TRANSFORMATION OF PHOSPHOROUS IN GYPSIFEROUS SOILS AS AFFECTED BY DIFFERENT FERTILIZERS, LAND USE AND INCUBATION PERIODS

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ABSTRACT

This study was investigated the P transformation in three soils gathered from different locations (Agricultural researches center in Tel Afar, Ain-Talawi and Sinu in Singar) in north of Iraq representing different gypsum content and land use [wheat (W), vegetable (V), uncultivated (Un)] after incubation period of (0, 5, 10, 30, 60, and 90) days. The soils were treated with 200 mg P kg^{-1} as superphosphate (S) or 30 g kg^{-1} soil manure as a cattle manure (A) or compost (p). The appropriate amounts of water were added to bring soil to estimated field capacity. After the specified time of each incubation period, sub-sample of soil analyzed for P, pH, EC and Ca. The results showed that P status affected by amendments and incubation periods. The soil which has more available P was the soil which treated with cattle manure. Generally, P was more available under (V) use compared to (W) use. After 90 days of incubation P solubility generally was higher than after 30 days. It appears from P solubility diagram that the best treatment was (A) which almost located between the two more soluble P compounds DCPD and DCP.

Key words: phosphorus availability, solubility diagram, land use, amendments, incubation

تحول الفسفور في الترب الجبسية المتاثرة بالأسمدة المختلفة، استخدام الأراضي وفترات الحضانة

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المستخلص

تم دراسة تحولات الفسفور في ثلاث ترب اخذت من مناطق مختلفة (مركز البحوث الزراعية–تلعفر, عين طلاوي وسينو–سنجار) في شمال العراق ذات محتوى مختلف من الجبس, ومن ترب اما مزروعة بالحنطة (W) او الخضروات (V) او غير مزروعة (Un) وحضنت لفترات تراوحت بين (0 و5 و 10 و30 و60 و 90) يوم. تم معاملة الترب ب 200 ملغم فسفور. كغم تربة $^{-1}$ على هيئة سوبر فوسفات (S) او 30 غم. كغم تربة $^{-1}$ اما على هيئة مخلفات ابقار (A) او كومبوست (P) وتم ترطيب التربة باضافة الكمية المناسبة لحدود السعة الحقلية. بعد كل فترة زمنية تم اخذ عينة من التربة لقياس الفسفورP و حموضة التربة pH و ملوحة التربة EC والكالسيوم Ca. أظهرت النتائج وجود تأثير للاسمدة وفترات الحضن على جاهزية الفسفور. حيث اعطت التربة المعاملة بالسماد الحيواني اعلى قيمة للفسفور ويشكل عام كانت جاهزية الفسفور اعلى تحت الترب المزروعة بالخضروات مقارنة بالترب المزروعة بالحنطة. وبعد 90 يوم من الحضن كانت قيم الفسفور اعلى مقارنة مع 30 يوم. يشير مخطط الاذابة بان افضل معاملة للحصول على اعلى جاهزية للفسفور هي الترب المعاملة بالسماد الحيواني (A) حيث وقعت بين الخطين الاكثر ذوبان DCPD و DCP.

