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Article

Effect of Adding Furfural Residues, Phosphate Fertilization, and Organic Matter on Soil Characteristics and Increasing Available Phosphorus

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Abstract: Laboratory experiment was conducted in department of Soil Science and Water Resources collage of Agriculture, University of Basrah for the purpose of studying the effect of adding Furfural, phosphorus and organic matter on availability of phosphorus in the soil. Three levels of furfural were used (0, 600, and 1200 mg kg^{-1}), three levels of phosphate fertilization in the form of urea phosphate fertilizer (0, 500, and 1000 mg P kg^{-1}), and two levels of organic matter from cow waste (0 and 40 tons ha^{-1}). Individually or overlapping with each other, soil samples were incubated intervals of 15 and 30 days, and after the end of the incubation period, a sample was taken from each treatment, and were estimate pH, available phosphorus, and organic matter. The results showed no significant effect of the treatments on soil pH values after 15 days of incubation, while there was a significant effect after 30 days. Adding a level of 1200 mg kg^{-1} of furfural, 1000 mg p kg^{-1} of phosphate fertilizer, and 40 tons ha^{-1} of organic matter gave a significantly increase in the available of phosphorus in the soil, whether at an incubation period of 15 days or 30 days. At the same time, it was found that adding levels of high levels of furfural and organic matter led to an increase in the organic matter content in the soil, while the organic matter content in the soil decreased with increasing levels of phosphate fertilizer. The results indicate that adding furfural, phosphate fertilizer, and organic fertilizer can significantly increase the availability phosphorus in calcareous soil.

Keywords: pH, available phosphorus, calcareous soil, organic matter

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1. Introduction

Phosphorus is one of the major key determinants of crop production and shows its importance in many physiological and biochemical processes [1]. It is a basic element that cannot be replaced by another element, the plant absorbs its need for phosphorus from the soil solution in the form of phosphate ions, HPO_4^{-2} and $H_2PO_4^{-1}$, and the preferred form for absorption is $H_2PO_4^{-1}$ The concentration of phosphorus in the soil solution is deficient and reaches 10^{-5} due to the deterioration of the phosphorus element in the soil, so it must always be added as phosphate fertilizers that are ready and available for absorption by the plant [2].

Furfural is one of the chemicals of plant origin, it is extracted from agricultural wastes such as corn, sugarcane stalks, cotton seeds, oats, and rice [3]. Furfural is a type of cheap acidic organic substance, it is the waste of corn coke after industrial distillation. It is dark brown and belongs to the organic substances with strong acidity, its pH is around 2.0. Furfural contains 0.15% K_2O, 0.15-0.20% P_2O_5, and 0.5-0.6% N, the humic acid content is 36%, and its organic matter content is higher than 98% [4]. Many studies have indicated that furfural affects the chemical properties and fertility of the soil in terms of the degree

of soil interaction, pH, cation exchange capacity (CEC), organic matter, and nutrient content [5, 6, 7]. [8] showed that adding furfural to the soil is considered a good soil improver, which works to increase the phosphorus and organic carbon content in the soil and improve the soil properties, as well as playing a major role in reducing the degree of soil pH.

Organic matter is a major storehouse of essential nutrients for plants, such as nitrogen, phosphorus, and microelements, it also plays a role in improving soil structure and fertility and is an energy source for microorganisms present in the soil, it also helps release nutrients into the soil and reduces the degree of soil pH [9]. The rate of decomposition of organic matter depends mainly on the type of organic matter, in addition to the level of moisture, ventilation, and soil temperature [10]. Many studies have indicated that the use of organic fertilizers contributed to increasing organic matter in the soil and improving the physical and chemical properties of the soil, which led to improving its fertility [11]. This study aims to in evaluate the effect of adding furfural residues and organic matter on increasing the availability of phosphorus in calcareous soil.

2. Materials and Methods

A laboratory experiment was conducted in the laboratories of the department of Soil Sciences and Water Resources, College of Agriculture, University of Basrah, where soil samples were randomly collected from the Agricultural Research and Experiments Station affiliated with the College of Agriculture, University of Basra, southern Iraq, soil sample was air-dried, ground, and sieved through a sieve with a hole diameter of 2 mm to for determine the physiochemical properties of soil, as shown in Table 1.

