in addition to the N it contains in the form of protein, which becomes ready for absorption after the decomposition process is complete (11, 18 and 19). It is characterized by its high content of OM, which ranges between 75-34% (25).

Date waste plays an essential role in increasing the OM in the soil, as it works to increase the percentage of NPK nutrients in it after its decomposition by microorganisms present in the soil, and it improves the soil structure by increasing the cohesion and bonding forces between particles and forming water-repellent complexes that work to reduce the breakdown of the soil structure during the hydration process (22). (10 and 16) indicated the effect of palm waste on some soil properties by increasing the percentage of OM. (28) mentioned the effect of adding levels of OM in improving the physical properties of the soil, and the results were significant in reducing the value of the true and BD of the soil and increasing the porosity of the soil at the level of 20 tons ha^{-1}. The bacterial inoculum contains beneficial microorganisms that secrete many enzymes, organic acids, growth regulators, and chelating materials, in addition to the ability of these organisms to dissolve P and K compounds and mineralize OM. They play a role in improving the physical and chemical properties of the soil due to their positive effect on soil structure and porosity and increase the soil's ability to retain water. They work to reduce the BD and increase the soil aggregates' stability (29 and 31). (14) showed that adding a combination of biofertilizers containing Azotobacter bacteria to the soil increased the percentage of OM and microbial density. (26) The effect of using biofertilizers with organic fertilizers on the growth and yield of broccoli was observed using Azotobacter and Azospirllum bacteria, and it improved the physical properties of the soil. Pseudomonas bacteria have a significant role in increasing the availability of major and minor nutrients for the plant and their effectiveness in improving soil properties (5).

Conclusions

After the use of white mushroom farm waste and dates juice laboratory waste as organic waste, as well as biomaries (pseudomonas and Azotobacter), a moral effect in most of the characteristics of fertilizer and vital soil, increased its content of organic matter, microbial density and important nutrients as well as improving its physical qualities.

Supplementary Materials:

No Supplementary Materials.

Author Contributions:

Author 1: Jian Adel, writing—original draft preparation, Huthaifa Jaseem and Jamal Salih writing—review and editing. All authors have read and agreed to the published version of the manuscript.

Funding:

This research received no external funding.

Institutional Review Board Statement:

The study was conducted following the protocol authorized by the Ministry of higher education, university of Anbar College of Agriculture Department of Soil Science and Water Resources, Iraq Republic.

Informed Consent Statement:

No Informed Consent Statement.

Data Availability Statement:

No Data Availability Statement.

Conflicts of Interest:

The authors declare no conflict of interest.

Acknowledgments:

The authors are grateful for the assistance the College Dean and Head of the Soil and Water Dept. of the College of Agriculture, University of Anbar, Iraq, provided. We would also like to thank the undergraduate students for their valuable help and technical assistance in conducting this research.

Disclaimer/Journal's Note:

The statements, opinions, and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of AJAS and/or the editor(s). AJAS and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions, or products referred to in the content.

References

1. Aasfar, A., Bargaz, A., Yaakoubi, K., Hilali, A., Bennis, I., Zeroual, Y., and Meftah Kadmiri, I. (2021). Nitrogen fixing Azotobacter species as potential soil biological enhancers for crop nutrition and yield stability. Frontiers in microbiology, 12: 628379. https://doi.org/10.3389/fmicb.2021.628379.
2. Abed, I. A., Al-joboory, W. M., Yaqub, M. T., and Hassan, M. A. (2024). Preparing and election microbial carrier for bacillus megaterium and Azo spirillum lipoferum and its impact on growth and yield of potato. Anbar Journal of Agricultural Sciences, 22(1): 763-772. https://doi.org/10.32649/ajas.2024.183835.
3. Alani, A. R., Mohammed, H. J., and Al-Shaheen, M. R. (2019). Effect of organic residues of cows and organic acids on the readiness of some micronutrients in the soil. Biochemical and Cellular Archives, 19: 2747-2752. DOI: 10.35124/bca.2019.19.S1.2747.
4. Alani, A. R., Mohammed, H. J., and Marzoog, A. (2021). Magnetic processing of saline water and its impact on some soil properties. Int. J. Agricult. Stat. Sci, 17: 1045-1051.
5. Al-Kahtani, S. H., Ahmed, M. A., Al-Selwey, W. A., and Abdel-Razzak, H. S. (2018). Evaluation of composted agricultural crop wastes application on growth, mineral content, yield, and fruit quality of tomato. Journal of Experimental Biology and Agricultural Sciences, 6(1): 159-167. http://dx.doi.org/10.18006/2018.6(1).159.167.

