Effect of Soil Phosphorus Chemical Equilibrium on P-availability for Wheat using Solubility Diagram and (DRIS-Chart) Methods

Akram Othman Esmail
College of Agriculture, University of Salahaddin

Abstract

The study included the comparison between solubility diagram method and DRIS-chart method in studying phosphorus availability and it's status in calcareous soil. The results refers to record the similar results in both methods, in both methods the best treatment for recording the highest wheat yield and phosphorus availability was application of 90 kg P ha^{-1}. On the other hand the nutritional balance among phosphorus and all the studied nutrients (nitrogen, potassium .calcium and magnesium) was recorded from application of 90 kg P ha^{-1} only.

KEYWORDS: *Solubility Diagram, DRIS-Chart, Phosphorus, Calcareous Soil.*

Introduction

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 Iraqi soils contain high amount of calcium carbonate having slightly alkaline pH which causes chemical and physical fixation of 70-90% of applied phosphorus fertilizers (Halvin *et al* .,2007). The phosphorus availability and status were studied by numerous of investigators in Iraq like Awad ;(1985), Hasan ;(1985), Al-Khateeb *et al*.;(1986) ,Al- Sulaivani ;(1993) ,Saeed ;(2008) and Galaly ;(2010) using solubility diagram.

The nutrients availability (phosphorus, nitrogen and potassium) and the balance between them were studied by numerous investigators and workers using diagnosis recommendation integrate system chart methodology (DRIS-chart methodology) like Esmail *et al*. ;(2011) ,Roberto and Pedro ;(2002) ,Hundal and Hrora ;(1995) and Sumner ;(1979) using DRIS-chart methodology.

It is appear from the above mentioned studies that most of investigators depended on this method for testing the status and balance among N, P, and K only, except

---

Date of research received 24 / 1 / 2012 and accepted 7 / 6 / 2012
arez96y@yahoo.com

Darwesh ;(2007) who suggested new DRIS-chart to study the balance among N, P, K, Ca, Mg, Fe and Zn in wheat plant grown in calcareous soil for this reason it was applied for comparison with solubility diagram in studying phosphorus status, chemical availability and its balance in wheat grown in calcareous soil.

Materials and methods

1-Field experiment, soil and wheat plant sampling.

Field experiment was conducted during the growing season of wheat (from 15th of November. -2009 to 1st of -July-2010) at Grdarasha agricultural farm, College of Agriculture ,University of Salahaddin ,Erbil with global positional system(GPS) reading (360 0 N ,440 01 E) ,(0411359 ,03997002 UTM),to study the effect of 10 levels of phosphorus (0 ,15 ,30 ,45 ,60,75 ,90 ,105 ,120 and 135 kg ha^{-1}) on phosphorus availability and wheat yield as indicator for studying phosphorus availability using completely randomized block design (RCBD) with 3 replicates. The field was divided into 3 plots after plowing, the space between blocks and experimental units were 1.5 and 0.5 meter respectively. The compost soil sample was taken before planting at 0-30 cm depth for routine analysis (table,1). At tillering stage plant and soil samples from each experimental unit were taken since this stage regards as a best stage for studying nutrient availability and balance**.** The plant samples were dried at 65 ^{0}C for 72 hours then grounded with stainless steel mill and stored in plastic container for chemical analysis. At the same time the soil samples were air dried and passed through 2 mm sieve then stored in plastic bottle prior to chemical analysis (table,2).Some chemical and physical analysis for soil properties (table 1 and 2) were done according to methods described in Jackson ;(1958) and Black ;(1965).Plant samples were digested by using di-acid digestion method (1:1 concentrate. HNO_3, $HClO_4$). Phosphorus content was determined spectrometrically as described in detail by Rowell;(1996).Nitrogen was determined by micro-kjeldhal method as described by Bremner and Mulvaney;(1982), the plant potassium content was determined according the method mentioned by Allen;(1974), while calcium and magnesium were determined by titration method using disodium-EDTA. The plants were harvested at 1st June, 2010 using hand method then separated to straw and grain by threshing machine to record the norm treatment (the highest yield treatment) which is necessary for comparison between solubility diagram method and DRIS-chart method.

