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# INTERACTION OF SOIL ORDERS AND LEVELS OF APPLIED PHOSPHORUS ON P-STATUS OF SOIL CALTIVATED WITH WHEAT AT ELONGATION STAGE

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**ABSTRACT**

A pot experiment was carried out during autumn growing season of 2016-2017 at the Gerdarasha field of College of Agriculture Engineering Sciences, to study the effect of three dominant soil orders (Mollisols (M), Vertisols (V) and Aridisols (A)), five levelsof applied triple super phosphate (TSP) fertilizer (0, 80, 160, 240 and 320 kg TSP $ha^{-1}$) and combination between them on chemical availability of phosphorus (P) using solubility diagram at elongation stage and wheat yield. The factorial experiment was depended using a completely randomized design (CRD) with three replicates. The results indicated that the soil orders were affected on phosphorus status, it has appeared that the studied soil order was located between TCP and HA for both Aridisols and Vertisols it means the solubility of phosphorus is low. but in Mollisols is slightly more than Vertisols and Aridisols. It is the P-status and availability was very low since shifting towards TCP, it means precipitation of P in a non-available form then decrease in its availability. The application of phosphorus fertilizers caused shifting the points towards a more soluble form of phosphorus.

The results indicated that the application of TSP fertilizer increased the solubility of P in the studied dominate soil orders. Then, the treatment combination (M, V, A) $TSP_0$ were the nearest point to TCP falling between TCP and OCP which were the lowest soluble of phosphorus there less available, phosphorus application of phosphorus caused to shifting towards DCP In contrast, for treatment combination (M,V and A) $TSP_{320}$ kg $ha^{-1}$ were located between OCP and DCP the nearest point treatment combination for DCP

***Keywords:*** Solubility Diagram; Phosphate, Soil orders

## INTRODUCTION

Phosphorus is an essential macronutrient for plant growth, and it is limiting crop production in many regions of the world in many agricultural systems in which the application of phosphorus to the soil is necessary to ensure plant productivity, in calcareous soils the recovery of applied P by crop plants in a growing season is very low, since more than 80% of the P becomes immobile and unavailable for plant uptake due to adsorption, or precipitation, (Parfitt, 1978, and Holford, 1997)

Iraqi soils are containing large amount of calcium carbonate with slightly alkaline pH which causes chemical and physical fixation of 70-90% of applied phosphorus fertilizers as reported by Esmail, (2012).

In a previous studies conducted by Roy *et al*., (2006) and Shand, (2007.), phosphorus was absorbed as the orthophosphate ion (either as $H_2PO_4^-$ or $HPO_4^{2-}$) depending on soil pH. As the soil pH increased, the relative proportion of $H_2PO_4^-$ and $HPO_4^{2-}$ were increased. P is essential for growth, cell division, root lengthening, seed and fruit development, and early ripening. It is a part of several compounds including oils and amino acids. The P compounds adenosine di phosphate (ADP) and adenosine triphosphate (ATP) act as energy carriers within the plants.

Phosphorus is one of the most important essential macronutrients for plants, which contributes in numerous vital functions in plants like photosynthesis, energy transfer, respiration and cell division. The phosphorus availability and status were studied by numerous of investigators in Iraq like Hasan ; (1985), AlKhateeb *et al*., (1986), Al- Sulaivani ;(1993), Saeed; (2008), Galaly; (2010) and Rahman (2013) using solubility diagram.

Iraqi soils illustration different degrees of development according to the dominant local conditions mainly climatic and geological conditions. The results of the morphological, physical and chemical soil properties indicated to presence of five soil orders included, Aridisols, Entisols, Inceptisols, Mollisols and Vertisols (Ahmad, *et al.,* (2014.).

For studying solubility equilibrium of phosphate the double function parameters consisting of phosphate potential $\log H_2PO^-_4$-pH and lime potential ($\log Ca^{2+} + 2pH$) were used to construct a solubility diagram for calcium phosphate minerals. It was assumed that the free ion activity of $H_2PO^-_4$ was controlled by lime potential and pH based on published solubility product (KSP). It was also assumed that the solubility of phosphate in calcareous soils is controlled by a solid phase of calcium phosphate minerals (Lindsay, 1979, Shang, Tiessen, 1998, Khoshnaw, and Esmail, 2020)

Solubility equilibrium studies generally categorize soils into those with low pH in which iron (Fe) or aluminium (Al) phosphates control P solubility, or those with high pH in which P solubility is controlled by calcium (Ca) phosphates as reported by McDowell, *et al.,* (2003).