6. Alkobaisy, J. S., Lafi, A. S. A., and Ghani, E. T. A. (2020). Influence of using Mycorrhizae (MH) with vermicompost (VRF) on soil properties, soybean (Glycine max L.) growth and yield. Systematic Reviews in Pharmacy, 11(6): 347-351. http://dx.doi.org/10.5530/srp.2019.2.04.
7. AL-Kobaisy, J. S., and Saleh, J. M. (2019). Effect of Ganoderma Mushroom on Increasing Soil Fertility Using Palm Residues and Increasing Broccoli Production. REVISTA AUS, 26(4): 94-104.
8. Al-Nuaymy, W. S., Mohammed, H. J., and Mohammed, A. M. (2020). Evaluation of Hosehold Wastewater and the Possibility of Isolating it for Irrigation in the Cities of Ramadi and Haditha. Diyala Agricultural Sciences Journal, 12(Special Issue): 1-11.
9. Al-Obidiy, J. A., Alkobaisy, J. S., and Mohammed, H. J. (2023). Effect of Mushroom Residues, Date Residues and Bacterial Inoculum (A. Chroococcum, P. Putida) on the Growth and Yield of Broccoli. In IOP Conference Series: Earth and Environmental Science, 1252(1): p. 012066. DOI: 10.1088/1755-1315/1252/1/012066.
10. Al Hasnawi, R. A., Mohammed, R. J., Jafar, A. A., and Hassan, D. F. (2018). Effect of adding two types of plant waste in some of the gypsum soil properties and the growth yield of wheat plant (Triticum aestivum L.). Journal of Kerbala for Agricultural Sciences, 5(5): 777-790. https://doi.org/10.59658/jkas.v5i5.677.
11. Al-Sayed, H. M., Hegab, S. A., Youssef, M. A., Khalafalla, M. Y., Almaroai, Y. A., Ding, Z., and Eissa, M. A. (2020). Evaluation of quality and growth of roselle (Hibiscus sabdariffa L.) as affected by bio-fertilizers. Journal of plant nutrition, 43(7): 1025-1035. https://doi.org/10.1080/01904167.2020.1711938.
12. Ashish, Singh, D., and Gupta, N. (2020). Impact of nanoparticles on PGPR and soil nutrient contents. Biogenic Nano-Particles and their Use in Agro-ecosystems, 247-257. https://doi.org/10.1007/978-981-15-2985-6_14.
13. Cowan, T. M. (1977). Organizing the properties of impossible figures. Perception, 6(1): 41-56. https://doi.org/10.1068/p060041.
14. Dubey, K. K., and Fulekar, M. H. (2011). Mycorrhizosphere development and management: The role of nutrients, micro-organisms and bio-chemical activities. Agric Biol JN Am, 2(2): 315-324.
15. Ghehsareh, A. M., and Kalbasi, M. (2012). Effect of addition of organic and inorganic combinations to soil on growing property of greenhouse cucumber. African Journal of Biotechnology, 11(37): 9102-9107. https://doi.org/10.5897/AJB11.1750.
16. Ghehsareh, A. M., Hematian, M., and Kalbasi, M. (2012). Comparison of date-palm wastes and perlite as culture substrates on growing indices in greenhouse cucumber. International Journal of Recycling of Organic Waste in Agriculture, 1: 1-4. https://doi.org/10.1186/2251-7715-1-5.
17. Kumar, M., Das, B. D., Prasad, K. K., and Kumar, P. (2013). Effect of integrated nutrient management on growth and yield of broccoli (Brassica oleracea var. italica) under Jharkhand conditions. Vegetable science, 40(01): 117-120.
18. Kwiatkowska, E., and Joniec, J. (2022). Effects of agricultural management of spent mushroom waste on phytotoxicity and microbiological transformations of C,