Soil sample weighing 300 g was taken and placed in 500 g plastic containers. Three levels of furfural were used (0, 600, and 1200 mg kg^{-1}), denoted as F_1, F_2, and F_3, respectively. Three levels of phosphorus, (0, 500, and 1,000 mg P kg^{-1}), denoted as P_1, P_2, and P_3, respectively, using urea phosphate fertilizer (44%) and two levels of organic matter (cow waste) 0 and 40 tons ha^{-1}, denoted O_1 and O_2, respectively. These fertilizers were mixed well with the soil, and moisture content was maintained within the limits of field capacity. The experiment was carried out according to a completely randomized block design with three replicates. The samples were incubated in the incubater at a temperature of 25°, with incubation periods of 15 and 30 days. After the end of the incubation period, the samples were air-dried, and sieved through a sieve with a diameter of 2 mm.

The pH in the soil suspension was measured at a ratio of 1:1 (water: soil) using a pH meter [12]. Available phosphorus was extracted using 0.5 M $NaHCO_3$ and determined using a spectrophotometer at a wavelength of 700 nm by the blue color method described by [13]. Soil organic matter was determined by the wet oxidation method according to the method of Walkley and Black described in Page *et al*. (1982). The data were analyzed statistically by Analysis of Variance to calculate the least significant difference (RLSD) at a significant level of 0.05.

Table 1. Some soil properties

Properties	Value	unit
pH (1:1) in water	8.38	-
EC (1:1)	8.5	(dS m^{-1})
CEC	13.10	($Cmol^{+}$ kg^{-1})

Available N	45	(mg kg^{-1})
Available P	52.33	(mg kg^{-1})
Available K	125.18	(mg kg^{-1})
Organic matter	2.46	(g kg^{-1})
Soluble ions		
Ca^{+2})	16.12	(mmole L^{-1})
Mg^{+2}	10.15	(mmole L^{-1})
Na^{+}	26.45	(mmole L^{-1})
K^{+}	9.48	(mmole L^{-1})
$HCO3^{-}$	8.49	(mmole L^{-1})
CO_3^{-2}	0.00	(mmole L^{-1})
Cl^{-}	31.16	(mmole L^{-1})
SO_4^{-2}	25.19	(mmole L^{-1})
Bulk density	1.38	(Mg gm^{-3})
Porosity	48	(%)
Sand	78.00	(gm kg^{-1})
Silt	450.00	(gm kg^{-1})
Clay	472.00	(gm kg^{-1})
Texture	Clay Loam	

3. Results and Discussion

Effect of furfural, phosphorus, and organic matter on soil pH values

The results in table 2 show no significant effect of furfural waste and phosphate fertilizer and their binary and triple intraction in the values of soil pH at a period of 15 days. The results in table 2 show a decreased in soil pH at the second level of organic matter O_2, which amounted to 8.31 compared to the first level O_1 (8.42). As a result of the decomposition of organic matter, releases carbon dioxide gas and organic acids, thus decreasing the soil pH [14].

Table 2. Effect of furfural, phosphorus, and organic matter residues on pH values at an incubation period of 15 days

Furfural levels (gm kg^{-1})	**Organic matter levels(gm kg^{-1})**	**Levels of added phosphorus, (gm P kg^{-1} soil)**			**F × O**
		P_1	P_2	P_3	
F_1	O_1	8.40	8.41	8.39	8.40
	O_2	8.33	8.31	8.32	8.32
F_2	O_1	8.43	8.45	8.44	8.44
	O_2	8.32	8.30	8.33	8.31
F_3	O_1	8.40	8.46	8.44	8.43
	O_2	8.30	8.33	8.30	8.31
R.L.S.D 0.05			N. S		N. S
Interaction of furfural and phosphorus					F
F × P	F1	8.36	8.36	8.35	8.36
	F2	8.37	8.38	8.38	8.38
	F3	8.35	8.40	8.37	8.37
R.L.S.D 0.05			N. S		N. S
Interaction of organic matter and phosphorus					O
O × P	O1	8.41	8.44	8.42	8.42
	O2	8.31	8.31	8.32	8.31
R.L.S.D 0.05			N. S		0.045
Averages		8.36	8.38	8.37	
R.L.S.D 0.05			**N. S**		