**Table 1:** Classification of the studied soils along with their geographic coordinates.

| Sample No | Location | Governorate | Order | Elevation above mean sea level (Altitude (m)) | GPS Reading | |
|---|---|---|---|---|---|---|
| | | | | | N | E |
| Hawler Vertisols | Harrier | Hawler | Vertisols | 619 | 36o32.793' | 44o18.308' |
| Hawler Mollisols | Hujran | Hawler | Mollisols | 787 | 36 o 16.387' | 44o17.796' |
| Hawler Aridisol | Makhmur | Hawler | Aridisol | 271 | 35.7773774 o | 43.562006 o |
| Duhok Vertisols | Semeel | Duhok | Vertisols | 569 | 36.867697 o | 42.969343 o |
| Duhok Mollisols | Zawita | Duhok | Mollisols | 967 | 36.900077 o | 43.146660 o |
| Duhok Aridisol | Fayda | Duhok | Aridisol | 372 | 36.712639 o | 42.971565 o |
| Sulaimani Vertisols | Bakrajo | Sulaimani | Vertisols | 731 | 35.529235 o | 45.335274 o |
| Sulaimani Mollisols | Halabja | Sulaimani | Mollisols | 501 | 35.300880 o | 45.954688o |
| Sulaimani Vertisols | Kfry | Sulaimani | Aridisol | 177 | 34.690550 o | 44.864398 o |

Phosphorus (P) retention and mobilization take place due to precipitation and adsorption in calcareous soils; however, it is not always easy to distinguish between the two mechanisms. Water soluble P fertilizers applied to soil react with the soil constituents to form less soluble phosphates. When added to soil containing large amounts of calcium, soluble P is usually precipitated as di calcium phosphate or octa-calcium phosphate as mentioned by Mam Rasul., (2016)., Muhawish,. and Al-Kafaje., (2017)

The high response for soil to orthophosphate O.P was recorded with respect to dicalcium phosphate dihydrate (DCPD) at high rate of application and within short and long period of O.P supply within 15 and 60 days mentioned by Rahman, (2013).

Rasheed, (2019) analyzed 120 soils from the wheat grown fields the results indicated that soils that have more available P, the P- compounds were in the form of DCP and TCP but soils that have less available P the P compounds were in the form of TCP and HA (un soluble form).

Since there are little or no studies about interaction of soil orders and levels of phosphorus fertilizer for this reason this studies was conducted to study the interaction effect of soil orders and levels of applied phosphorus on P-availability using solubility diagram

## MATERIALS AND METHODS

The studied soils included three dominant soil orders Mollisols (M), Vertisols (V) and Aridisols (A) according to United State Department of Agriculture (USDA) soil Taxonomy (soil survey staff, 1999), and Global Positioning System (GPS) reading of the selected locations were recorded from Table ( 1 )

Soils were included three dominant soil orders which were collected from Hawler, Sulaimani and Duhok governorates from the depth of 0-30 cm, then transported to Gerdarasha field then air dried and sieved by 4mm sieves for pot experiment. On 24/11/2016 (18) seeds of wheat (*Triticum aestivum*) directly planted in each pot, using factorial (CRD) with three replicates. Each soil order was taken from three locations and regarded as replications. The weight of soil per pots was 10 kg air dried soil.

Five levels of phosphorus fertilizer (0, 80, 160, 240 and 320 kg TSP $ha^{-1}$ ) which equivalent to (0, 0.2, 0.4, 0.6 and 0.8g TSP for 10 kg $^{-1}$ soil (pot) in three dominant soils orders (M, V, and A), while fixed amount of urea (0.6 g. urea 10 $kg^{-1}$ soils) which equivalent to (240 kg urea $ha^{1}$) was added to all pots. After the seeds were planted the pots were watered to field capacity, while subsequently irrigation depended on weighing method whenever needed. The irrigation was done after depletion 75% of available water depending on weighing method. The soil samples were taken at elongation stage for preparing solubility diagram

### Chemical and physical properties

The soils were air-dried, and sieved by 2 mm sieve and stored for laboratory analysis, table (2) shows some chemical and physical properties for the main soil order at different locations.

The soil analysis included Electrical Conductivity, soil calcium carbonate content (CaCO3) hygroscopic moisture content (H M), moisture at field capacity (FC) and wilting point (W.P), Particle size distribution, Soil pH, and organic matter content which were determined according to the standard methods mentioned by (Bashour and Sayegh, 2007). Used the regression equations to estimate the field capacity and wilting point depending upon the clay fraction % .( Karim, 1999).