-2-Solubility diagram

For studying solubility equilibrium of phosphate the double function parameters (DFP) consisting of phosphate potential($\log {}^{H_2PO_4}$ –pH) and lime potential ($\log {}^{Ca}$ -2pH) have been used (Lindsay and Moreno, 1960).For preparing phosphate solubility diagram 3 g of soil from each sample was taken and shacked with 0.01 *M*olarity of KCl (1:10) ratio for 15 minutes then incubated at 25 ^{0}C for 16 hours, after that the suspension was filtered then the pH, Ca^{2+} and soluble phosphorus were determined as described by Black ;(1980).

3-DRIS-chart

The recent DRIS methodology was used for studying the balance between phosphorus and each of nitrogen, potassium, calcium and magnesium (P/N ,P/K ,P/Ca and P/Mg). If the ratio located within the origin (in the center of the small circle) represents the optimum (balance) values of the studied nutrients concentrations in plant for high yielding treatments, while the values of nutrient ratio which located between both circles, represent the

critical value (imbalance),but the values outside of the large circle is a zone of highly imbalance denoted by vertical arrows being either too high or too low as recorded from suggested DRIS-chart which mentioned by Darwesh ;(2007).

Results and Discussion

1-Effect of phosphorus levels on wheat grain yield

Table (3) shows that the levels of applied phosphorus affected significantly on grain yield the highest yield (1.922 *Mg* ha^{-1}) was recorded from treatment P_6 (application of 90 kg P ha^{-1}), while the lowest value (1.334 *M*g ha^{-1})was obtained from control treatment (P_0). It is appear that application of more than 90 kg P ha^{-1} not caused any significant increase in wheat yield ha^{-1} ,it means that the application of 90 kg P ha^{-1} is adequate for wheat growth and the highest yield of wheat similar results were obtained by Darwesh and Esmail ;(2008).

2-Studying phosphorus availability

For explaining the chemical availability of soil solution phosphorus and its role in limiting the wheat yield, phosphorus solubility diagram and DRIS-chart methodology for P were gave the following results:

Figure (1) refers to low soluble form of phosphorus compounds in case of P_O and P_1 treatments since P_0 and P_1 treatments were falling between beta-tri calcium phosphate ((DCPD) B-TCP) and hydroxy apatite (HA) which are less soluble phosphorus compounds. While application of different levels of phosphorus caused the shifting of points towards di-calcium phosphate (DCP) and di-calcium phosphate di-hydrate (DCPD) which are more soluble phosphorus compounds, it is appear from phosphorus solubility diagram that the best treatment is P_6 or application of 90 kg p ha^{-1}, which located between two more soluble phosphorus compounds (DCPD and DCP) ,this explain recording the highest wheat yield from treatment P_6 and obtaining the lowest yield from P_0 similar results were recorded by Saeed ;(2008) and Galaly ;(2010),On the other hand Al-Khateeb *et al* ;(1986), Kahraman;(1989) indicated that the phosphorus mineral which control the solubility of phosphorus is BTCP, while AL-Sulivani ;(1993)explained that after 70 days of phosphorus application to calcareous soil the phosphorus compounds which are controlling phosphorus availability are BTCP and OCP they are less soluble compounds in compare to(DCPD and DCP). BFigure (2)shows the phosphorus DRIS-chart for wheat plant grown in calcareous soil which suggested by Darwesh ;(2007), this chart explain the ratio and balance between phosphorus and other nutrients like N, Ca^{2+}, Mg^{2+}…. and K^{+} in wheat plant depending on DRIS-chart, table (4) shows the concentration of some nutrients and the ratio between phosphorus and some nutrients in wheat, if the ratio between P and any nutrient falling within the inner circle would be considered to be balanced, if the ratio between P and any nutrient moves away from inner cycle the degree of imbalance between them will increase ,for this reason the points or treatments or ratio between p and other nutrients which falling between inner and outer circles and outside of the outer circle regards as bad treatments or the ratio between P and other nutrients are in imbalance condition which causes decrease in yield, depending on above explanations the ratio between (P/N , P/Ca , P/Mg and P/K) from P_6 were falling within inner circle or the balance between P and the studied nutrients were recorded from treatment P_6 , while in case of P_7 the nutrient balance was recorded between