Table 3 shows a decreased soil pH at an incubation period of 30 days when adding the F_3 level of furfural, as it reached 7.90 compared to the first and second levels. The reason for the low degree of soil pH may be due to the addition of furfural, which leads to improving the properties of the soil because it has an acidic degree of pH in addition to its high content of organic matter. These results are consistent with the findings of [7] and this was confirmed by [15]. There is no significant effect on the added phosphate fertilizer. The results show that adding the second level of organic matter led to a decreased in soil pH, which amounted to 8.10 compared to the first level. These results were identical to the results during the 15-day incubation period, where the degree of soil pH decreased compared to the control level.

Table 3. Effect of furfural, phosphorus, and organic matter on pH at an incubation period of 30 days

Furfural levels (gm kg^{-1})	**Organic matter levels (gm kg^{-1})**	**Levels of added phosphorus, (gm p kg^{-1} soil)**			**F × O**
		P_1	P_2	P_3	
F_1	O_1	8.31	8.32	8.31	8.31
	O_2	8.28	8.26	8.27	8.27

F_2	O_1	8.24	8.23	8.23	8.23
	O_2	8.20	8.16	8.18	8.18
F_3	O_1	7.96	7.94	7.98	7.96
	O_2	7.87	7.85	7.83	7.85
R.L.S.D 0.05			NS		0.042
Interaction of furfural and phosphorus					F
F × P	F1	8.29	8.29	8.29	8.29
	F2	8.22	8.19	8.20	8.20
	F3	7.91	7.89	7.90	7.90
R.L.S.D 0.05			NS		0.025
Interaction of organic matter and phosphorus					O
O × P	O1	8.17	8.16	8.17	8.16
	O2	8.11	8.09	8.09	8.10
R.L.S.D 0.05			NS		0.021
Averages		8.14	8.12	8.13	
R.L.S.D 0.05			**NS**		

Effect of furfural, phosphorus, and organic matter on concentration of available phosphorus in the soil

Table 4 shows a significant effect of the three study factors and their interaction on concentration of available phosphorus interval of 15 days, as it is noted that the third level F_3 increased the concentration of available phosphorus, which reached 412.33 mg P kg $^{-1}$ compared to the first and second levels (329.05 and 231.22 mg P km^{-1}). [16] noted that adding furfural residues to the soil has a significant effect in increasing the availability of available phosphorus by reducing the processes of phosphorus fixation in calcareous soils. Adding the third level, P_3, of phosphate fertilizer led to an increased in the available phosphorus in the soil, reached 583.55 mg kg^{-1} compared to the first and second levels. This may be due to the content of high phosphate fertilizer (44 %) and its dissolution for the soil. The results of the table showed that the second level (314.33 and 74.72 mg P km^{-1}) of organic o_2 matter increased the availability of phosphorus in the soil, as it reached 344.66 mg P K $^{-1}$ compared to the first level O_1 (303.74 mg P kg^{-1}).

Table 4. Effect of furfural, phosphorus, and organic matter on available phosphorus (mg kg^{-1}) in soil at an incubation period of 15 days

Furfural levels (gm kg^{-1})	**Organic matter levels (gm kg^{-1})**	**Levels of added phosphorus, (gm p kg^{-1} soil)**			**F × O**
		P_1	P_2	P_3	
F_1	O_1	52.33	234.33	326.66	204.44
	O_2	63.33	274.00	436.66	258.00
F_2	O_1	71.00	298.33	556.66	308.66
	O_2	77.66	316.66	654.00	349.44
F_3	O_1	87.33	366.00	741.00	398.11
	O_2	96.66	396.66	786.33	426.55

R.L.S.D 0.05			16.54		10.64
Interaction of furfural and phosphorus					F
F × P	F1	57.83	254.16	381.66	231.22
	F2	74.33	307.50	605.33	329.05
	F3	92.00	381.33	763.66	412.33
R.L.S.D 0.05			11.68		6.75
Interaction of organic matter and phosphorus					O
O × P	O1	70.22	299.55	541.44	303.74
	O2	79.22	329.11	625.66	344.66
R.L.S.D 0.05			9.56		5.50
Averages		74.72	314.33	583.55	
R.L.S.D 0.05			**6.75**		