### Determination of soluble P for solubility diagram:

Phosphorus in soil has been extracted by using distilled water with 0.01 *M* KCl and determined spectrometric ally according to Murphy and Riley (1962) as described in Black, (1980) using spectrophotometer model (Shimadzo at wave length 880nm). The chemical analysis and calculations for drawing solubility diagram were recorded in table (3).

### Phosphate solubility Diagram

Double function parameters consisting of phosphate potential log $H_2PO^-_4$-pH and lime potential (log $Ca^{2+}$ + 2pH) were used to construct a solubility diagram for calcium phosphate minerals. It was assumed that the free ion activity of $H_2PO^-_4$ was controlled by lime potential and pH based constant of solubility product (Ksp). It was

**Table 2:** The mean for some chemical and physical properties for dominant soil orders Mollisols, Vertisols, Aridisol in Hawler, Sulaimani and Duhok.

| Treatment | Particle Size Destitution | | | H M | FC | WP | SP | $CaCO_3$ | pH | EC |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | % | | | | g $kg^{-1}$ | | dS $m^{-1}$ |
| Mollisols Hawler | Sand | 23.00 | Silty loam | 5.05 | 21.25 | 11.59 | 39.52 | 300 | 7.39 | 0.36 |
| | Silt | 56.93 | | | | | | | | |
| | Clay | 20.06 | | | | | | | | |
| Mollisols Sulaimani | Sand | 11.41 | Siltyloam | 6.00 | 30.35 | 19.62 | 56.45 | 230 | 7.31 | 0.54 |
| | Silt | 45.59 | | | | | | | | |
| | Clay | 43.00 | | | | | | | | |
| Mollisols Duhok | Sand | 17.62 | Siltyclay | 4.86 | 30.25 | 19.53 | 56.27 | 210 | 7.54 | 0.485 |
| | Silt | 39.63 | | | | | | | | |
| | Clay | 42.75 | | | | | | | | |
| Vertisols Hawler | Sand | 45.24 | Siltyclay | 4.24 | 32.17 | 21.22 | 59.83 | 300 | 7.47 | 0.41 |
| | Silt | 7.19 | | | | | | | | |
| | Clay | 47.57 | | | | | | | | |
| Vertisols Sulaimani | Sand | 4.32 | Siltyclay | 4.71 | 35.37 | 24.04 | 65.78 | 268 | 7.464 | 0.31 |
| | Silt | 40.05 | | | | | | | | |
| | Clay | 55.63 | | | | | | | | |
| Vertisols Duhok | Sand | 3.50 | Siltyclay | 9.20 | 33.50 | 22.39 | 62.30 | 240 | 7.47 | 0.37 |
| | Silt | 45.58 | | | | | | | | |
| | Clay | 50.92 | | | | | | | | |
| Aridisol Hawler | Sand | 22.02 | Clay loam | 2.34 | 24.01 | 14.03 | 44.65 | 488 | 7.78 | 0.51 |
| | Silt | 50.96 | | | | | | | | |
| | Clay | 27.02 | | | | | | | | |
| Aridisol Sulaimani | Sand | 14.37 | Siltyclay loam | 3.78 | 25.76 | 15.58 | 47.92 | 460 | 7.72 | 0.45 |
| | Silt | 54.18 | | | | | | | | |
| | Clay | 31.45 | | | | | | | | |
| Aridisol Duhok | Sand | 22.11 | Clay loam | 2.89 | 27.78 | 17.35 | 51.67 | 590 | 7.92 | 0.46 |
| | Silt | 41.36 | | | | | | | | |
| | Clay | 36.53 | | | | | | | | |