الكلمات الفتاحية: جاهزية الفسفور, مخطط الاذابة, استخدام الاراضي, مصلحات, الحضن

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INTRODUCTION

Gypsiferous soils are the soils which containing more than 3% $CaSO_4.2H_2O$ (4) can be found in arid and semi-arid regions. Gypsum soils cover an estimated area of 88,000 km^2 in Iraq, representing about 20% of the country's total area (5). Soil gypsum originates principally from runoff water from gypsum-bearing rocks and water ground containing gypsum (25). A large proportion of total P is unavailable to plants in these soils due to rapid fixation of P into un-soluble form, which is not readily accessed by plant. Soils usually contain total P between 0.02% to 0.15 %. Nearly 80% of applied mineral P may be retained in the soil (6). The great part of P is not available for plants; therefore, it is considered one of the constrains of crop production (18). It has been found by Kordlaghari, *et al* (20) that the percentage of gypsum has a significant effect on phosphorous transformations and its sorption. They examined soils with different percentages of gypsum (0% and 13%) and showed that soils with 13% gypsum increase in large quantities the percentage of p sorption and therefore gave more precipitated forms until got to Hydroxyapatite form. At a high pH range, the precipitation of calcium phosphate increases as a result of the low solubility of these minerals (22). Therefor providing adequate P to plants can be difficult, especially in gypsiferous soils. Phosphorous (P) is an essential nutrient for plant growth, development, and production (24, 34). Available P relies on many factors, including organic matter content, soil texture, pH, precipitation with (Ca, Fe and Al), moisture content, diffusion rates, precipitation-dissolution processes and relative rates of adsorption-desorption (8). Phosphorus in soil is considered to be distributed among several geochemical forms that include soil solution and exchangeable phase, OM phase, Ca-bound phase, and Fe and Al-bound phases. The degree of P association with different geochemical forms strongly depends upon phyisico-chemical properties of the soils due to soil type, climate and management practices. These P fractions have remarkable differences in mobility, bioavailability, and chemical behaviors in soil and can be transformed under certain conditions. Muhawish, and Al-Kafaje (26) reported that the addition of organic amendments could represent an important strategy to maintain soil fertility. The application of cattle manure and organic residues to the soil reduces the capacity of P sorption and increases the available P to plants (15). This is supposed to be the outcome of the combined actions of several processes. These processes may include blockage sites of P sorption by organic products released from organic materials decomposition, and forming complexes with toxic ions such as Fe and Mn by organic acids (16).The most important factor in converting P to available P and in the soil is time, Kashem *et al.* (19) discovered that adding swine manure increased the water-extractable P fraction initially, but after 16 weeks of incubation, the water-extractable P fraction declined, while the P-$NaHCO_3$ fraction increased. A measure of the forms of P in soil amended with manures, and how these forms change with time, can provide important information on how these amendments affect soil test p and plant available P (19). In general, because P produced from manure is gradually transformed into available forms over time, manure application has a significant dynamic impact on P fractions (14). Identifying the predominate individual forms of inorganic P in soils is helpful in the determining potential availability of P in soils. Therefor the purpose of this study was to examine the effect of incubation time on the transformation of P fractions in gypsiferous soils after they were treated with various forms and rates of organic and inorganic fertilizers.

MATERIALS AND METHODS

Soil samples were taken from three sites in north of Iraq, the first was near the Agricultural researches center (AC) in Tal Afar district (36°22'19.77"N latitude and 42°23'39.47"E longitude), the second and third were from Ain Talawi (T) and Sinu (Si) villages in Sinjar district (36°22'1.30"N latitude and 42°13'33.18"E longitude) (36°21'12.15"N latitude and 42°10'59.76"E longitude) respectively, during the growing season 2020-2021. Three composite soil samples were taken from the surface layer (0-30cm) containing a wide range of sulfate content under different land uses, i.e. after harvest of wheat (W), vegetables (V) and uncultivated as a control (Un). The soil samples were air-dried, ground, sieved through a 2-mm sieve and subjected to various chemical analyses to assess the value of chemical and physical properties of these soils (Table 1). Soil pH and electrical conductivity were measured in extract of 1:2 soil-water ratios (7). Soluble cations (Ca^{++}, Mg^{++}, Na^{+}, K^{+}) and anions (HCO_3^{-}, CO_3^{-}, Cl^{-} and $SO_4^{=}$) were determined by standard methods according to (32). Cation exchange capacity (CEC) was determined using the method of extraction with ammonia acetate (1N) NH_4OAC (17). Total Nitrogen (TN) was determined using the Kjeldahl digestion procedure (9). Available phosphorus in soil was determined by extracting with 0.5 M $NaHCO_3$ at pH 8.5 outlined by (30). The total P (TP) was determined following wet digestion with H_2SO_4 (29) and the P was determined according to (27). The particle size distribution was measured using the hydrometer method, following the procedure of (13). Organic matter (OM) content was measured by the method described by (36). Equivalent calcium carbonate was measured with 1N HCl using Calcimeter apparatus. Active calcium carbonate (A-$CaCO_3$) was determined titremetrically using Droulinean procedure according by (21). Gypsum content was determined according to the method outlined by (31).