Many studies have indicated that the addition of organic matter reduced the adsorption of phosphorus on the surfaces and particles of soil colloids and reduced the concentration of exchanged calcium, which leads to an increasing in the release of phosphorus from its sources [17, 18]. As for the effect of the binary interaction between furfural and organic matter, the highest concentration of available phosphorus in the soil was recorded in the F3O2 treatment over other treatments, which amounted to 426.55 mg kg^{-1}. As for the binary interaction between furfural and phosphorus, the highest concentration rate of available phosphorus was recorded in the soil when treated with F3P3 over other treatments amounting to 763.66 mg p kg^{-1}.

The results of the table also show the binary interaction between organic fertilizer and phosphorus. The highest rate of available phosphorus was recorded in the P3O2 treatment over other treatments, which amounted to 625.66 mg p kg^{-1}. The triple interaction coefficients between furfural, phosphorus, and organic matter indicate an increase in the concentration of available phosphorus in the F3P3O2 treatment, as the highest rate of available phosphorus was recorded over other treatments, which amounted to 786.33 mg p kg^{-1}.

Table 5. Effect of furfural, phosphorus, and organic matter on available phosphorus (mg kg^{-1}) in soil at an incubation period of 30 days

Furfural levels gm kg^{-1}	**Organic matter levels gm kg^{-1}**	**Levels of added phosphorus, gm p kg^{-1} soil**			**F × O**
		P_1	P_2	P_3	
F_1	O_1	42.66	98.33	140.00	93.66
	O_2	55.00	181.33	203.66	146.66
F_2	O_1	62.66	164.33	266.66	164.55
	O_2	71.66	173.00	286.00	176.88
F_3	O_1	76.66	185.00	342.66	201.44
	O_2	95.00	240.00	383.33	239.44
R.L.S.D 0.05			8.86		4.88

Interaction of furfural and phosphorus					F
F × P	F1	48.83	139.83	171.83	120.16
	F2	67.16	168.66	276.33	170.72
	F3	85.83	212.50	363.00	220.44
R.L.S.D 0.05			5.70		3.42
Interaction of organic matter and phosphorus					O
O × P	O1	60.66	149.22	249.77	153.22
	O2	73.88	198.11	291.00	187.66
R.L.S.D 0.05			4.88		2.82
Averages		67.27	173.66	270.38	
R.L.S.D 0.05			**3.42**		

Table 5 shows the effect of furfural residues, phosphorus, and organic matter on the values of available phosphorus at an incubation period of 30 days. These results are in line with what was obtained in table 4. It is noted that the third level, F3, increased the concentration of available phosphorus, which amounted to 220.44 mg P kg^{-1} compared to the first and second levels (170.72 mg P kg^{-1}). Adding the third level, P3 of phosphate fertilizer led to an increase in the availability of phosphorus in the soil, reaching 270.38 mg P kg^{-1} compared to the first and second levels (173.66 and 67.27 mg P kg^{-1}). The results of the table 5 showed that the second level of organic fertilizer, O2 increased the availability of phosphorus in the soil, reaching 187.66 mg P kg^{-1}. Compared to the first level O1 (153.22 mg P kg^{-1}). As for the effect of the binary interaction between furfural and organic fertilizer, the highest rate of available phosphorus in the soil was recorded in the F3O2 treatment over other treatments, which amounted to 239.44 mg p kg^{-1}. As for the binary interaction between furfural and phosphorus, the highest rate of available phosphorus in the soil was recorded when treating F3P3 over other treatments, which amounted to 363.00 mg p kg^{-1}.

The results of the table also show the binary interaction between organic fertilizer and phosphorus. The highest rate of available phosphorus was recorded in the O2P3 treatment over other treatments, which amounted to 291.00 mg p kg^{-1}. The triple interaction treatments between furfural, phosphorus, and organic fertilizer indicate an increased in the concentration of phosphorus in the F3P3O2 treatment, as the highest rate of available phosphorus was recorded over other treatments, which amounted to 383.33 mg p kg^{-1}.