**Table 3:** pH, (calcium and phosphorus activity), P-potential and lime potential for studied combination treatments.

| Code | pH | Soluble P mgL$^{-1}$ | Ca mgL$^{-1}$ | P moleL$^{-1}$ | Ca moleL$^{-1}$ | Log $H_2PO^{-4}$ | Log $Ca^{+2}$ | Log $Ca^{+2}$+2pH | Log $H_2PO_{-4}$.pH |
|---|---|---|---|---|---|---|---|---|---|
| Mollisols(H, S, D)$TSP_0$ | 7.763 | 0.098 | 38 | 3.16E-06 | 0.00095 | -5.49989 | -3.02228 | 12.50372 | -13.2629 |
| Mollisols (H, S, D)$TSP_{80}$ | 7.73 | 0.157 | 39 | 5.05E-06 | 0.000975 | -5.29639 | -3.011 | 12.449 | -13.0264 |
| Mollisols (H, S, D)$TSP_{160}$ | 7.753 | 0.179 | 42 | 5.76E-06 | 0.00105 | -5.23959 | -2.97881 | 12.52719 | -12.9926 |
| Mollisols (H, S, D)$TSP_{240}$ | 7.752 | 0.217 | 45 | 7.01E-06 | 0.001125 | -5.15446 | -2.94885 | 12.55515 | -12.9065 |
| Mollisols (H, S, D)$TSP_{320}$ | 7.877 | 0.340 | 46 | 1.10E-05 | 0.00115 | -4.96023 | -2.9393 | 12.8147 | -12.8372 |
| | | | | | | | | | |
| Vertisols(H, S, D)$TSP_0$ | 7.766 | 0.079 | 40 | 2.55E-06 | 0.001 | -5.59317 | -3 | 12.532 | -13.3592 |
| Vertisols(H, S, D)$TSP_{80}$ | 7.9 | 0.147 | 44 | 4.74E-06 | 0.0011 | -5.32404 | -2.95861 | 12.84139 | -13.224 |
| Vertisols(H, S, D)$TSP_{160}$ | 7.8 | 0.155 | 43 | 4.99E-06 | 0.001075 | -5.30228 | -2.96859 | 12.63141 | -13.1023 |
| Vertisols(H, S, D)$TSP_{240}$ | 7.9 | 0.167 | 44 | 5.39E-06 | 0.0011 | -5.26836 | -2.95861 | 12.84139 | -13.1684 |
| Vertisols(H, S, D)$TSP_{320}$ | 7.95 | 0.208 | 46 | 6.71E-06 | 0.00115 | -5.17307 | -2.9393 | 12.9607 | -13.1231 |
| | | | | | | | | | |
| Aridisols(H, S,D)$TSP_0$ | 7.8572 | 0.076 | 43 | 2.45E-06 | 0.001075 | -5.61163 | -2.96859 | 12.74581 | -13.4688 |
| Aridisols(H, S,D)$TSP_{80}$ | 7.81 | 0.120 | 48 | 3.88E-06 | 0.0012 | -5.41138 | -2.92082 | 12.69918 | -13.2214 |
| Aridisols(H, S,D)$TSP_{160}$ | 7.87 | 0.130 | 49 | 4.20E-06 | 0.001225 | -5.37631 | -2.91186 | 12.82814 | -13.2463 |
| Aridisols(H, S,D)$TSP_{240}$ | 7.94 | 0.142 | 48 | 4.58E-06 | 0.0012 | -5.33907 | -2.92082 | 12.95918 | -13.2791 |
| Aridisols(H, S,D)$TSP_{320}$ | 7.98 | 0.165 | 55 | 5.32E-06 | 0.001375 | -5.27388 | -2.8617 | 13.0983 | -13.2539 |

also assumed that the solubility of phosphate in calcareous soils is controlled by a solid phase of calcium phosphate minerals (Lindsay, 1979)

## RESULTS AND DISCUSSION

The results in Figure (1) explains phosphorus application on P status (solubility) at elongation stage of wheat plant, for the studied soil orders.

Figure (1) shows that the application of phosphorus fertilizers caused shifting the points towards more soluble form of phosphorus minerals. The P status in cause of ($TSP_0$,$TSP_{80}$, $TSP_{160}$) kg ha$^{-1}$ were plotted or located between tri-calcium phosphate TCP andoctacalcium phosphate OCP forms or the availability of phosphorus is very low, while in case of TSP 240 the point was located on OCP or the phosphorus is in equilibrium with OCP which is available form at rahizospher. On the other hand in case of application 320 kg TSP ha$^{-1}$ the point was plotted between OCP and DCP line, it means the application of 320 kg TSP ha$^{-1}$ caused increase in P-availability due to shifting the point towards the more soluble form of phosphorus minerals.

The results of the current study indicated that OCP and TCP minerals may be stable forms of P mineral in all soil orders. This is in agreement with the finding of Zhang *et al.,* (2014) who found that the solubility of phosphate in soil orders was controlled by TCP while in unfarmed soil it was controlled by HA. They also reported the increase in P-availability in farmed calcareous soil after several years due to P- fertilization. The increase in application of P-fertilizers caused increased in availability of phosphorus (Fig 1) which caused increase in wheat yield from 2.27 to 3.44 *Mg* ha$^{-1}$ for $TSP_0$ and $TSP_{320}$ respectively (table 4), supported by Saeed; (2008), Galaly ;(2010) and Esmail,(2012).

