# Effect Of Incubation Periods And Some Organic Materials On Phosphorus Forms In Calcareous Soils

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**Abstract.** An incubation experiment was carried out in plastic pots to study the application effects of the investigated organic materials (Humic acid (HA), Vinase (V), Clover straw (CS), and Ethylene diamin tetra acetic acid (EDTA).) on P forms in calcareous soils. Each organic material was applied to 200g soil at two levels (2.5 and 5.0%) as organic matter. The experiment was carried out for incubation time periods (0, 30, 60, and 120 days). The results indicated that the addition of all investigated organic materials caused increases in most soil P forms (Resin-P, organic-$P_o$, inorganic-$P_i$, and HCl-P) of the studied soils. These increases in P forms depended upon the type and level of the used organic material, the time of incubation and the soil type. Generally, in all studied soils, the investigated organic materials had the order of Vinasse > HA > CS > EDTA.

**Keywords:** Organic materials; Incubation; P forms and Calcareous soils.

## 1 Introduction

Phosphorus (P) is an essential macronutrient that is required by plants in relatively large quantities. It is an important nutrient in crop production, since many soils in their natural state do not contain sufficient levels of available P to maximize crop yield. Providing adequate P to plants can be difficult, especially in calcareous soils [8]. Organic acids, $CO_2$ and other products resulting from the microbial decomposition of organic matter may solubilize the insoluble phosphate forms by chelating cations, lowering soil pH and / or the partial occupation of organic anions on the surface of $CaCO_3$ and clay minerals [6]; [5]. Manure or alfalfa residues were reported to increase the resin Pi after 28 days of incubation. The water extractable P significantly increased above the control with biosolids, hog manure, cattle manure and commercial P fertilizer [12]. Application of Leucaena residues increased $NaHCO_3$-$P_i$ and NaOH-$P_i$ fractions from 6.45 to 20.63 mg / kg and from 14.36 to 20.47 mg / kg, respectively, at 4weeks of incubation [13]. Applications of manure to the soil showed to have the greatest influence on the HCl-P relative to the other P fractions [2].The addition of rice straw the residual P increased from 47.45 to 66.83 mg / kg at 4 weeks of incubation and decreased to 40.02 mg / kg at 8 weeks [13]. The main objectives of this study are to evaluate the application effect of some organic materials on P forms in calcareous soils and the P uptake by wheat plants grown on these soils.

## 2 Materials and Methods

### 2.1 Soil Sampling

Four soil samples were collected from the surface layers (0-20 cm) of some cultivated and uncultivated calcareous soils located in the areas of Wadi El-Assiuti and its interference zone with the Nile Valley. The soil samples were air-dried, ground and sieved through a 2-mm sieve. Some physical and chemical properties of the studied soils samples are shown in Table (1).

### 2.2 Types of organic materials

Four organic materials were used in order to study their effects on the phosphorus forms of these studied calcareous soils. They include 1). Humic acid (HA), 2) Vinase (V), 3) Clover straw (CS), and 4) Ethyllyene diamin tetra acetic acid (EDTA). Some chemical characteristics of these organic materials are shown in Table (2). Each used organic material was added to 200 g soil at two levels i.e., 2.5 and 5.0% as organic matter.

### 2.3 An incubation experiment

For types of soil samples (A, B, C and D) and four for types of organic materials were used in this experiment. Each used organic material was added to 200g of each soil in the plastic pot at two levels (2.5 and 5.0%) as previously mentioned. The experiment was carried out during 4 incubation time periods (0, 30, 60, and 120 days). Each treatment was replicated three times. Soil sample was moistened to its field capacity, then all soil samples were incubated at 24±2ºC.The incubated soil samples were adjusted their field capacity. Soil samples were taken from each treatment at the end of each incubation period. They were analyzed for some soil chemical properties, the available P and the extracted phosphorus forms.

### 2.4 Sequential phosphorus extraction.

A sequential phosphorus forms method reported by Hedley et al. (1982. Resin-P was extracted by shaking 1.5 g soil sample, 0.4 g resin oversaturated with 0.5M $NaHCO_3$ at 8.5 in a nylon bag and 30 mL deionized water for 16 h. according to [1]. Each soil sample after the previous step without the resin was shaked with 30mL of 0.5 M $NaHCO_3$ at 8.5 for 16 h to extract organic and inorganic P [3]. After extraction with $NaHCO_3$, the soil sample was shacked with 30mL of 0.1M NaOH for 16 h [23].