Effect of furfural, phosphorus, and organic matter on soil organic matter values

Results in table 6 show that adding the third level, F3 of furfural residues led to an increase in the soil's organic matter content, which reached 5.22 g kg^{-1} compared to the first and second levels (5.00 and 4.79 g kg^{-1}). This is confirmed by previous studies [7, 19, 20, 24] that adding furfural to the soil increases the soil's organic matter content. The addition of the third level P_3 of phosphate fertilizer has led to a decreased in the soil content of the organic material, as it reached 4.91 g kg^{-1} compared to the first and second levels (5.01 and 5.01 gm kg^{-1}). [21] pointed that the increase in phosphorous levels in the soil leads to an increased in the growth of the roots of plants and their secretions, and this affects the activity of microorganisms, which increases their ability to decompose the organic matter.

Table 6. Effect of furfural, phosphorus and organic matter on organic matter values (g kg^{-1}) soil duration of 15 days incubation period

Furfural levels (gm kg^{-1})	**Organic matter levels (gm kg^{-1})**	**Levels of added phosphorus, (gm p kg^{-1} soil)**			**F × O**
		P_1	P_2	P_3	
F_1	O_1	2.47	2.42	2.34	2.41
	O_2	7.29	7.18	7.05	7.17
F_2	O_1	2.62	2.60	2.60	2.60
	O_2	7.52	7.40	7.27	7.39
F_3	O_1	2.92	2.84	2.74	2.83
	O_2	7.72	2.62	2.48	7.61
R.L.S.D 0.05			NS		NS
Interaction of furfural and phosphorus					F
F × P	F1	4.88	4.80	4.69	4.79
	F2	5.07	5.00	4.93	5.00
	F3	5.32	5.23	5.11	5.22
R.L.S.D 0.05			NS		0.047
Interaction of organic matter and phosphorus					O
O × P	O1	2.67	2.62	2.56	2.62
	O2	7.51	7.40	7.27	7.39
R.L.S.D 0.05			0.081		0.037
Averages		5.09	5.01	4.91	
R.L.S.D 0.05			**0.047**		

The results of the table also showed that the second level of organic matter O2 increased the soil content with organic material, as it reached 7.39 mg kg $^{-1}$ compared to the first level O1 (2.62 g kg^{-1}). [22, 23] showed that the addition of organic matter improves soil structure and increases its water retention capacity, which increase the activity of microorganisms in the soil and accelerates the process of decomposition of organic matter . The binary interaction between organic matter and phosphorus indicate that the P1O2 treatment increased the soil content of organic matter over other parameters ,which amounted to 7.51 mg kg^{-1}. Table 6 shows no significant effect of binary and triple interactions of furfural and phosphate fertilizer.

Table 7. Effect of furfural, phosphorus and organic matter on soil organic matter values (g kg^{-1}) at 30 days

Furfural levels (gm kg^{-1})	**Organic matter levels (gm kg^{-1})**	**Levels of added phosphorus, (gm p kg^{-1} soil)**			**F × O**
		P_1	P_2	P_3	
F_1	O_1	2.24	2.22	2.20	2.22
	O_2	6.53	6.24	6.13	6.30

F_2	O_1	2.43	2.37	2.31	2.37
	O_2	6.75	6.48	6.36	6.53
F_3	O_1	2.64	2.62	2.62	2.63
	O_2	6.96	6.70	6.57	6.74
R.L.S.D 0.05			NS		NS
Interaction of furfural and phosphorus					F
F × P	F_1	4.39	4.23	4.16	4.26
	F_2	4.59	4.43	4.33	4.45
	F_3	4.80	4.66	4.59	4.68
R.L.S.D 0.05			NS		0.040
Interaction of organic matter and phosphorus					O
O × P	O_1	2.44	2.40	2.37	2.40
	O_2	6.75	6.47	6.35	6.52
R.L.S.D 0.05			0.058		0.032
Averages		4.59	4.44	4.36	
R.L.S.D 0.05			**0.040**		

phosphate fertilizer and the interaction between furfural and phosphorus on organic matter values at 15 days incubation period.