The results in Fig (2) shows the effect of dominant soil orders (Mollisols, Vertisols and Aridisols) on phosphate solubility in Hawler, Sulaimani and Duhuk soils of Kurdistan region at elongation stage for wheat plant in the studied soils.

Figure (2) illustrated that the P status was located between TCP and HA for Aridisols it means the solubility of phosphorus is low due to low solubility of phosphorus form (TCP and HA) for Aridisol .It is the nearest point for TCP line it means low phosphorus availability, but for Vertisols located on the TCP line while for Mollisols was located between TCP and OCP. Figure (2) explains the solubility of P in Mollisols is slightly more than Vertisols and Aridisols. It means the P-status and availability was very low due to shifting towards TCP, it means precipitation of P in non-available form then decrease in its availability reported by McDowell et al., (2003)and Rasheed, (2019).The

**Table 4.** Effect of different levels of phosphorus on grain yield and total dry

| Levels kg ha$^{-1}$ | Grain yield Mg ha$^{-1}$ |
|---|---|
| TSP0 | 2.27 |
| TSP80 | 2.54 |
| TSP160 | 2.85 |
| TSP240 | 3.29 |
| TSP320 | 3.44 |

**Table 5.** Effect of soil orders on grain yield and total dry matter

| Orders | Grain yield Mg ha$^{-1}$ |
|---|---|
| Mollisols | 3.09 |
| Vertisols | 2.83 |
| Aridisols | 2.71 |

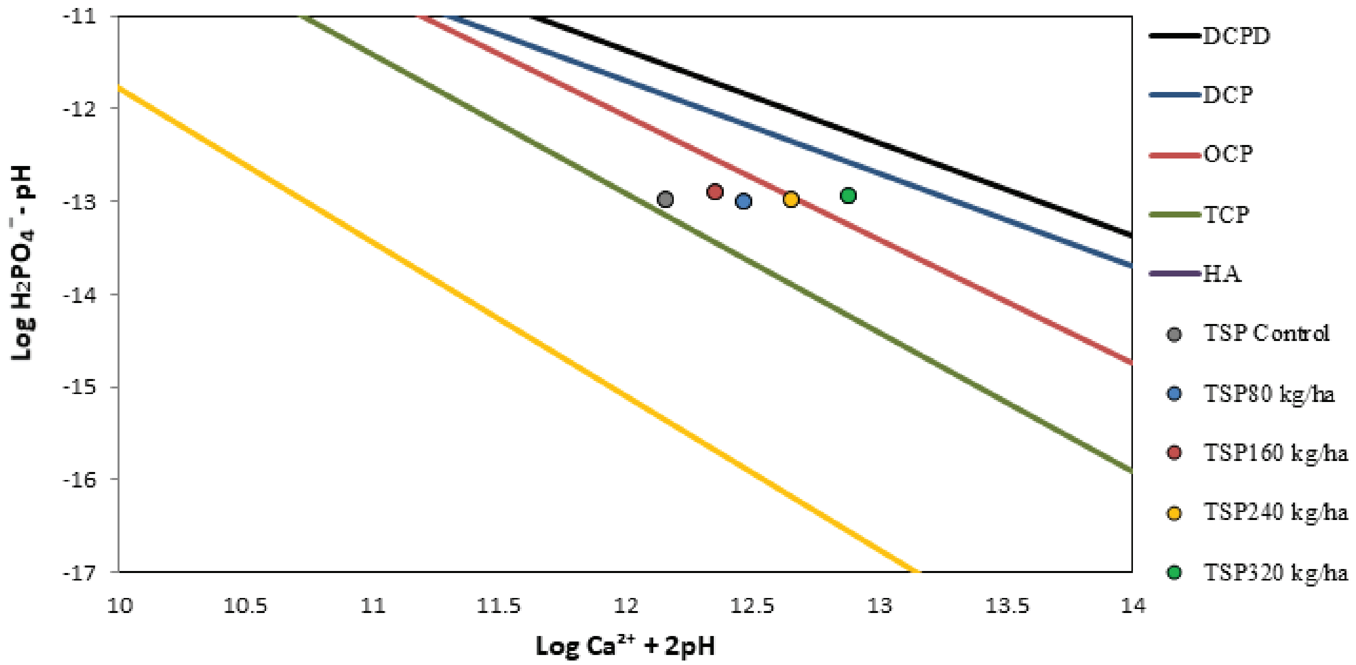


**Figure 1** shows the effect of levels of applaied phosphorus on availability of phosphorus at elongation stage of wheat.