Incubation experiment

250g (air-dried, < 2 mm) of each soil was taken and treated with inorganic P (200 mg P kg^{-1}) as superphosphate or manure (30 g kg^{-1} soil) in the form of cattle manure or compost (produced from leaves, vegetables and fruits residues) (sieved from < 4 mm) (Table.2). The treated soils transferred to plastic containers (25 cm in Diameter), incubated at 25 ±1°C for up to 90 days and maintained at field capacity by weight calibration. The appropriate amount of water was added to bring the soil to the estimated field capacity. After the specified time 0, 5, 10, 30, 60 and 90 days, 30 g sub-sample of soils was obtained from each container, air-dried and analyzed for P, pH, EC and Ca. The incubation experiments were carried out in duplicate.

RESULTS AND DISCUSSION

Results of agricultural research center (AC) under wheat (W) use after 30 days of incubation were shown in figure 1. Soil that has more available P was the soil which treated with cattle manure (A), it located near the di-calcium phosphate (DCP) line. The other treatments i.e. compost (P), superphosphate (S) and the control (C) had less available p since they located on octa-calcium phosphate (OCP) line which have less soluble p compounds. The reason for that could be due to the high p concentration in cattle manure compared to compost Table 2. Waldrip *et al.* (35) reported that addition of cattle manure during the incubation period increased the soluble phosphorous. They attributed that to the mineralization of organic P which increase the desorption of mineral phosphorous. Figure 1, (V) showed data of the same location (AC) but was under vegetable use. The (A) treatment was falling between DCP and OCP, while (P) treatment located on di-calcium phosphate di-hydrate (DCPD) line and both (S) and (C) treatments on DCP line. Generally, phosphorous availability under (V) use was more than under (W) use, this may be due to the higher organic matter content and high available P in (V) soil caused by the high rate of phosphorous fertilizer applied to this soil during each season, presently, farmers do not use any system at all, and added fertilizers according to experience (personal communication with farmers) Table 1. Or this may be because organic matter reduces P adsorption and reduces the energy of P binding with mineral soil (11). It had been found a significant and positive correlation between organic matter and available phosphorous in soils (33). Considering Ain-Talawi (T) location, in general availability of phosphorous under (W) cultivation was higher for all treatment compared with (W) in (AC) location. Soil treated with cattle manure (A) had more available P under both (W) and (V) cultivation, its location was on DCPD for (W) and falling between DCPD and DCP for (V) use.

Table 1. Some physiochemical properties of used soils.

Samples Sites		AC			T			Si	
Land use	W	V	Un	W	V	Un	W	V	Un
pH	8.14	7.78	7.83	7.68	7.78	7.85	7.49	7.87	7.81
EC dSm^{-1}	0.55	4.22	4.02	5.28	4.88	4.80	4.94	5.44	4.40
Ca^{+2} (mmolc L^{-1})	4.80	40.00	38.50	64.40	59.60	60.00	63.20	60.40	56.70
Mg^{+2} (mmolc L^{-1})	1.20	14.00	4.30	8.60	6.40	5.00	3.80	11.60	4.20
Na^{+} (mmolc L^{-1})	0.32	1.78	0.22	1.94	0.65	0.24	0.44	1.21	0.21
K^{+} (mmolc L^{-1})	0.05	0.14	0.08	0.39	0.11	0.27	0.23	0.18	0.24
$CO3^{-}$ (mmolc L^{-1})	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$HCO3^{-}$ (mmolc L^{-1})	3.60	4.40	3.20	2.00	3.60	3.60	4.40	2.40	3.30
Cl^{-} (mmolc L^{-1})	1.60	4.00	2.20	3.60	1.60	1.20	1.20	1.60	2.50
$SO4^{-2}$ (mmolc L^{-1})	1.17	47.51	34.20	69.73	61.56	60.72	62.07	69.39	55.32
CaCO3 g kg^{-1}	334.12	303.45	268.32	171.09	300.22	192.08	225.17	69.41	162.20
A-CaCO3 g kg^{-1}	165.0	85.00	111.32	135.0	160.0	125.0	110.0	275.0	120.54
Gypsum g kg^{-1}	48.90	51.89	69.85	529.51	113.61	250.27	387.67	806.73	235.32
TN g kg^{-1}	1.10	1.40	1.45	1.10	1.70	1.70	1.60	4.50	1.66
P mg/l	4.78	37.89	4.35	7.17	16.39	9.56	10.92	18.26	8.69
OM g kg^{-1}	7.36	26.43	6.47	5.02	12.38	17.73	8.36	19.74	15.92
CEC Cmolc Kg^{-1}	24.97	23.29	18.98	12.75	9.23	17.15	7.17	11.95	10.11
Clay (g kg^{-1})	470.0	360.0	272.0	235.0	135.0	185.0	110.0	160.0	140.0
Silt (g kg^{-1})	400.0	330.0	453.0	375.0	650.0	425.0	470.0	620.0	510.0
Sand (g kg^{-1})	130.0	310.0	420.0	390.0	215.0	390.0	420.0	220.0	350.0
Texture	SC	CL	CL	L	SL	L	L	SL	SL