**Table (1).** Some physical and chemical properties of the selected soil samples under study.

| Property | Soil sample | | | |
|---|---|---|---|---|
| | A | B | C | D |
| Partical-siz distribution | | | | |
| Sand (%) | 77.43 | 78.11 | 90.50 | 92.17 |
| Silt (%) | 9.07 | 7.80 | 5.20 | 4.03 |
| Clay (%) | 13.50 | 14.09 | 4.30 | 3.80 |
| Texture | Loamy sand | Loamy sand | Sand | Sand |
| Saturation capacity (%) | 27.00 | 28.00 | 21.00 | 23.00 |
| pH (1:2.5) | 8.55 | 8.50 | 8.59 | 8.65 |
| EC (1:2.5 dS/m) | 1.30 | 1.27 | 1.79 | 1.43 |
| Organic matter (%) | 1.52 | 2.26 | 0.53 | 0.51 |
| $CaCO_3$ (%) | 16.50 | 19.00 | 25.00 | 35.00 |
| Soluble cations and anions (mmol/kg) | | | | |
| $Na^+$ | 4.55 | 2.55 | 7.57 | 5.10 |
| $K^+$ | 0.55 | 0.43 | 1.55 | 0.89 |
| $Ca^{+2}$ | 3.13 | 3.12 | 10.56 | 6.86 |
| $Mg^{+2}$ | 1.19 | 0.63 | 1.13 | 1.56 |
| $HCO_3^-$ | 0.58 | 0.83 | 0.71 | 0.42 |
| $Cl^-$ | 1.04 | 1.05 | 2.90 | 1.25 |
| $SO_4^{-2}$ | 60.00 | 57.50 | 103.00 | 75.00 |
| NaAOC-extractable Ca (g/kg) | 1.51 | 1.49 | 1.10 | 1.06 |
| $NaHCO_3$-extractable P (mg/kg) | 22.89 | 40.00 | 12.97 | 12.40 |
| P forms (mg/kg) | | | | |
| Resin-P | 13.24 | 24.34 | 7.34 | 6.54 |
| $NaHCO_3$-$P_i$ | 15.9 | 55.14 | 12.04 | 9.95 |
| $NaHCO_3$-$P_o$ | 9.09 | 44.46 | 5.22 | 5.09 |
| NaOH-$P_i$ | 19.44 | 45.64 | 13.05 | 8.54 |
| NaOH-$P_o$ | 10.61 | 36.88 | 5.05 | 4.69 |
| HCl-P | 184.30 | 221.10 | 86.18 | 78.29 |
| Residual-P | 775.52 | 1310.36 | 840.07 | 810.94 |
| Total of P | 1028.10 | 1738.19 | 968.95 | 924.04 |

**Table (2).** Some chemical characteristics of the studied organic materials.

| Character | Organic material | | |
|---|---|---|---|
| | Humic acid | Vinase | Clover straw |
| pH (1:2.5) | 11.66 | 4.36 | 7.16 |
| EC (1:2.5,dS/m) | 16.45 | 15.00 | 6.42 |
| Organic matter (%) | 2.99 | 5.01 | 98 |
| Total Ca (%) | 0.49 | 0.60 | 0.41 |
| Total P (%) | 0.015 | 0.02 | 0.06 |

Organic and inorganic P forms were determined in both $NaHCO_3$ and NaOH extracts that were determined after the addition of 5.5N $H_2SO_4$ and 0.4 g of ammonium persulfate $\{(NH_4)_2 S_2O_8\}$ and then the digestion for 1 h at 127 $^0$C . In the other aliquot, inorganic P was measured without any digestion and then the organic P was calculated by subtracting the inorganic P form amount. The soil sample from the previous step was shaked with 30mL of 1M HCl for 16 h according to [22].

## 3 Results and Discusion

### 3.1 Effect of Adding Organic Materials on Phosphorus Forms in Calcareous Soils

The results of P forms of the studied soils as affected by adding some organic materials (humic acid, vinasse, clover straw and EDTA) are showing in Tables 3, 4, 5 and 6. The addition of all investigated organic materials caused increases in most soil P forms of the studied soils. These increases in P forms depended upon the type and level of the used organic material, the time of incubation and the soil type. The effect of the investigated organic materials on soil P forms included the resin-P, $NaHCO_3$-$P_i$, $NaHCO_3$-$P_o$, NaOH-$P_i$, NaOH-$P_o$, HCl-P and residual-P.

#### 3.1.1 Resin-P

The soil resin-P form is considered the most available P pool for plant uptake. It was affected by the addition of organic materials. Moreover, it increased with increasing the level of the organic material. As the incubation time increased, the resin-P in all studied soils increased up to 60 days and then, it decreased at 120 days. (Tables 3, 4, 5 and 6). These results coincide with finding of [12]. On the other hand, [16] found that the addition of manure did not increase the most labile resin- extractable P after 2 and 16 weeks of incubation. In general, vinasse gave the highest levels of resin- P at each incubation time at both levels (2.5 and 5%) of application when it was added to all studied soils. It was followed by humic acid and then clover straw in their effect on increasing the levels of resin P in all studied soils. Generally, EDTA resulted in the lowest amounts of resin-Pin all soils at each incubation time. So, the investigated organic materials in most cases could be ranked in the order of vinasse > HA > CS > EDTA in increasing the level of resin-P form in all studied soils. Raslan (2007) found that the concentration of resin-P increased from 6.5 to 6.89 mg P $kg^{-1}$ after 5 years of continuous application of crop residues and from 5.75 to 11.56 mg P $kg^{-1}$ after 16 years of continuous application of crop residues. It is clear that B soil showed the highest level of resin-P form followed by A soil and then C soil. Meanwhile, D soil had the lowest level of this form. Therefore, the studied treated soils could be ranked according to the relative increases in the resin-P form in the order of D soil > C soil > A soil > B soil. As it was mentioned previously that D soil contained the highest content of $CaCO_3$ followed by C soil and then B soil. Meanwhile, A soil showed the lowest level of $CaCO_3$. So, the effect of the investigated organic materials on the dissolution of $CaCO_3$ and the chelation of dissolved calcium will be most pronounced in D soil in the resin-P form and less resulting in the higher respective increase noticed in B soil showing the lowest relative increase of this form.