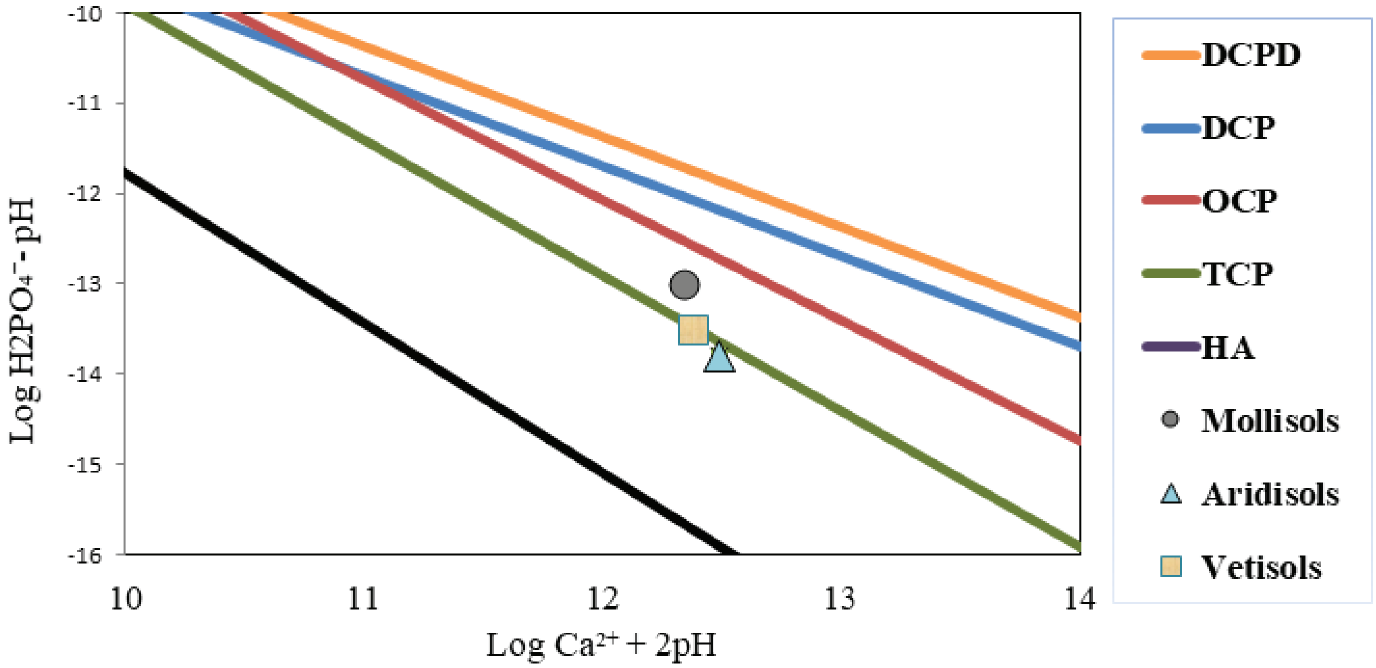


**Figure 2** The effect of dominant soil orders (Mollisols, Vertisols and Aridisols) on the solubility equilibria of phosphorus at elongation stage for wheat plant