(SC=Silty Clay, CL= Clay loam, L= Loam, Silty loam)

Table 2. Some characteristics of cattle manure and compost

	Cattle Manure	Compost
pH (1:5)	7.54	7.2
EC dSm^{-1}	10.13	5.51
TN g Kg^{-1}	16.3	8.5
TP mg Kg^{-1}	4625.36	160.44
C:N ratio	17.85	15.74
C:P ratio	62.91	833.95
OM g Kg^{-1}	501.8	230.8
OC g Kg^{-1}	291.04	133.88

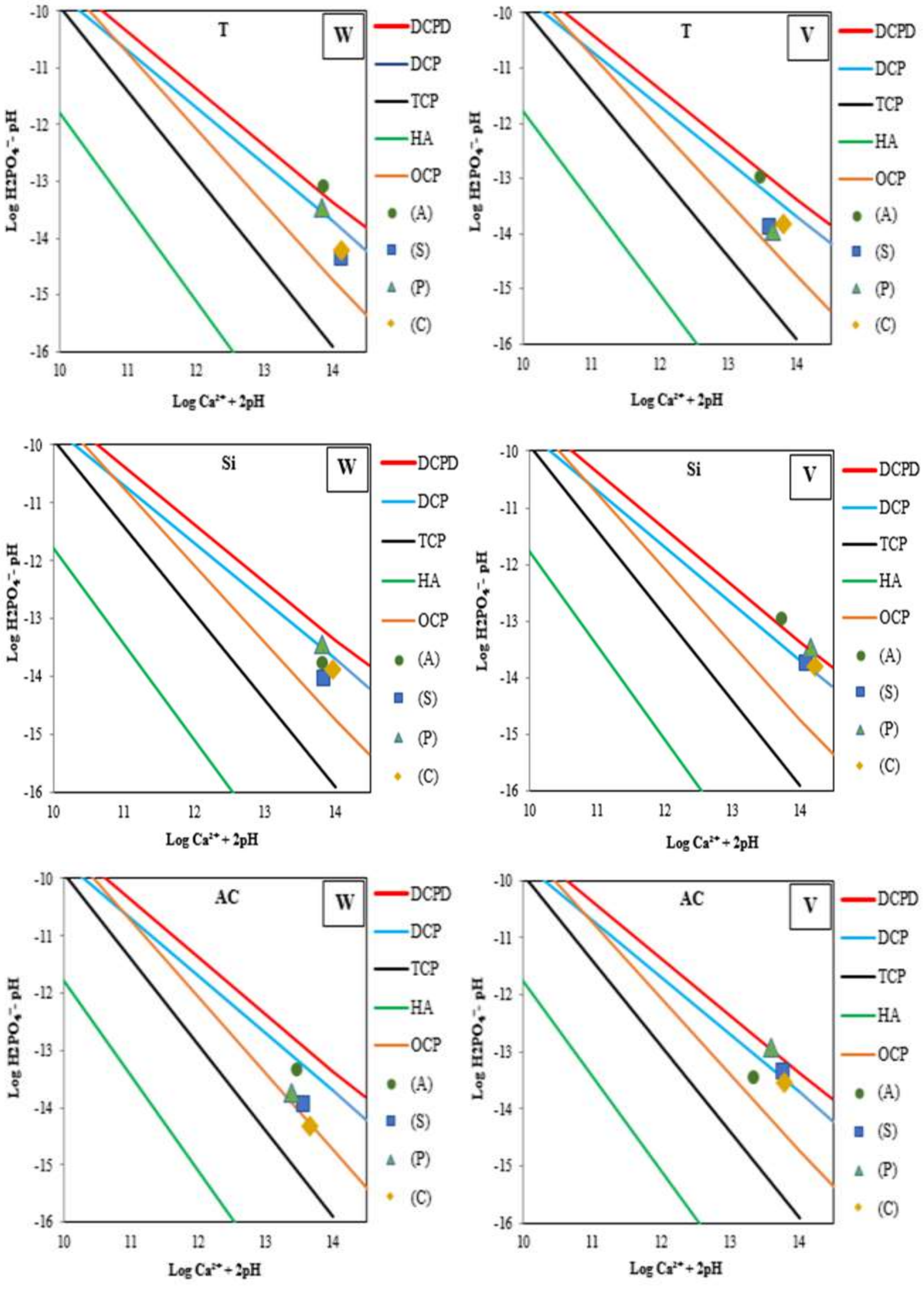

Figure 1. The effect of fertilizers and land use on availability of phosphorus after 30 days of incubation

The compost (P) plotted on DCP under (W) use whereas P was less soluble for the same treatment under (V) cultivation, i.e. it located between DCP and OCP. No differences were found between (P) and (C) treatments for (T) location, they fall between DCP and OCP but P was more available under (W) cultivation. The differences between the two locations (AC) and (T) may be related to the differences in clay percentage, organic matter content and active $CaCO_3$ (10) Table 1. Makttoof *et al.* (23) stated that active calcium carbonate has a large effect on P adsorption. In Sinu location (Si), P was less available under (W) compared to (V) use. compost (P) located on DCP while other treatments fall behind DCP line. Under (V) cultivation all treatments located between the two more soluble P compound DCPD and DCP. In general P availability was higher under (V) compared to (W) cultivation for all locations, this may be due to that the limiting factor was the percentage of clay and organic matter content which affect the CEC and control the exchange reactions (1). In addition, it could be attributed to the high initial P concentration in (V) soils Table 1. After 90 days of incubation, the solubility of P generally was higher than after 30 days Figure 2. Naser (28) mentioned that type of organic amendments and incubation period had a clear difference in amount of soluble P. The higher P availability occurred in (A) treated soil especially under (V) cultivation, it was behind DCP line after 30 days Figure 1, (V) and shifted above the most soluble line DCPD Figure 2, (V). No noticeable differences were found with (P) and (C) treatments after 90 days compared