(P/N ,P/Ca and P/Mg), on the other hand in case of P_8 and P_9 the balance was only recorded between P/Mg ,it means the balance between all the studied nutrient with phosphorus was recorded only from treatment P_6 which caused obtaining the highest yield similar result was recorded by Darwesh ;(2007). It is appear from results of solubility diagram and DRIS-chart that the best treatment is treatment P_6 which recorded the highest phosphorus compounds solubility (figure,1) and the best balance between phosphorus and others nutrients (figure ,2), it means the applied methods were giving the similar results or there is a good association between them and these two methods are very suitable in this investigation for studying phosphorus status and availability. The results of determine of simple correlation between phosphate potential and each of wheat yield and phosphorus concentration as shown from figure (3 and 4) indicate to significance correlation coefficient (r=0.82* and 0.70*) between phosphate potential and each of wheat yield and phosphorus concentration in the soil. This explains the similarity between the role of phosphate potential in increasing wheat yield and soil phosphorus availability, or in directly it means that the solubility diagram and DRIS-chart method are giving the similar results in studying phosphorus availability. On the other hand it is not easy to limit or select the best method, since this scientific decision requires more detail studies including the main soil orders of Iraq and Kurdistan region and at least two types of plants one of them monocotyledonous and the other is dicotyledonous plants.

Table (1): Some chemical and physical properties of the studied soil.

PSD g kg^{-1}			Textural name	Water content (Kpa)		
Clay	Silt	Sand		S.P	F.C	W.P
350.7	521.3	128.0	Silty clay loam	50.52	26.81	14.98

Soluble ions $mmol_cL^{-1}$									
Ca^{2+}	Mg^{2+}	Na^{1+}	K^{1+}	HCO_3^{1-}	CO_3^{2-}	Cl^{1-}	SO_4^{2-}	pH	EC dS m^{-1}
2.63	0.72	0.43	0.20	2.32	0.0	0.54	1.32	7.51	0.42

OM g kg^{-1}	$CaCO_3$ g kg^{-1}	Active $CaCO_3$ g kg^{-1}	Available phosphorus (mg kg^{-1} soil)
10.1	24.31	4.52	2.47

Table (2): Some essential soil chemical properties for solubility diagram at tillering stage.

Log H_2PO_4	pH	Log H_3PO_4-pH	Log Ca^{++}	Log Ca^{++} +2pH
-7.310	7.500	-14.810	-2.523	12.477
-6.950	7.470	-14.420	-2.509	12.431
-5.570	7.470	-13.040	-2.523	12.41
-5.120	7.440	-12.560	-2.538	12.342
-4.980	7.520	-12.500	-2.481	12.559
-5.210	7.450	-12.660	-2.523	12.377
-4.450	7.480	-11.930	-2.495	12.465

-4.490	7.510	-12.000	-2.509	12.511
-4.830	7.430	-12.260	-2.523	12.337
-4.950	7.490	-12.440	-2.509	12.471

Table (3:) The effect of different levels of phosphorus on wheat yield.*

Levels of applied phosphorus (kg P ha^{-1})	Yield (*M*g ha^{-1})
P_0 = 0 kg ha^{-1}	1.334^{d}
P_1= 15 kg ha^{-1}	1.363^{d}
P_2= 30 kg ha^{-1}	1.420^{bd}
P_3= 45 kg ha^{-1}	1.501^{b}
P_4= 60 kg ha^{-1}	1.570^{b}
P_5= 75 kg ha^{-1}	1.689^{c}
P_6= 90 kg ha^{-1}	1.922^{a}
P_7= 10 5kg ha^{-1}	1.911^{a}
P_8= 120 kg ha^{-1}	1.920^{a}
P_9= 135 kg ha^{-1}	$1.*901^{a}$

* *M*g =Mega gram =1 metric ton.

Table (4): Concentration of some nutrients (%) in dry matter and their ratio with phosphorus.