Table 7 shows the effect of furfural, phosphorus and organic matter on organic matter values at a 30-day incubation period, as the results show that the third level F3 increased the soil content of organic matter, which amounted to 4.68 g kg^{-1} compared to the first and second levels (4.45 and 4.26 g kg^{-1}). The addition of the P3 level of phosphate fertilizer led to a decreased in the soil content of organic matter, as it reached 4.36 g kg^{-1} compared to the first and second levels. The results of the table 7 showed that the second level of organic fertilizer O2 increased the soil content of organic matter, reaching 6.52 g kg^{-1} compared to the first level O1 (2.40 g kg^{-1}). The binary interference coefficients between organic matter and phosphorus indicate that the O2P1 treatment increased the soil content of organic matter over other treatments which amounted to 6.75 g kg^{-1}. These results were similar to those of the 15-day period. It is noted that there is no significant effect of the bilateral and triple interactions of furfural and phosphate fertilizer added and the interaction between furfural and phosphorus on the values of organic matter.

4. Conclusion

The results showed that the 30-day incubation period was superior to the 15 days in terms of reducing the degree of soil pH, values, and increasing available phosphorus in the soil. Also, the level of addition of 1200 mg kg^{-1} soil of furfural residue was superior in reducing the degree of soil pH and increasing available phosphorus in the soil and the soil content of Organic matter: Adding phosphate fertilizer at a level of 1000 mg P kg^{-1} led to an increase in the availability of phosphorus in the soil, and the level of adding organic matter of 40 tons ha^{-1} increased the availability of phosphorus in the soil and the soil content of organic matter.

REFERENCES

[1] R. J. Simpson, A. Oberson, R. A. Culvenor, M. H. Ryan, E. J. Veneklaas, H. Lambers, and A. E. Richardson, "Strategies and Agronomic Interventions to Improve the Phosphorus-Use Efficiency of Farming Systems," *Plant Soil*, vol. 349, pp. 89-120, 2011.

[2] T. L. Roberts and A. E. Johnston, "Phosphorus Use Efficiency and Management in Agriculture," *Resour., Conserv. Recycl.*, vol. 105, pp. 275-281, 2015.

[3] A. Martínez-García, M. Ortiz, R. Martínez, P. Ortiz, and E. Reguera, "The Condensation of Furfural with Urea," *Ind. Crops Prod.*, vol. 19, no. 2, pp. 99-106, 2004.

[4] H. R. Yang and W. G. Gong, "The Influence of Different Soil Amendments on Physico-Chemical Properties of Saline-Alkali Soil in Songnen Plain," *J. Anhui Agric. Sci.*, vol. 20, pp. 8715-8716, 2008.

[5] Y. Wu, G. Xu, and H. B. Shao, "Furfural and Its Biochar Improve the General Properties of a Saline Soil," *Solid Earth*, vol. 5, no. 2, pp. 665-671, 2014.

[6] Y. Sun, Z. Wang, Y. Liu, X. Meng, J. Qu, C. Liu, and B. Qu, "A Review on the Transformation of Furfural Residue for Value-Added Products," *Energies*, vol. 13, no. 1, pp. 21, 2019.

[7] Y. Zhao, Z. Yan, J. Qin, Z. Ma, Y. Zhang, and L. Zhang, "The Potential of Residues of Furfural and Biogas as Calcareous Soil Amendments for Corn Seed Production," *Environ. Sci. Pollut. Res.*, vol. 23, pp. 6217-6226, 2016.

[8] M. M. Al-Jaberi, "Effect of Paper Mill Sludge (Furfural) on Soil Respiration, Urease Activity, and Ammonia Volatilization of Calcareous Soils," *J. Wildl. Biodivers.*, vol. 28, no. 7, pp. 217-229, 2023.

[9] J. Esmaeilzadeh and A. G. Ahangar, "Influence of Soil Organic Matter Content on Soil Physical, Chemical and Biological Properties," *Int. J. Plant, Anim. Environ. Sci.*, vol. 4, no. 4, pp. 244-252, 2014.

[10] F. J. Stevenson, "Extraction, Fractionation and General Chemical Composition of Soil Organic Matter," in *Humus Chemistry: Genesis, Composition, Reactions*, F. J. Stevenson, Ed., 1982.