to 30 days. It was appeared that P from (S) treatment under (W) cultivation was fixed and became less available after 90 days of incubation. Galay (12), Muhawish and Al-Kafaje (26) stated that soluble P when added to soil containing high Ca, phosphorus precipitated as dicalcium phosphate or octa-calcium phosphate. Same trend was found in (T) location, the P availability increased for all treatments after 90 days Figure 2 (W) and (V) except for (S) treatment. Phosphorus from cattle manure (A) treatments were the highest, it located above DCPD line the most soluble form. The results for Sinu (Si) location also showed that the soil that have more available P was the (A) treated soil, it was shifted above DCPD line, whereas the water-soluble P (i.e. (S) treatment) which applied as superphosphate had less P availability Figure 2, (W) and (V). Figure 3 illustrate the changes in available P with incubation periods for the three locations. The effect of time on P availability varied with amendments and land use (2). In their study on the sequential fractionation of P in organic amendments showed that forms of P differ among different organic amendments. The two locations (AC) and (T) nearly gave a same trend for all treatments, i.e. there was more soluble P initially fallowed by a decrease between incubation periods 5-30 days then followed by increase except for the (S) and (Un) treatment the results clearly showed that the changes were very small. Al- Qurashy (3) reported that 1-2 months incubation period was not enough for transformation of P to the non-labile pool. The changes in solubility with time were best illustrated at the addition of cattle manure (A) under (V) use. The phosphorus availability follows the order VA >WA> VP> WP> VS> WS and (Un). Considering (Si) location the trend was different from the other two locations. Initially availability of P increased after 5 days with a concomitant decrease in (A) treatment under (W) cultivation. There was a decrease between 5-60 days of incubation, this indicates that the most labile P moved into less labile fraction, perhaps as a result of sorption processes (19).