Concentration of some nutrients					Ratio between P and nutrients				
Treatments	P	N	K	Ca	Mg	P/N	P/K	P/Mg	P/Ca
P_0	0.11	2.30	3.66	2.90	0.42	0.046	0.030	0.260	0.037
P_1	0.14	2.40	3.60	3.55	0.56	0.058	0.039	0.250	0.039
P_2	0.15	2.51	3.94	3.95	0.47	0.059	0.038	0.320	0.038
P_3	0.15	2.31	4.40	3.12	0.55	0.064	0.034	0.270	0.048
P_4	0.12	2.09	3.24	2.70	0.36	0.055	0.037	0.330	0.044
P_5	0.14	2.35	3.04	2.45	0.35	0.060	0.046	0.340	0.057
P_6	0.18	2.70	3.67	3.32	0.39	0.065	0.049	0.460	0.054
P_7	0.20	2.60	3.80	3.57	0.46	0.077	0.052	0.430	0.056
P_8	0.18	2.30	3.84	3.00	0.41	0.078	0.051	0.440	0.060
P_9	0.19	2.20	3.58	3.17	0.48	0.086	0.053	0.400	0.060

*The number of the ratios must be 3 numbers after point like (DRIS-chart)

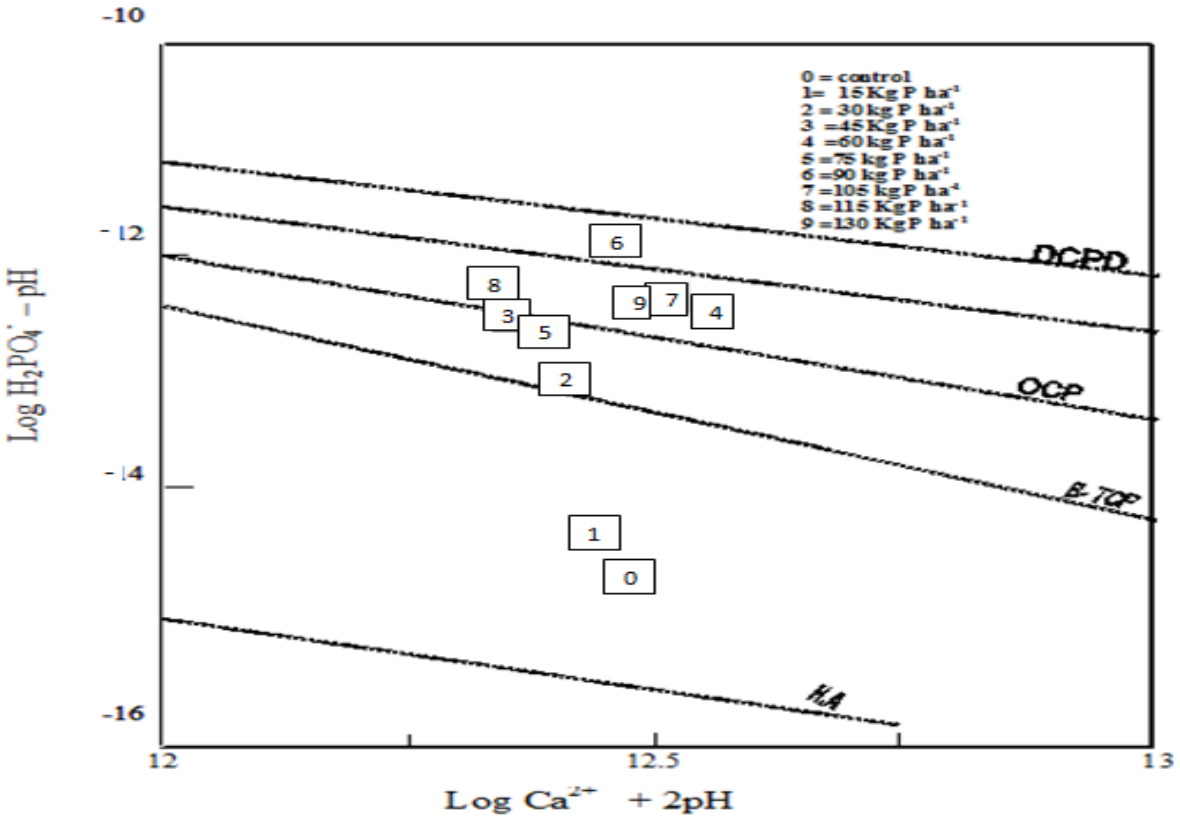


Figure (1): Phosphorus solubility diagram explain the effect of levels of applied phosphorus on P-availability.

