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Interactions of Phosphatic Fertilizers and Organic Matter under Different Incubation Periods for Enhancement of Phosphorous Availability in Soil

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ABSTRACT

Background: A laboratory incubation experiment was conducted to determine the enhancement in phosphorus availability in combination with organic matter and phosphatic fertilizers.

Methods: A factorial experiment was designed with a completely randomized design (CRD) with three replications and three factors to evaluate the phosphorus availability at three incubation periods of 15, 33 and 60 days, respectively. The first factor is mono potassium phosphate fertilizer (KH_2PO_4) at four levels (0, 10, 20, 30) mg P kg^{-1} soil and the second factor are two types of organic matter (OM), sheep and poultry manure and the third factor is organic matter levels (0, 1, 2%).

Result: The results showed a significant increase in the average of available phosphorus levels (28.07, 29.02 and 29.67) mg P kg^{-1} for P3 level at 15, 33 and 60 days, respectively. Results showed that poultry manure was significantly superior (21.62, 22.56 and 23.54 mg P kg^{-1}) compared to sheep manure (15.92, 16.59 and 17.35 mg P kg^{-1}) at all incubation periods, 15, 33 and 60 days, respectively. The level (2%) of organic matter presented the highest significant result for phosphorus available. Moreover, the combination of the added phosphate fertilizer with organic matter led to an increase in phosphorus availability over time. Therefore, for sustainable agricultural management for using fertilizer with higher efficiency, it's recommended to mix it with organic manure to ensure a continuous supply of phosphorus for plants during the growing season.

Key words: Fertilizer, Manure, Nutrient availability, Organic matter, Phosphorus.

INTRODUCTION

Phosphorus (P) is considered one of the macronutrients that plays an important role in the growth and development of crop plants (Barman *et al.*, 2023). The total content of this element in the soil surface is low and its average is 0.6% P. Phosphorous is available in two forms of organic and inorganic forms needed by crop plants (Griffith, 2011). Most soils all over the world have low available phosphorus due to the nature of their composition, despite the fact that the total amount of it is still high (Nussaume *et al.*, 2011). In addition, most of the phosphorus is chelated by cations like calcium and magnesium (Von Vexhull and Mutert,1998), which makes it less available to plants (Raghothama, 1999). The behavior of adsorption, desorption and absorption for phosphorus is an important part of its migration and transformation in soils (Perazzolli *et al.*, 2016). Large quantities of phosphate fertilizer added can stimulate a rapid reaction between phosphorus and iron, calcium and aluminum, leading to the formation of complexes and making the nutrients difficult to absorb by the plant root. In addition, many factors affect the amount of fixed phosphorus, including soil pH, humidity, clay minerals in soil and temperature (Toro, 2007). Therefore, calcareous soil has a sufficient content of phosphate, but it is in the form of low-soluble compounds as a result of the reactions to which it is exposed, such as fixation with carbonates in the soil solution (Al-Husseini, 2013).

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Organic fertilization is an important technique used to help manage land. Organic fertilizers are added to the soil and will help to facilitate the reaction between P and Ca^{+2}, Al^{+2} and Fe^{+3} as they chelate to these cations, which enhances the solubility of phosphate compounds and, more importantly, the concentration of nutrients such as phosphorus in the soil. The addition of organic fertilizers will also lower pH, cover the adsorption zones and prevent

P from precipitating as hydroxyapatite (HA) (Shariatmadari, 2006). Organic fertilizers can be made from either plant or animal materials. Charcoal has been shown to improve both chemical and physical properties of soil (Ahmed *et al*., 2025). The addition of organic matter to the soil will readily increase the amount of available phosphorus and the soil fertility (Spencer, 2008; Bader *et al*., 2021; Raju, 2025). An example of a viable alternative to chemical fertilizers is poultry manure (pm). The primary purpose of using (pm) in agriculture trials is to act as an organic soil amendment to introduce nutrients to the soil that will help sustain crops. Due to the presence of NPK and other high nutrient levels within (pm), it is considered a unique organic fertilizer (Garg and Bahla, 2008). Sheep manure is considered an effective source of organic fertilizer that helps improve soil properties. Sheep droppings improve the availability and soluble phosphorus by extending the incubation time, as per AL-Magimia (2019).