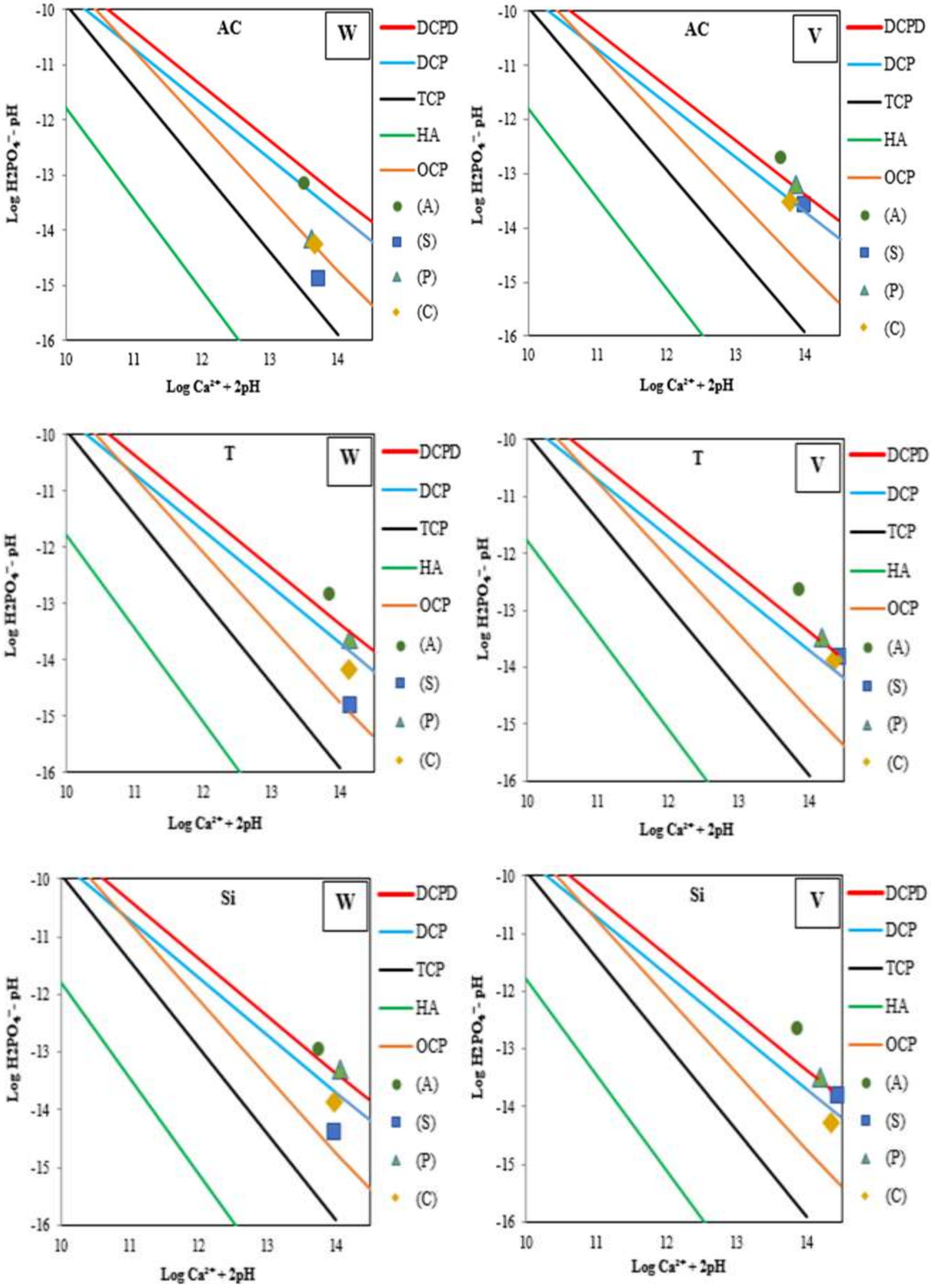

Figure 2. The effect of fertilizers and land use on availability of phosphorus after 90 days of incubation