#### 3.1.2 $NaHCO_3$ -P ($P_i$ and $p_o$).

Both $NaHCO_3$-$P_i$ and $NaHCO_3$-$P_o$ (Tables 3, 4, 5 and 6) of the studied soils increased with applying each investigated organic material. They also increased with increasing the applied level of each organic material. The $NaHCO_3$-$P_i$ form increased with increasing the time period of incubation up to 120 days. However, the amount of $NaHCO_3$-$P_o$ increased with increasing the time of incubation up to 60 days, and then, it decreased at 120 days. The highest levels of $NaHCO_3$- extractable P ($P_i$ and $P_o$) forms in most cases of the studied soils were recorded with the adding the vinasse, followed by humic acid and then clover straw for inorganic form. The lowest levels of both inorganic and organic forms were shown for EDTA treated soils. However, the application of both clover straw and humic acid resulted in similar $NaHCO_3$-$P_o$ levels in most studied soils. Generally, the application effect of the studied organic materials on increasing $NaHCO_3$-P in the studied soils had the order of vinasse > humic acid > clover straw > EDTA for the inorganic form and vinasse > humic acid ≈ clover straw > EDTA for the organic form. [12] found that the concentration of phosphorus in the $H_2O$, $NaHCO_3$, NaOH and HCl forms significantly increased above the control with addition levels from hog and cattle manures and fertilizers P amendments.

**Table (3):** Phosphorus forms of soil A as affected by some organic materials at different times of incubation.

| Treatment | Level | Resin- P | $NaHCO_3$ | | NaOH | | HCl-P | Residual-P |
|---|---|---|---|---|---|---|---|---|
| | | | Pi | Po | Pi | Po | | |
| | | (mg/kg) | | | | | | |
| | | Zero time | | | | | | |
| Control | 0 | 13.27 | 16.66 | 10.49 | 19.60 | 11.21 | 179.80 | 777.07 |
| Humic acid | 2.50% | 19.14 | 39.29 | 25.33 | 42.41 | 19.74 | 255.44 | 754.25 |
| Humic acid | 5% | 26.17 | 49.82 | 38.25 | 48.51 | 26.29 | 343.97 | 750.09 |
| Vinasse | 2.50% | 22.34 | 41.25 | 24.23 | 46.84 | 21.51 | 229.95 | 749.98 |
| Vinasse | 5% | 31.19 | 57.53 | 32.90 | 55.62 | 28.86 | 294.34 | 743.66 |
| Clover straw | 2.50% | 16.53 | 18.29 | 13.17 | 22.90 | 16.28 | 201.37 | 753.31 |
| Clover straw | 5% | 20.98 | 23.53 | 18.83 | 29.85 | 20.48 | 229.86 | 712.07 |
| EDTA | 2.50% | 14.99 | 20.20 | 16.69 | 23.59 | 14.45 | 189.55 | 748.63 |
| EDTA | 5% | 19.71 | 24.84 | 22.40 | 29.35 | 17.63 | 207.42 | 706.75 |
| | | | | 30 days | | | | |
| Control | 0 | 13.52 | 18.87 | 12.82 | 20.84 | 13.21 | 175.51 | 773.33 |
| Humic acid | 2.50% | 34.81 | 43.90 | 28.35 | 47.29 | 30.56 | 268.36 | 702.33 |
| Humic acid | 5% | 42.86 | 51.13 | 41.24 | 55.19 | 37.60 | 369.80 | 685.28 |
| Vinasse | 2.50% | 44.58 | 47.51 | 27.14 | 52.03 | 36.90 | 235.89 | 692.05 |
| Vinasse | 5% | 52.78 | 59.78 | 36.54 | 61.21 | 44.22 | 315.93 | 673.64 |
| Clover straw | 2.50% | 27.59 | 25.25 | 22.78 | 29.12 | 24.18 | 222.74 | 690.19 |
| Clover straw | 5% | 33.85 | 28.54 | 33.47 | 39.18 | 33.79 | 245.32 | 641.45 |
| EDTA | 2.50% | 19.36 | 23.97 | 19.25 | 26.93 | 20.73 | 195.96 | 721.90 |
| EDTA | 5% | 26.67 | 25.14 | 26.15 | 34.04 | 27.57 | 218.82 | 669.71 |