This study was focused on the interaction between organic fertilizer and phosphorus to increase the availability of nutrients, especially phosphorus. As mentioned by Matura *et al*. (2023) the organic fertilizer makes the soil environment rich in nutrients by increasing fixation (Nitrogen), mineralization (phosphate) and solubilization (potassium). It is believed that the decomposition of organic matter over time and the release of essential nutrients like phosphorus may be the reason. Therefore, this research is aimed at finding out the impact of various doses and kinds of organic waste on phosphorus availability during different incubation periods.

MATERIALS AND METHODS

Soil sampling and analyses

The laboratory experiment was conducted at the plant production department at Northern Technical University Technical Institute, Hawija, Iraq, during the summer season 2024-2025. The sampling was taken from the surface layer at a depth of 0-30 cm from the agricultural field at Kirkuk state, Iraq, which is located at longitude 43.78106 east and north latitude 35.33603. The soil sample was air-dried and then sieved through a 2 mm sieve. Soil pH and electrical conductivity (EC)1:3 soil to distilled water ratio, 35 min shaking, according to Black (1965), organic matter (OM) (Walkley-Black method) by using wet oxidation and described in Jackson (1958), for $CaCO_3$ was used back titration method (Jackson,1958) and soil texture (hydrometer method) contents were determined according to the methods of Black (1965).While the available nutrients for each of the nitrogen estimated by potassium chloride (2M KCl) according to the method of Mulvaney and Bremner (1982), phosphorus was estimated by soil extraction with sodium bicarbonate ($NaHCO_3$ 0.5M) at pH 8.5 (Olsen *et al.*, 1954) using a spectrophotometer at 840 nm. The potassium was estimated by ammonium acetate (1N) (Pratt, 1965). The results of soil properties are shown in Table 1.

Poultry and sheep manure analysis

Organic extract (1:5 organic fertilizer: water) was used to estimate pH according to Jackson (1958). Organic fertilizer was digested by the wet method, taking 0.2 g of manure and adding concentrated sulfuric acid for 24 hours and then heating up for 30 min then adding the acid concentration 70% until a clear solution was obtained. Organic carbon calculated by wet oxidation, Walkley-Black method, according to Jackson (1958). Total nitrogen in manures was estimated using concentrated acids (H_2SO_4 and $HClO_4$) microkeldhal (Page *et al.*, 1982). Estimated total phosphorus using a spectrophotometer (882 nm) after digesting the samples, following the method mentioned by Matt (1970). For determining total potassium using a flame photometer, the following method by Richards (1954). The content of poultry and sheep manure is shown in Table 2.

Incubation experiments and design

The experiment was conducted in the laboratory of the plant production department at Northern Technical University Technical Institute, Hawija, Iraq. To carry out the factorial experiment with three factors, a completely randomized design (CRD) with three replications was employed. Since the first factor was a phosphate fertilizer and the mono potassium phosphate fertilizer (KH_2PO_4) was the source of P, the four levels of phosphate fertilizer (0, 10, 20 and 30) mg P kg^{-1} soil were denoted as (P0, P1, P2, P3), respectively.

Table 1: Physical and chemical properties of soil.

Parameters		Value	Unit
pH (1:1)		7.6	-
EC (1:1)		2.63	ds m^{-1}
Organic matter		0.95	%
Calcium carbonate		15	%
Available nitrogen		12	mg kg^{-1}
Available phosphorus		7.90	mg kg^{-1}
Available potassium		168	mg kg^{-1}
Soil texture	Sand	37	%
	Silt	48	%
	Clay	15	%
Textural class		Loam	

Table 2: Chemical properties of poultry and sheep manure used in the experiment.