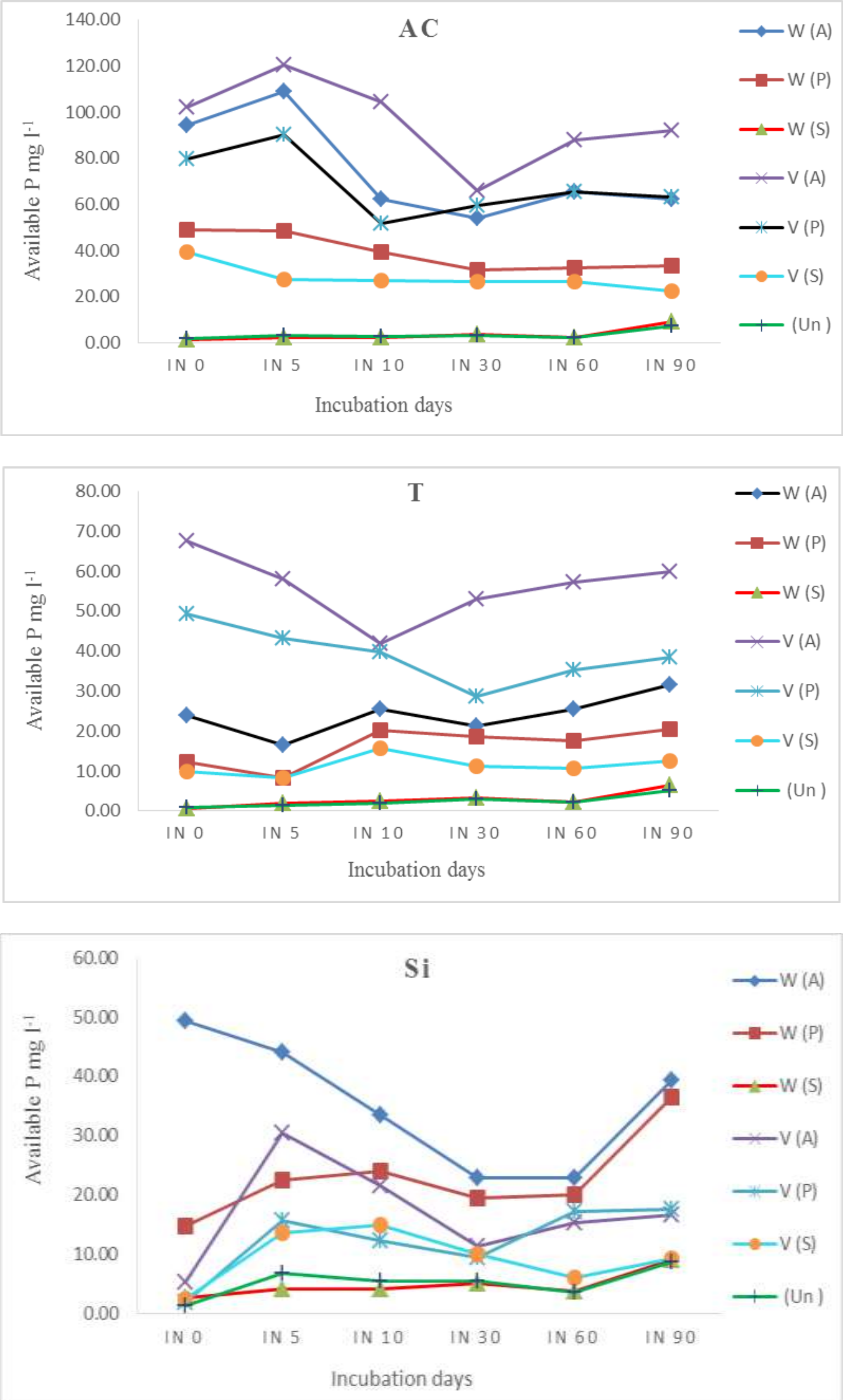

Figure 3. Effect of incubation periods on available phosphorus

Or this could be attributed to the differences in the physio-chemical properties of the soil used Table 1. The order of P availability followed the order WA>WP>VA> VP> VS> WS and Un.

CONCLUSION

This study showed a wide range of differences in P status of the different cultivated soils. Concerning the results of Figure 1,2 and 3, it appears from P solubility diagram that the best treatment was (A) which almost located between the two more soluble P compound DCPD and DCP.

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