[11] G. Appireddy, K. S. Saha, B. L. Mina, S. Kundu, G. Selvakumar, and H. S. Gupt, "Effect of Organic Manures and Integrated Nutrient Management on Yield Potential of Ball Pepper (Capsicum Annuum) Varieties and on Soil Properties," *Arch. Agron. Soil Sci.*, vol. 54, no. 2, pp. 127-137, 2008.

[12] A. L. Page, R. H. Miller, and D. R. Kenney, *Methods of Soil Analysis. Part 2 Chemical and Biological Properties*, Amer. Soc. Agron. Inc., Madison, WI, 1982.

[13] T. Murphy and J. R. Riley, "A Modified Single Solution Method for the Determination of Phosphate in Natural Waters," *Anal. Chim. Acta*, vol. 1, no. 27, pp. 31-36, 1962.

[14] H. Waldrip, M. S. Erich, and Z. He, "Effects of Poultry Manure Amendment on Uptake by Ryegrass, Soil Phosphorus Fractions and Phosphatase Activity," *Biol. Fertil. Soils*, vol. 47, no. 4, pp. 407-418, 2011.

[15] A. T. Smit and W. J. J. Huijgen, "The Promotional Effect of Water-Soluble Extractives on the Enzymatic Cellulose Hydrolysis of Pretreated Wheat Straw," *Bioresour. Technol.*, vol. 243, pp. 994-999, 2017.

[16] A. N. Sharpley, U. Singh, G. Uehara, and J. Kimble, "Modeling Soil and Plant Phosphorus Dynamics in Calcareous and Highly Weathered Soils," *Soil Sci. Soc. Am. J.*, vol. 53, no. 1, pp. 153-158, 1989.

[17] J. A. S. A. Al-Arkwasi, "The Effect of Organic and Phosphate Fertilizers on Phosphorus Readiness During the Growth Stages of Tomato Plants," M.S. thesis, Dept. Soil and Water Sci., College of Agriculture, Baghdad Univ., Iraq, 2000.

[18] L. Wang, X. Sun, S. Sun, T. Zhang, W. Zhang, and P. Zhang, "Application of Organic Amendments to a Coastal Saline Soil in North China: Effects on Soil Physical and Chemical Properties and Tree Growth," *vol. 9*, no. 2, e89185, 2014.

[19] Y. N. Dou, Y. P. Zhang, and G. Cui, "Study on Preparation of Humic Acid Soluble Fertilizer by Using Furfural Residue," *J. Anhui Agric. Sci.*, vol. 43, pp. 41-43, 2015.

[20] A. Deng, Q. Lin, Y. Yan, H. Li, J. Ren, C. Liu, and R. Sun, "A Feasible Process for Furfural Production from the Pre-Hydrolysis Liquor of Corncob via Biochar Catalysts in a New Biphasic System," *Bioresour. Technol.*, vol. 216, pp. 754-760, 2016.

[21] B. L. Turner and L. M. Condron, "Pedogenesis, Nutrient Dynamics, and Ecosystem Development: The Legacy of T. W. Walker and J. K. Syers," *Plant Soil*, vol. 367, pp. 1-10, 2013.

[22] K. Hu, H. X. Li, W. S. Lu, Y. J. Liu, and L. B. Wang, "Effect of Microbial Organic Fertilizer Application on Soil Microbial Activity," *Chin. J. Eco-Agric.*, vol. 18, no. 2, pp. 303-306, 2010.

[23] S. Bhunia, A. Bhowmik, R. Mallick, and J. Mukherjee, "Agronomic Efficiency of Animal-Derived Organic Fertilizers and Their Effects on Biology and Fertility of Soil: A Review," *Agronomy*, vol. 11, no. 5, pp. 823, 2021.

[24] R. F. H. Al-Muhammadawi, "Polyphosphate Decomposes in Two Sandy and Muddy Soils and Its Effect on Some Indicators of the Growth of the Hair Vulgar L.," M.S. thesis, Dept. Soil and Water Sci., College of Agriculture, Albasrah Univ., 2016.

[25] M. Abd, A. Al-Kadhim, A. Sarab, A. Al-Janabi, and D. F. Hassan, "The Effect of Organic Waste and the Duration of Incubation on the Chemical Equilibrium Phases of Phosphorus in Gypsum Soils," *Iraqi Agric. Res. J.*, vol. 22, special issue, pp. 2027, 2017.