Parameters	Value		Unit
	Sheep manure	Poultry manure	
pH	7.66	7.29	-
Nitrogen	2.81	3.89	%
Phosphorus	0.498	0.539	%
Potassium	0.88	0.56	%
Carbon	42.05	34.10	%
C : N	14.96	10.80	-
C : P	84.43	78.01	-

The content of KH_2PO_4 fertilizer is P_2O_5= 52% and K_2O= 34%. The second factor is the type of organic waste (sheep and poultry manure), these being indicated by S1 and S2, respectively. The third factor, organic waste level (0, 1, 2) % for both kinds of manure, is indicated by (M0, M1, M2). Soils after air drying and sieving through a 2 mm mesh were weighed at 1 kg and put in plastic containers. Phosphorus and organic waste were added at the levels specified above. After mixing fertilizer and organic waste with soil, distilled water was sprinkled to bring the soil moisture back to field capacity and then it was placed in a conditioner at 25°C. Data collection was done at three dates (15, 33 and 60 days) during the two-month (60-day) incubation period. At the end of these times, the Olsen extractable-P was extracted with $NaHCO_3$ at pH 8.5 and its concentration was determined by a spectrophotometer at 840 nm.

Statistical analysis

All data in the research were collected and analyses using a SAS program. The Duncan test was set up to determine the significant differences among means at the confidence level (0.05) (Al-Rawi and Khalaf Allah, 2000).

RESULTS AND DISCUSSION

The results in Table 3 show a significant difference among phosphorus levels at the incubation period 15 days, which increased with higher addition levels. Notably, P3 achieved the highest value (28.07) mg kg^{-1}, compared to the control treatment, which provided the lowest value (8.75) mg kg^{-1}.

The results obtained from poultry manure excelled those on sheep manure in increasing the availability of phosphorus on average (21.62, 15.92) mg kg^{-1}, respectively. This corresponds because poultry manure has a higher content of available nitrogen and phosphorus (Table 2), which leads to an enhancement of the availability of phosphorus in the soil, which is consistent with Al-Obaidi (2022). While the level (M2) significantly excelled at the rest of the levels and provided a value (25.40) mg kg^{-1} compared to the levels (M0, M1), which were given average (11.50, 19.41) mg kg^{-1}, respectively. These results are in line with the outcomes by Joseph *et al*. (2025).

The highest significant interaction between the phosphorus and the type of OM was at treatment P3S2 (32.33) mg kg^{-1}, while the lowest rate was with treatment P0S1 (7.72) mg kg^{-1}. As a binary interaction between the type of OM and its level, the highest value was at treatment

Table 3: Effect of phosphatic fertilizers and different levels of organic matter on available phosphorous at a 15-day incubation period (mg P kg^{-1} soil).

P	S		Average P
	S1	S2	
P0	7.72h	9.77g	8.75d
P1	11.00f	14.66e	12.83c
P2	21.16d	29.72b	25.44b
P3	23.81c	32.33a	28.07a

S	M			Average S
	M0	M1	M2	
S1	11.50e	16.79d	19.48c	15.92b
S2	11.50e	22.04b	31.33a	21.62a

M	P				Average M
	P0	P1	P2	P3	
M0	3.66i	6.00h	15.33f	21.00d	11.50c
M1	8.25g	15.16f	29.91b	24.33c	19.41b
M2	14.33f	17.33e	31.08b	38.88a	25.40a

M×S×P

P	S	M0	M1	M2
P0	S1	3.66k	10.00i	15.66fg
	S2	3.67k	6.50j	13.00h
P1	S1	6.03j	17.33f	20.66e
	S2	6.00j	13.00h	14.00gh
P2	S1	15.31g	36.16b	37.66b
	S2	15.33g	23.66d	24.50d
P3	S1	21.00e	24.66cd	51.33a
	S2	21.05e	24.00d	26.43c

M2S2 (31.33) mg kg^{-1} and the lowest value was at treatment M0S1(11.50) mg kg^{-1}. The interaction between M × P resulted in the treatment P0M0 having the lowest value (3.66 mg kg^{-1}), while the highest value was observed in the treatment P3M2 (38.88 mg kg^{-1}).