**Table (3):** Continued

| Treatment | Level | Resin- P | $NaHCO_3$ | | NaOH | | HCl-P | Residual-P |
|---|---|---|---|---|---|---|---|---|
| | | | Pi | Po | Pi | Po | | |
| | | mg/kg | | | | | | |
| | | 60 days | | | | | | |
| Control | 0 | 13.13 | 20.20 | 14.10 | 21.45 | 13.88 | 179.58 | 765.76 |
| Humic acid | 2.50% | 35.45 | 45.87 | 37.46 | 50.07 | 35.32 | 271.44 | 679.99 |
| Humic acid | 5% | 45.55 | 53.33 | 44.17 | 58.35 | 42.95 | 379.97 | 658.78 |
| Vinasse | 2.50% | 46.25 | 49.75 | 39.40 | 54.94 | 40.84 | 259.95 | 644.97 |
| Vinasse | 5% | 54.33 | 59.93 | 48.66 | 64.19 | 49.35 | 334.34 | 633.30 |
| Clover straw | 2.50% | 29.01 | 26.53 | 24.87 | 32.77 | 25.47 | 221.37 | 681.83 |
| Clover straw | 5% | 36.98 | 31.36 | 35.45 | 43.92 | 35.44 | 239.86 | 632.59 |
| EDTA | 2.50% | 20.55 | 24.54 | 20.65 | 29.08 | 22.12 | 201.55 | 709.61 |
| EDTA | 5% | 30.20 | 26.14 | 28.37 | 39.22 | 29.51 | 220.42 | 654.24 |
| | | | | 120 days | | | | |
| Control | 0 | 12.02 | 19.24 | 12.77 | 19.39 | 12.33 | 187.51 | 764.84 |
| Humic acid | 2.50% | 20.44 | 57.10 | 26.78 | 54.90 | 20.96 | 299.36 | 676.06 |
| Humic acid | 5% | 29.22 | 67.96 | 32.32 | 63.96 | 29.07 | 403.80 | 656.77 |
| Vinasse | 2.50% | 28.87 | 59.22 | 31.76 | 56.82 | 24.33 | 291.89 | 643.21 |
| Vinasse | 5% | 33.97 | 71.42 | 38.00 | 68.22 | 31.66 | 369.93 | 630.90 |
| Clover straw | 2.50% | 26.80 | 31.43 | 21.63 | 34.39 | 22.88 | 226.74 | 677.98 |
| Clover straw | 5% | 31.81 | 40.71 | 28.06 | 46.93 | 31.40 | 248.32 | 628.37 |
| EDTA | 2.50% | 14.77 | 26.79 | 19.14 | 32.56 | 20.56 | 213.96 | 700.32 |
| EDTA | 5% | 20.08 | 33.70 | 24.59 | 42.57 | 25.05 | 228.82 | 653.29 |

**Table (4):** Phosphorus forms of B soil as affected by some organic materials at different times of incubation.

| Treatment | Level | Resin- P | $NaHCO_3$ | | NaOH | | HCl-P | Residual-P |
|---|---|---|---|---|---|---|---|---|
| | | | Pi | Po | Pi | Po | | |
| | | mg/kg | | | | | | |
| | | Zero time | | | | | | |
| Control | 0 | 30.62 | 55.59 | 44.99 | 46.24 | 37.07 | 226.94 | 1296.65 |
| Humic acid | 2.50% | 39.94 | 59.88 | 49.87 | 64.35 | 45.54 | 321.43 | 1284.68 |
| Humic acid | 5% | 45.80 | 64.81 | 56.66 | 75.45 | 50.77 | 429.27 | 1270.43 |
| Vinasse | 2.50% | 45.43 | 63.41 | 52.64 | 68.55 | 49.86 | 302.56 | 1263.74 |
| Vinasse | 5% | 49.66 | 69.45 | 60.87 | 79.32 | 55.87 | 411.69 | 1227.33 |
| Clover straw | 2.50% | 32.79 | 57.14 | 47.89 | 46.17 | 40.42 | 251.80 | 1275.73 |
| Clover straw | 5% | 38.82 | 60.72 | 53.79 | 49.47 | 44.76 | 323.80 | 1194.33 |
| EDTA | 2.50% | 29.98 | 56.51 | 45.32 | 45.52 | 38.69 | 231.98 | 1290.19 |
| EDTA | 5% | 35.89 | 58.79 | 51.55 | 47.37 | 42.33 | 314.22 | 1188.04 |
| | | 30 days | | | | | | |
| Control | 0 | 31.03 | 56.66 | 47.32 | 48.03 | 37.87 | 252.92 | 1264.36 |
| Humic acid | 2.50% | 45.03 | 79.65 | 61.45 | 74.22 | 54.70 | 346.21 | 1204.43 |
| Humic acid | 5% | 53.23 | 85.36 | 68.65 | 83.52 | 66.60 | 459.08 | 1176.75 |
| Vinasse | 2.50% | 51.12 | 84.59 | 63.86 | 78.44 | 59.04 | 327.93 | 1181.21 |
| Vinasse | 5% | 62.31 | 92.87 | 71.69 | 89.78 | 72.99 | 439.60 | 1124.95 |
| Clover straw | 2.50% | 37.87 | 66.56 | 59.59 | 66.33 | 47.89 | 293.82 | 1179.88 |
| Clover straw | 5% | 42.99 | 72.42 | 68.24 | 69.87 | 53.88 | 384.45 | 1073.84 |
| EDTA | 2.50% | 32.47 | 63.90 | 54.36 | 59.81 | 42.89 | 275.23 | 1209.53 |
| EDTA | 5% | 39.07 | 67.05 | 62.34 | 64.80 | 49.65 | 345.78 | 1209.53 |