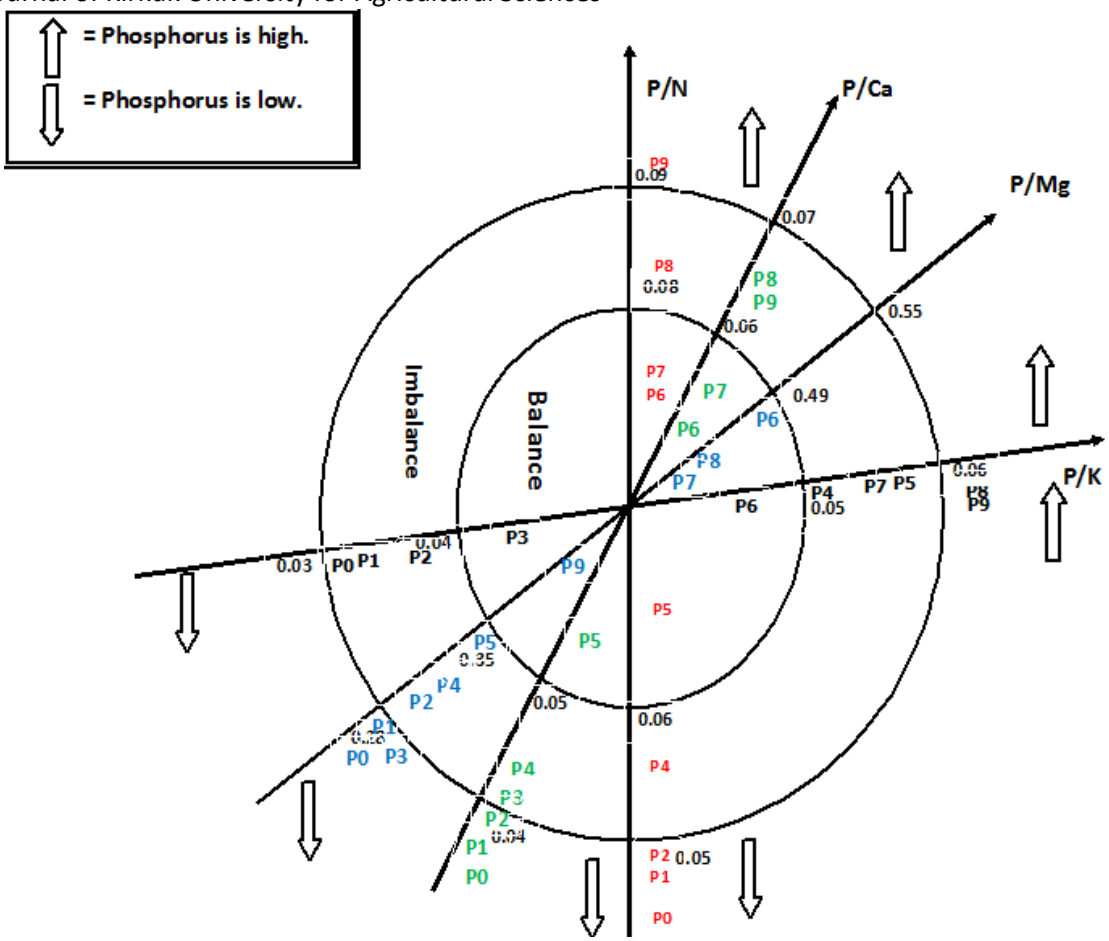
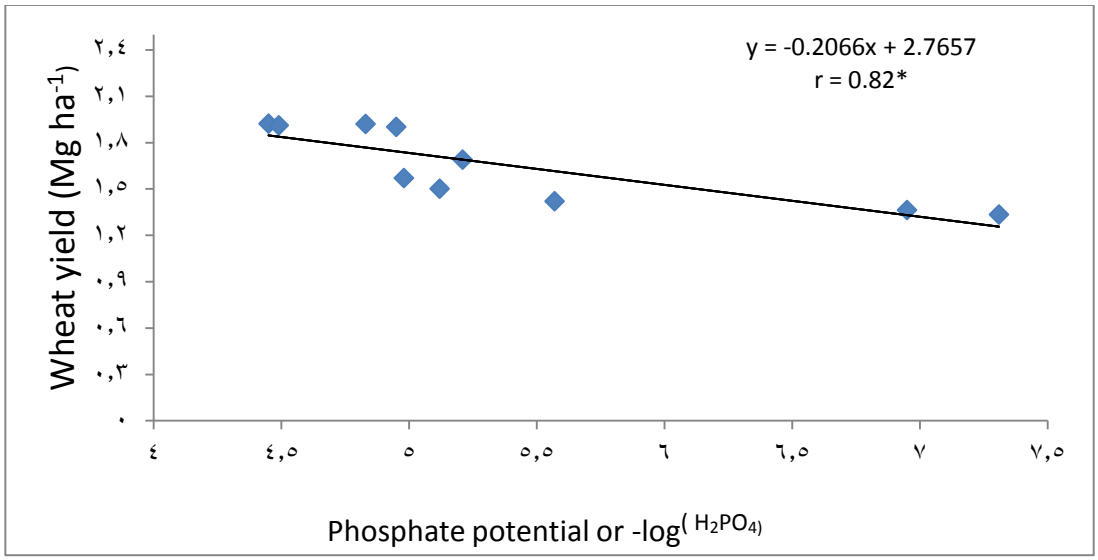
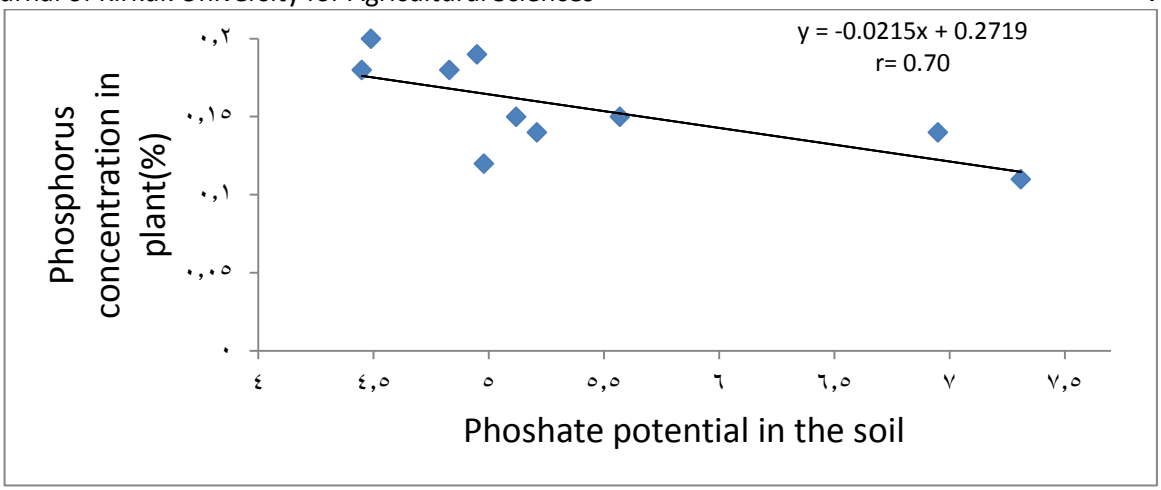