While the interaction of triple factors had a significant effect, as the P3S1M2 provided the highest mean (51.33) mg kg^{-1}, which surpassed the rest of the treatments, meanwhile, the lowest value was for the P0S1M0, which was at a rate of (3.66) mg kg^{-1}.

The results of Table 4 indicate that the concentration of available phosphorus in the soil increased with increasing phosphorus levels, as the (P3) offered the highest concentration average of phosphorus (29.02) mg kg^{-1}, whereas the level without the addition (P0) reached (9.66) mg kg^{-1} at the incubation period of 33 days. The results obtained showed that the available phosphorus increased with the increase in the levels of added phosphate fertilizer, which may be attributed to the fact that these soils are considered poor in their content of this element and respond to fertilizer additions. In addition to this increase is attributed to the role played by these wastes in increasing the availability of phosphorus, due to their production of carbon dioxide gas, which, through its release from the process of decomposing organic wastes and as a result of the dissolution of CO_2 in water, produces carbonic acid, which works to dissolve the precipitated phosphate compounds (Jenkinson, 1991). These results are consistent with AL-Migimia (2019). As for the type or source of animal manure, poultry manure was significantly superior to sheep manure and each of them reached (22.56 and 16.59) mg kg^{-1}, respectively. These results are consistent with what was reached by Donatus (2017). In addition to the level of animal fertilizer, which exceeded the third level (M2), its average reached (27.19) mg kg^{-1} compared to the control treatment (10.03) mg kg^{-1}.

The results of the Table 4 show that the interaction between phosphorus levels and the type of organic fertilizer was positive, P3S2 treatment recorded the highest average (33.69) mg kg^{-1}, while the control treatment P0S1 was (8.58) mg kg^{-1} recorded the lowest value. While the interaction of the type and level of OM and its levels, the treatment S2M2 had an average (33.22) mg kg^{-1} that exceeded all averages, as well as the combination S0M0 provided the lowest value (10.03) mg kg^{-1}. The interaction between phosphorus and organic matter level had a positive effect as the treatment P3M2 achieved (40.92) mg kg^{-1}, which was the highest value compared to the control treatment was (3.00) mg kg^{-1} was provided the lowest value. The treatment resulting from the triple interaction of phosphorus, OM type and levels

Table 4: Effect of phosphatic fertilizers and different levels of organic matter on available phosphorous at a 33-day incubation period (mg P kg^{-1} soil).

P	S		Average P
	S1	S2	
P0	8.58h	10.75g	9.66d
P1	11.86f	15.52e	13.69c
P2	21.57d	30.28b	25.92b
P3	24.36c	33.69a	29.02a

S	M			Average S
	M0	M1	M2	
S1	10.03e	18.58d	21.16c	16.59b
S2	10.03e	24.43b	33.22a	22.56a

M	P				Average M
	P0	P1	P2	P3	
M0	3.00k	5.09j	13.03h	19.00e	10.03c
M1	10.33i	16.74f	31.81c	27.15d	21.51b
M2	15.66g	19.25e	32.94b	40.92a	27.19a

M×S×P

P	S	M0	M1	M2
P0	S1	3.00m	12.66j	16.58h
	S2	3.03m	8.00k	14.74i
P1	S1	5.07l	18.74g	22.74f
	S2	5.09l	14.75i	15.75hi
P2	S1	13.06j	38.07c	39.74b
	S2	13.03j	25.54e	26.14e
P3	S1	19.00g	28.26d	53.81a
	S2	19.03g	26.04e	28.03d

P3S1M2 provided an average of (53.81) mg kg^{-1}, which was significantly superior to the rest of the treatments.