**Table (4):** Continued

| Treatment | Level | Resin- P | $NaHCO_3$ | | NaOH | | HCl-P | Residual-P |
|---|---|---|---|---|---|---|---|---|
| | | | Pi | Po | Pi | Po | | |
| | | mg/kg | | | | | | |
| | | 60 days | | | | | | |
| Control | 0 | 32.33 | 47.54 | 48.25 | 48.78 | 36.68 | 268.44 | 1256.17 |
| Humic acid | 2.50% | 48.32 | 82.63 | 63.04 | 76.25 | 56.54 | 370.05 | 1168.86 |
| Humic acid | 5% | 57.83 | 89.26 | 69.32 | 87.45 | 68.52 | 471.13 | 1149.68 |
| Vinasse | 2.50% | 56.87 | 85.37 | 66.54 | 79.36 | 61.76 | 359.74 | 1136.55 |
| Vinasse | 5% | 66.63 | 94.14 | 73.81 | 93.89 | 74.67 | 436.78 | 1114.27 |
| Clover straw | 2.50% | 39.64 | 67.61 | 61.59 | 67.06 | 49.89 | 316.30 | 1149.85 |
| Clover straw | 5% | 46.39 | 73.63 | 70.47 | 72.19 | 55.22 | 392.70 | 1055.09 |
| EDTA | 2.50% | 35.33 | 64.52 | 56.54 | 62.24 | 46.88 | 296.48 | 1176.20 |
| EDTA | 5% | 41.32 | 69.90 | 64.59 | 66.21 | 51.58 | 358.95 | 1085.64 |
| | | 120 days | | | | | | |
| Control | 0 | 30.41 | 46.21 | 46.35 | 48.84 | 36.09 | 272.10 | 1258.19 |
| Humic acid | 2.50% | 43.23 | 84.79 | 55.81 | 89.41 | 48.87 | 377.54 | 1201.04 |
| Humic acid | 5% | 51.23 | 91.07 | 60.10 | 98.54 | 57.17 | 475.43 | 1224.65 |
| Vinasse | 2.50% | 53.89 | 92.94 | 59.18 | 93.32 | 53.13 | 367.45 | 1126.28 |
| Vinasse | 5% | 58.87 | 99.53 | 65.89 | 103.16 | 66.85 | 438.10 | 1121.79 |
| Clover straw | 2.50% | 34.43 | 76.37 | 51.92 | 71.34 | 40.15 | 321.43 | 1156.30 |
| Clover straw | 5% | 43.38 | 81.82 | 59.31 | 79.70 | 48.32 | 409.28 | 1043.88 |
| EDTA | 2.50% | 32.48 | 68.91 | 47.49 | 65.72 | 36.55 | 304.96 | 1182.08 |
| EDTA | 5% | 38.81 | 74.06 | 53.83 | 72.08 | 43.99 | 369.39 | 1086.03 |

**Table (5):** Phosphorus forms of C soil as affected by some organic materials at different times of incubation.

| Treatment | Level | Resin- P | $NaHCO_3$ | | NaOH | | HCl-P | Residual-P |
|---|---|---|---|---|---|---|---|---|
| | | | Pi | Po | Pi | Po | | |
| | | mg/kg | | | | | | |
| | | Zero time | | | | | | |
| Control | 0 | 7.42 | 12.15 | 5.25 | 13.25 | 5.11 | 86.88 | 838.89 |
| Humic acid | 2.50% | 13.43 | 23.59 | 10.65 | 25.87 | 9.91 | 226.77 | 786.23 |
| Humic acid | 5% | 21.58 | 29.51 | 16.84 | 31.43 | 19.09 | 281.92 | 823.58 |
| Vinasse | 2.50% | 19.3 | 26.3 | 18.32 | 29.01 | 19.6 | 216.39 | 748.03 |
| Vinasse | 5% | 28.4 | 36.45 | 24.87 | 38.75 | 28.5 | 263.55 | 764.43 |
| Clover straw | 2.50% | 8.44 | 17.24 | 8.52 | 16.93 | 7.63 | 134.29 | 789.65 |
| Clover straw | 5% | 13.14 | 23.81 | 13.11 | 22.29 | 15.95 | 164.56 | 743.59 |
| EDTA | 2.50% | 9.67 | 18.59 | 8.75 | 20.88 | 8.94 | 124.56 | 777.56 |
| EDTA | 5% | 15.08 | 26.73 | 12.09 | 26.78 | 16.51 | 152.8 | 718.96 |
| | | | | | 30 days | | | |
| Control | 0 | 12.59 | 13.58 | 5.85 | 15.06 | 5.42 | 99.95 | 816.5 |
| Humic acid | 2.50% | 26.16 | 30.27 | 20.68 | 35.15 | 17.36 | 232.06 | 769.77 |
| Humic acid | 5% | 38.13 | 39.66 | 28.78 | 47.64 | 26.78 | 290.27 | 822.69 |
| Vinasse | 2.50% | 31.98 | 37.1 | 27.36 | 39.39 | 21.59 | 220.69 | 698.84 |
| Vinasse | 5% | 43.87 | 49.88 | 35.14 | 54.48 | 35.76 | 278.91 | 686.91 |
| Clover straw | 2.50% | 19.01 | 23.31 | 15.24 | 18.87 | 11.54 | 174.51 | 720.22 |
| Clover straw | 5% | 26.22 | 31.22 | 20.47 | 28.3 | 21.66 | 202.99 | 665.59 |
| EDTA | 2.50% | 15.23 | 24.33 | 14.37 | 21.48 | 13.28 | 150.01 | 730.25 |
| EDTA | 5% | 21.45 | 33.5 | 19.25 | 29.96 | 19.15 | 182.33 | 663.31 |