P, and S in soil and their consequences for the greenhouse effect. International journal of environmental research and public health, 19(19): 12915. https://doi.org/10.3390/ijerph191912915.
19. Landschoot, P., and McNitt, A. (1995). Using spent mushroom substrate (mushroom soil) as a soil amendment to improve turf. Staff paper, Pennsylvania State University USA.
20. Mahmood, J. M., Al-Joboory, W. M., and Abed, I. A. (2024). Role of organic, bio and mineral fertilizers in environmental sustainability and enhancing lettuce productivity. Anbar Journal of Agricultural Sciences, 22(2): 1139-1154. https://doi.org/10.32649/ajas.2024.184474.
21. Mohammed, H., Sarheed, B., Salum, M., and Alshaheen, M. (2019). The effect of the source and the level of residues in some of the characteristics of the soil and yield of broad bean (vicia faba l.). Plant Archives, 19(1): 898-903.
22. Mohd Hanafi, F. H., Rezania, S., Mat Taib, S., Md Din, M. F., Yamauchi, M., Sakamoto, M., ... and Ebrahimi, S. S. (2018). Environmentally sustainable applications of agro-based spent mushroom substrate (SMS): an overview. Journal of Material Cycles and Waste Management, 20: 1383-1396. https://doi.org/10.1007/s10163-018-0739-0.
23. Muhammed, S. A. H., and Al-Joboory, W. M. (2024). Effect of levels and methods of zinc addition on the growth and yield of wheat cultivated in saline soils. Anbar Journal of Agricultural Sciences, 22(1): 343-357. https://doi.org/10.32649/ajas.2024.139484.1037.
24. Mukherjee, V., and Mishra, P. K. (2012). Broccoli-an underexploited neutraceutical. Science Research Reporter, 2(3): 291-294.
25. Muslat, M. M., and Saleh, S. A. (2017). Influence of date palm wastes fertilization on some growth and yield of cucumber parameters under protected cultivation. Anbar Journal of Agricultural Sciences, 15(1): 181-190.
26. Owaid, M. N., Abed, I. A., and Al-Saeedi, S. S. S. (2017). Applicable properties of the bio-fertilizer spent mushroom substrate in organic systems as a byproduct from the cultivation of Pleurotus spp. Information Processing in Agriculture, 4(1): 78-82. https://doi.org/10.1016/j.inpa.2017.01.001.
27. Rajavat, A. S., Mageshwaran, V., Bharadwaj, A., Tripathi, S., and Pandiyan, K. (2022). Spent mushroom waste: An emerging bio-fertilizer for improving soil health and plant productivity. In New and Future Developments in Microbial Biotechnology and Bioengineering, 345-354. https://doi.org/10.1016/B978-0-323-85579-2.00010-1.
28. Temiz, C., Akca, M. O., Cayci, G., and Baran, A. (2021). Assessment of the effect of different compost materials on aggregation and mechanical properties in an Entisol. Communications in Soil Science and Plant Analysis, 52(8): 871-885. https://doi.org/10.1080/00103624.2020.1869770.
29. Tétard-Jones, C., Edwards, M. G., Rempelos, L., Gatehouse, A. M., Eyre, M., Wilcockson, S. J., and Leifert, C. (2013). Effects of previous crop management, fertilization regime and water supply on potato tuber proteome and yield. Agronomy, 3(1): 59-85. https://doi.org/10.3390/agronomy3010059.

30. Urra, J., Alkorta, I., and Garbisu, C. (2019). Potential benefits and risks for soil health derived from the use of organic amendments in agriculture. Agronomy, 9(9): 542. https://doi.org/10.3390/agronomy9090542.
31. Zhang, J., Cook, J., Nearing, J. T., Zhang, J., Raudonis, R., Glick, B. R., ... and Cheng, Z. (2021). Harnessing the plant microbiome to promote the growth of agricultural crops. Microbiological Research, 245: 126690. https://doi.org/10.1016/j.micres.2020.126690.