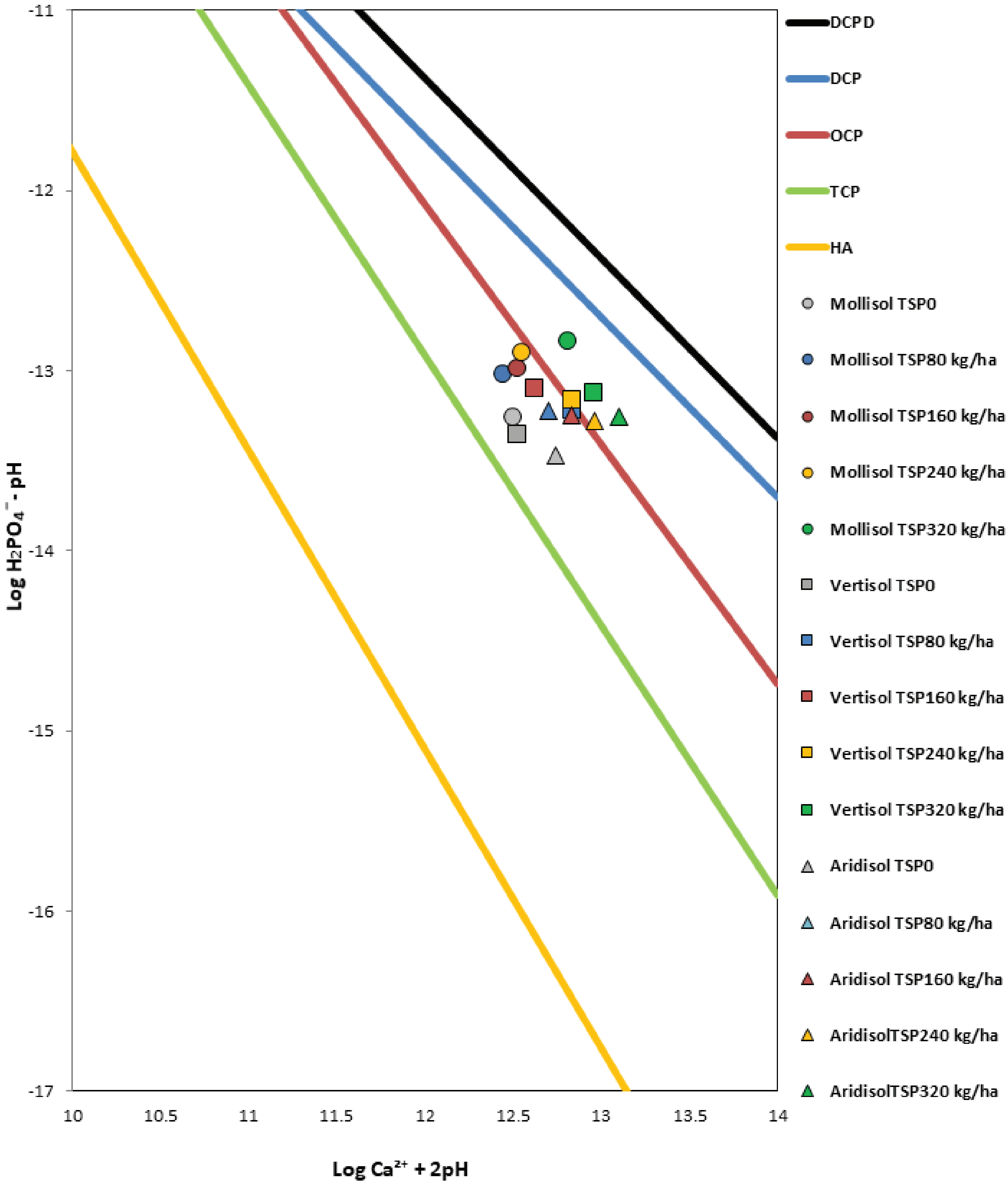


**Figure 3** Combination effect soil orders and levels of applied phosphorus on the P- solubility equiliberiain Kurdistan region at elongation stage of wheat plant

data analysis in the table (5) revealed the high mean yield value were (3.09, 2.83, 2.712 ) recorded in soil orders (Mollisols, Vertisols, Aridisols) respectively explains the above results for P- availability depending on solubility diagram

Figure (3) explains combination effect of soil orders and levels of applied TSP fertilizers on P-availability at elongation stage of wheat plant.

In general the combination between soil orders and levels of applied phosphorus fertilizer affected on phosphorus status.

The treatment combinations divided in to three groups. First group included 9 treatment combinations (Mollisols-$TSP_0$), (Vertisols-$TSP_0$), (Aridisols-$TSP_0$), (Mollisols-$TSP_{80}$) , (Aridisols-$TSP_{80}$), (Mollisols-$TSP_{160}$), (Vertisols-$TSP_{160}$), (Aridisols-$TSP_{160}$)and (Molisols-$TSP_{240}$) which were located between OCP and TCP. Second group, included three treatment combinations (Vertisols-$TSP_{80}$),