**Table (5):** Continued

| Treatment | Level | Resin- P | $NaHCO_3$ | | NaOH | | HCl-P | Residual-P |
|---|---|---|---|---|---|---|---|---|
| | | | Pi | Po | Pi | Po | | |
| | | mg/kg | | | | | | |
| | | 60 days | | | | | | |
| Control | 0 | 11.64 | 13.55 | 3.87 | 15.88 | 5.76 | 96.44 | 821.81 |
| Humic acid | 2.50% | 28.27 | 34.52 | 22.54 | 37.58 | 19.05 | 238.69 | 718.8 |
| Humic acid | 5% | 42.56 | 39.34 | 28.51 | 49.55 | 28.73 | 305.19 | 740.07 |
| Vinasse | 2.50% | 31.62 | 38.43 | 33.98 | 42.89 | 25.21 | 227.95 | 680.87 |
| Vinasse | 5% | 49.23 | 52.26 | 39.93 | 56.23 | 43.1 | 292.75 | 661.45 |
| Clover straw | 2.50% | 21.24 | 25.68 | 17.85 | 22.15 | 13.08 | 178.09 | 706.61 |
| Clover straw | 5% | 28.21 | 33.32 | 22.37 | 31.96 | 23.73 | 211.12 | 650.74 |
| EDTA | 2.50% | 16.21 | 27.37 | 15.87 | 23.36 | 15.11 | 161.55 | 715.48 |
| EDTA | 5% | 23.87 | 36.89 | 20.46 | 33.98 | 25.32 | 189.33 | 642.1 |
| | | | | | 120 days | | | |
| Control | 0 | 9.13 | 13.31 | 3.57 | 14.66 | 4.12 | 98.43 | 825.73 |
| Humic acid | 2.50% | 18.3 | 38.38 | 18.41 | 38.15 | 14.75 | 245.6 | 712.86 |
| Humic acid | 5% | 29.25 | 45.83 | 24.35 | 46.39 | 20.1 | 321.16 | 727.87 |
| Vinasse | 2.50% | 25.38 | 50.98 | 22.62 | 44.33 | 18.87 | 239.96 | 665.81 |
| Vinasse | 5% | 35.36 | 63.52 | 29.57 | 58.24 | 28.27 | 314.28 | 646.71 |
| Clover straw | 2.50% | 19.63 | 32.25 | 12.07 | 27.6 | 14.7 | 168.59 | 699.86 |
| Clover straw | 5% | 23.35 | 38.64 | 17.23 | 37.84 | 25.47 | 202.87 | 643.05 |
| EDTA | 2.50% | 10.12 | 29.28 | 15.38 | 22.22 | 10.06 | 168.13 | 704.76 |
| EDTA | 5% | 16.13 | 37.29 | 18.88 | 29.77 | 17.16 | 201.94 | 638.78 |

**Table (6):** Phosphorus forms of D soil as affected by some organic materials at different times of incubation.

| Treatment | Level | Resin- P | $NaHCO_3$ | | NaOH | | HCl-P | Residual-P |
|---|---|---|---|---|---|---|---|---|
| | | | Pi | Po | Pi | Po | | |
| | | mg/kg | | | | | | |
| | | Zero time | | | | | | |
| Control | 0 | 6.23 | 11.21 | 5.03 | 9.32 | 4.61 | 78.88 | 808.76 |
| Humic acid | 2.50% | 10.94 | 19.01 | 8.21 | 24.08 | 9.88 | 173.69 | 805.73 |
| Humic acid | 5% | 18.20 | 27.22 | 14.35 | 29.37 | 16.48 | 274.52 | 798.90 |
| Vinasse | 2.50% | 15.95 | 22.21 | 15.87 | 25.47 | 17.17 | 141.77 | 793.60 |
| Vinasse | 5% | 24.70 | 34.32 | 20.36 | 36.91 | 25.29 | 198.84 | 799.62 |
| Clover straw | 2.50% | 7.02 | 13.93 | 6.46 | 15.87 | 7.46 | 114.60 | 772.45 |
| Clover straw | 5% | 10.01 | 19.99 | 9.81 | 21.34 | 11.41 | 128.85 | 750.13 |
| EDTA | 2.50% | 8.02 | 15.83 | 7.48 | 17.92 | 9.75 | 103.60 | 761.44 |
| EDTA | 5% | 12.62 | 21.58 | 10.24 | 24.91 | 13.78 | 124.29 | 716.62 |
| | | 30 days | | | | | | |
| Control | 0 | 7.41 | 12.16 | 6.45 | 10.36 | 4.76 | 83.50 | 799.40 |
| Humic acid | 2.50% | 23.34 | 28.38 | 18.25 | 29.05 | 13.65 | 185.23 | 753.64 |
| Humic acid | 5% | 36.07 | 37.33 | 25.54 | 38.63 | 19.32 | 284.33 | 737.82 |
| Vinasse | 2.50% | 28.04 | 32.83 | 24.35 | 34.22 | 22.69 | 156.63 | 733.28 |
| Vinasse | 5% | 41.24 | 46.22 | 33.75 | 48.33 | 39.91 | 228.34 | 702.25 |
| Clover straw | 2.50% | 17.44 | 20.44 | 13.45 | 18.54 | 11.24 | 129.19 | 727.49 |
| Clover straw | 5% | 22.92 | 28.50 | 18.54 | 27.41 | 19.40 | 158.97 | 675.80 |
| EDTA | 2.50% | 11.44 | 21.70 | 12.82 | 21.75 | 13.21 | 115.88 | 727.24 |
| EDTA | 5% | 15.31 | 30.97 | 17.77 | 29.42 | 18.88 | 137.04 | 674.65 |