Table 5 displays the effect of added phosphate, the type of OM and its level on phosphorus availability at the incubation period of 60 days. The adding phosphate fertilizer controlled to a significant enhancement in phosphorus availability at all levels and its averages reached (10.54, 14.79, 26.77 and 29.67) mg kg^{-1} for levels P0, P1, P2 and P3, respectively and with an increase related to the control treatment (40.32, 153.98, 181.49) % for levels P1, P2, P3, respectively. This increase may be attributed to the fact that increased phosphorus levels led to an increase in the forms of exchangeable and dissolved phosphorus, which leads to increased availability (AL-Migimia, 2013). While poultry manure fertilizer outperformed sheep manure, both of them reached (23.54 and 17.35) mg kg^{-1}, respectively. In addition to the superiority of the last level over the rest of the levels, M2) of OM provided the highest rate (28.96) mg kg^{-1} and the lowest rate was in the control treatment (M0), which was (8.79) mg kg^{-1}.

Table 5 shows the results of the interaction of phosphorus levels and the type of OM, which was highly significant and the treatment P3S2 achieved the highest interaction rate (34.56 mg kg^{-1}). While the lowest interaction for that combination, P0S1, was (9.21 mg kg^{-1}). The result of the level and type interaction of OM was positive and the treatment S1M2 achieved significant differences, as it provided the highest average (34.75 mg kg^{-1}). However, S1M0 treatment provided the lowest average (8.80 mg kg^{-1}). The interaction of phosphate fertilizer and the level of OM, as the treatment P3M2 presented the highest average (43.34 mg kg^{-1}), while the lowest interaction was with the P0M0 treatment, which had a rate of (2.31 mg kg^{-1}). The resulting combination of the triple interaction between phosphorus, OM types and its level achieved P3S1M2 (56.66 mg kg^{-1}), the highest value and the treatment P0S1M0 provided the lowest value (2.30 mg kg^{-1}). It was observed that with increased incubation periods, an increase in phosphorus availability occurred, as the longer the incubation period, the higher the phosphorus availability, because the organic waste released phosphorus during the decomposition stage and the reactions to which it is exposed, including adsorption and precipitation. These results were in line with the findings of Mohsen (2025), who found that the organic acid present in organic fertilizers is the main agent that breaks down phosphate rock, which subsequently increases the level of released phosphorus in soil and enhances plants' absorption of it.

Table 5: Effect of phosphatic fertilizers and different levels of organic matter on available phosphorous at 60-day incubation period (mg P kg^{-1} soil).

P	S		Average P
	S1	S2	
P0	9.21g	11.78f	10.54d
P1	12.94f	16.64e	14.79c
P2	22.44d	31.09b	26.77b
P3	24.78c	34.56a	29.67a

S	M			Average S
	M0	M1	M2	
S1	8.80e	27.08b	34.75a	17.35b
S2	8.79e	20.08d	23.17c	23.54a

M	P				Average M
	P0	P1	P2	P3	
M0	2.31h	4.55g	10.97f	17.35e	8.79c
M1	12.33f	19.00de	34.66b	28.33c	23.58b
M2	17.00e	20.84d	34.66b	43.34a	28.96a

M×S×P

P	S	M0	M1	M2
P0	S1	2.30h	15.00f	18.33f
	S2	2.32h	9.66g	15.66f
P1	S1	4.60h	21.33e	24.01de
	S2	4.50h	16.66f	17.66f
P2	S1	10.94g	42.33b	40.00b
	S2	11.01g	27.00cd	29.33c
P3	S1	17.36f	29.66c	56.66a
	S2	17.35f	27.00	30.01c

CONCLUSION

The higher level of phosphate fertilization and organic matter addition provided a higher phosphorus availability and the poultry manure surpassed the sheep manure. For the incubation periods, the longer the incubation period provided the higher the phosphorus availability. Moreover, the combination of phosphate fertilizer addition with organic matter resulted in an enhancement in phosphorus availability over time. Therefore, for sustainable agricultural management for using fertilizer with higher efficiency, it's recommended to mix it with organic waste to ensure a continuous supply of phosphorus for plants during the growth seasons.

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Conflict of interest

The authors state that there is no conflict of interest.

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