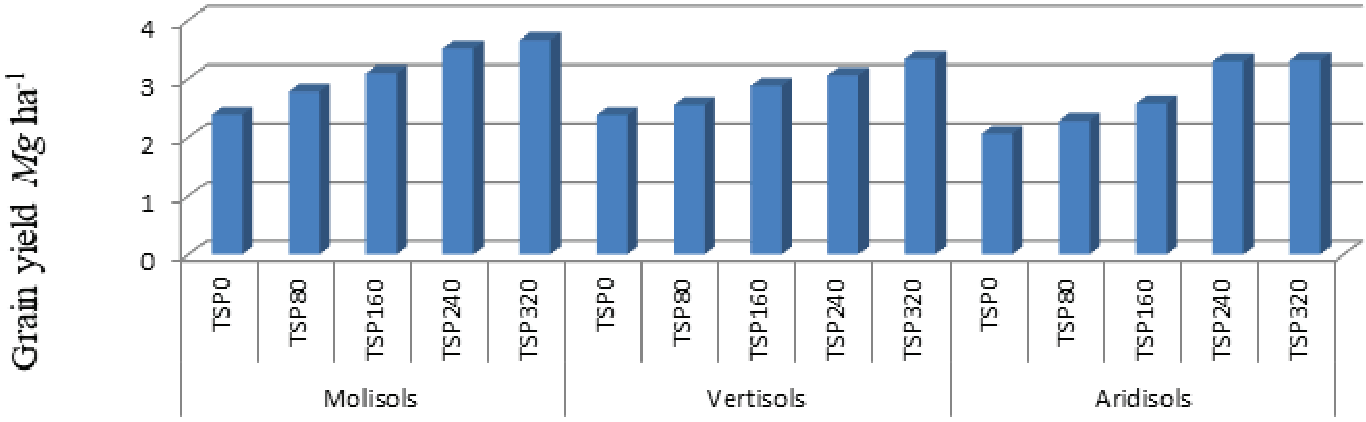


**Figure 4** Combination effect of levels applied phosphorus and soil orders on grain wheat

(Vertisols-$TSP_{240}$) and (Aridisols-$TSP_{240}$), the treatment combinations were plotted on OCP line.Third group, three of treatment combinations (Mollisols-$TSP_{320}$), (Vertisols-$TSP_{320}$) and (Aridisols-$TSP_{320}$) were located between OCP and DCP. The phosphorus status in the last group was better or more soluble than other groups due to solubility of OCP and DCP in rhizospher.

As a result increase in the levels of TSP for soil orders caused increase in availability of P, the best treatment combination was (Mollisols- $TSP_{320}$) because it is the nearest point or treatment combination to DCP, it means the increase in solubility of P caused increase in yield (Fig 4). These results agree with Galaly, (2010), Rasheed, (2019) and Khoshnaw, and Esmail, (2020) . While, the results provide information about the relation between P availability and the dominant soil orders. Organic matter may also increase P solubility through calcium chelating which caused either a permanent or a temporary delay in the formation of basic calcium phosphate.

In general in calcareous soils phosphate solubility is low due to rapid immobilization by calcium carbonate and slow recrystallization as poorly soluble calcium phosphate minerals. The initial formed phosphate mineral is di-calcium phosphate, which is then converted into octa-calcium phosphate and more basic hydroxyapatite.

As a result increase the of levels of TSP for soil orders caused to increase solubility P, and increase availability of phosphorus reported by Muhawish, and Al-Kafaje, (2017), Rekani, *et al.,* (2018),and Rasheed, (2019). While, the results provide information about the relation between P availability and the dominant soil orders. Organic matter may also increase P solubility through calcium chelating which causes either a permanent or a temporary delay in the formation of basic calcium phosphate Organic matter plays important roles in improving soil physical, chemical, and biological properties. It is considered as a very important parameter of soil fertility and productivity. It provides nutrients to the soil, improves water holding capacity and helps the soil to maintain better aeration and soil quality for seed germination and plant root development (Ding, *et al.*, (2006), Oorts, *et al.,* (2003) and Zia, (1993).

The studied soil orders, levels of applied phosphorus and their combination had great effect on phosphorus status and wheat yield, due to their effect on forming different phosphorus compounds range between non soluble to soluble form of phosphorus compound or from Hydroxy apatite to Di- calcium phosphate di hydrate as explained by solubility diagrams for phosphorus. Application of different levels of phosphorus caused the shifting towards di-calcium phosphate (DCP) and di-calcium phosphate di-hydrate (DCPD). The treatment combination Mollisols $TSP_{320}$ was recorded the highest grain yield.

## CONCLUSION

Phosphorus were less available in the treatment combinations Mollisols-$TSP_0$, Vertisols-$TSP_0$ and Aridisols-$TSP_0$ refers to low soluble were falling between TCP and OCP, then the lowest soluble phosphorus so as less available, While application of different levels of phosphorus caused the shifting of points towards dicalcium phosphate (DCP) , then for treatment combination Mollisols $TSP_{320}$ kg $ha^{-1}$ was the highest grain availability, the best treatment combination was Mollisols $TSP_{320}$ kg $ha^{-1}$. Application was shifted towards DCP, which are more soluble phosphorus compounds, it is appear from phosphorus solubility diagram.

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