**Table (6):** Continued

| Treatment | Level | Resin- P | $NaHCO_3$ | | NaOH | | HCl-P | Residual-P |
|---|---|---|---|---|---|---|---|---|
| | | | Pi | Po | Pi | Po | | |
| | | mg/kg | | | | | | |
| | | 60 days | | | | | | |
| Control | 0 | 7.32 | 12.18 | 4.27 | 13.51 | 3.83 | 92.63 | 794.28 |
| Humic acid | 2.50% | 25.19 | 30.54 | 20.58 | 30.72 | 14.95 | 194.89 | 734.67 |
| Humic acid | 5% | 38.81 | 38.54 | 26.13 | 41.3 | 22.92 | 298.41 | 712.93 |
| Vinasse | 2.50% | 29.25 | 34.7 | 28.34 | 36.93 | 24.22 | 181.1 | 697.5 |
| Vinasse | 5% | 47.31 | 48.59 | 35.93 | 50.44 | 40.67 | 269.21 | 647.89 |
| Clover straw | 2.50% | 18.68 | 22.12 | 15.54 | 19.35 | 13.04 | 135.22 | 713.84 |
| Clover straw | 5% | 24.37 | 29.25 | 19.25 | 29.67 | 21.89 | 165.82 | 661.29 |
| EDTA | 2.50% | 13.33 | 23.95 | 13.56 | 23.33 | 13.95 | 127.99 | 707.93 |
| EDTA | 5% | 17.28 | 32.89 | 18.25 | 31.87 | 22.89 | 150.1 | 653.76 |
| | | 120 days | | | | | | |
| Control | 0 | 7.26 | 11.78 | 3.43 | 13.35 | 3.64 | 95.12 | 789.46 |
| Humic acid | 2.50% | 14.88 | 38.83 | 15.08 | 31.78 | 12.22 | 209.37 | 729.38 |
| Humic acid | 5% | 25.12 | 45.21 | 21.37 | 43.32 | 19.29 | 315.4 | 709.33 |
| Vinasse | 2.50% | 22.21 | 45.95 | 18.08 | 37.7 | 20.75 | 189.32 | 698.03 |
| Vinasse | 5% | 29.74 | 56.52 | 27.35 | 57.65 | 29.75 | 298.14 | 640.89 |
| Clover straw | 2.50% | 17.89 | 28.85 | 9.85 | 26.25 | 8.89 | 138.58 | 707.48 |
| Clover straw | 5% | 20.84 | 35.63 | 13.83 | 34.33 | 16.17 | 181.97 | 648.77 |
| EDTA | 2.50% | 8.1 | 28.7 | 10.34 | 23.15 | 9.67 | 139.84 | 704.24 |
| EDTA | 5% | 10.22 | 36.34 | 14.72 | 29.6 | 17.06 | 151.85 | 653.25 |

[4] also reported that the amount of $NaHCO_3$ ($P_i$ and $P_o$) increased with the highest levels of manure addition. The levels of organic P form (extracted by $NaHCO_3$) at 5 to 20 cm depth tended to increase with applying of biosolid amendment [21]. The results on indicated that $NaHCO_3$-extractable $P_i$ levels are higher than $NaHCO_3$-$P_o$ ones in all studied soils. These may be attributed to that these studied soils of the arid regions have ion levels of organic matter. McGill and Cole (1981) showed that the increases in the organic P form, particularly NaOH- $P_o$, could be attributed the effects of biochemical immobilization. However, [19] found that the application of dairy manure had relatively little organic P leaching after 1 year. They also found that the continuous application of compost + NPK decreased the organic-P content with time.

**3.1.3 NaOH- ($P_i$ and $p_o$)**

Both inorganic and organic P forms extracted by NaOH increased with applying the investigated organic materials to all studied soils (Tables 3, 4, 5 and 6). They also increased with increasing the applied level of each organic material. Levels of inorganic P extracted with NaOH were higher than those of organic P in all studied soils that have low content of organic matter. The NaOH- extractable $P_i$ level increased with increasing the time of incubation up to 120 days, while the NaOH-$P_o$ level increased up to 60 days and then it decreased. The highest levels of both NaOH-$P_i$ and NaOH-$P_o$ were recorded for all soils that were treated with vinasse. Humic acid came in the second order after vinasse in increasing both inorganic and organic P levels extracted by NaOH in all studied soils. Both clover straw and EDTA caused lower NaOH-$P_i$ and NaOH-$P_o$ increases in all soils then humic acid. Similar results of these two forms were found with using clover straw and EDTA in A and D soils. In general, the investigated organic materials could be ranked according to both NaOH-$P_i$ and NaOH-$P_o$ increases in the order of vinasse > humic > clover straw > EDTA for A and B soils, and in the order of vinasse > humic acid > clover straw ≈ EDTA for C and D soils. A similar increase in the NaOH-$P_i$ of the soil due to applying organic matter was reported by [20] and [10]. Also, [18] showed that the concentration of NaOH-$P_i$ was the lowest under treatments that contained no organic additions and the largest concentration of NaOH extracted $P_i$ was observed under treatments with organic fertilizers. This contraversy may be due to using organic manure that had a high amount of inorganic P.

**3.1.4 HCl-P**

The HCl-extractable P is considered the Ca- and Mg-associated inorganic P [22]. It is generally assumed to be of low availability to plants [15]. The influence of the investigated organic materials, their level of application and the time of incubation on HCl-P levels of A, B, C and D soils are present in Tables 3, 4, 5 and 6, respectively. Levels of the HCl-P form of all studied soils increased with applying all investigated organic materials. Moreover, these levels increased with increasing the applied level of each organic material. The level of this form increased with increasing the time of incubation up to 120 days. Generally, in all studied soils, the investigated organic materials had the order of humic acid > vinasse > clover straw > EDTA concerning the recorded increases in the HCl-P form. Humic acid and EDTA have the highest ability to chelate and solublize the calcium of calcium phosphate minerals. However, the humic acid shows higher ability than EDTA. Humic acid have more sites to chelate calcium than EDTA. Vinasse has an acid effect so that it can solublize the calcium of calcium phosphate menirals. Clover straw produces organic acids during its decomposition. These results agree with those obtained by [9] they reported that in calcareous soils, the organic acids produced from the decomposition of organic materials increase the solubility of dicalcium phosphate dehydrate, a precursor for hydroxyapatite, and the major calcium bound P form at high pH values. On the other hand, [24] found that the HCl-P was the predominant P pool in the soil. Its relative content was not significantly affected by the treatments (liquid dry manure and minerals fertilizers).

**3.1.5 Residual-P**

The results of the residual P (Tables 3, 4, 5 and 6) in the studied soils indicated that B soil had the highest amounts of this P form. On the other hand, the other three soils had relative lower amounts of this form. Meanwhile, these three soils (soils A, C and D) had almost similar levels of this form. So, the treated studied soils could be arranged according to the residual P level as soil B >> soil C ≈ soil D ≈ soil A. Concerning the relative reductions of the residual P form induced by the addition of investigated organic materials, the studied soils could be ranked as C soil > D soil > A soil ≈ B soil. So, although B soil has the highest content of residual P, it has a low relative reduction percentage of this form resulting in a low percentage of P transforms to other soil P forms. [11] reported that the proportion of residual-P fraction declined slightly with dung manure application. In addition, [20] found that the residual P increased to 21% with time. In compost plot, the residual P was the predominant form (about 39% of total P) at the initial stage, followed by $P_i$ (around 28% of the total P) and $P_o$ (about 22% of total P). From previous discussion, it appears that the distribution of various soil forms of P with respective their levels native studied soils in the differed from a soil to another and according to their characteristics, especially their content of $CaCO_3$ and organic matter. A and D soils had a similar distribution of P forms. Their P from distribution had the order of Residual P > HCl- P > NaOH -$P_i$ ≈ $NaHCO_3$- $P_i$ > Resin- P > $NaHCO_3$- $P_o$ ≈ NaOH- $P_o$. Both A and D soils have high levels of $CaCO_3$ and low levels of organic matter (Table 2). On the other hand, A soil and B contain relatively low levels of $CaCO_3$ and high levels of organic matter (Table 2). The distribution of P forms in the native A soil showed the order of Residual -P > HCl- P > NaOH -$P_i$ ≈ $NaHCO_3$- $P_i$ > $NaHCO_3$- $P_o$ ≈ NaOH- $P_o$ > Resin- P and in the native B soil had the order of Residual-P > HCl-P > $NaHCO_3$- Pi > NaOH -$P_i$ ≈ $NaHCO_3$- $P_o$ > NaOH- $P_o$ > Resin- P.

## 4 Conclusion

Organic material additions resulted in increases in the levels of P forms due to the release of P from insoluble phosphate minerals and dissolution of calcium carbonate as a result of the products of organic material decomposition,

such as organic acids, $CO_2$ evolution and the released mineralized phosphorus.

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