Figure (2): Phosphorus status Depending on phosphorus DRIS chart (Darwesh; 2007).



Figure(3)The relation between phosphate potential and wheat yield



Figurr(4)Explain the relation between phosphorus concentration in wheat plant and phosphate potential in the soil

Refrences

1-Allen, S .E. (1974). Chemichal analysis of some ecological material. firstedition. Black well.Oxford:1-1500.

2-Al-Sulaivani,S.I.A.(1993).Physico-chemical behavior of ortho and pyro-phosphate in some calcareous soils from northern of Iraq. Ph.D. Dissertation College of Agriculture, University. of Baghdad.

3- Al-khateeb ,I. K., Raihan, M.J., and Asker, S. R. (1986).Phase equilibrium and kinetics of orthophosphate in some Iraqi soils. Soil Sci. 141:31-37. . Awad, K.M.(1985). Reaction of applied super- phosphate fertilizer in calcareous soils. JAWRR.4 (1):39-52.

4- Black C. D.(1965).Method of soil analysis. Part 1 and 2, American. Society of. Agronomy., Madison, Wisconsin., USA.pp:1-1157

5-Bremner, J. M., Mulvancy, C. (1982).Methods of Soil Analysis. Part 2, Agronomy 2 ed. American Journal of Soil Science Society. Madison pp: 595-624.

6-Darwesh, D. A.(2007).Role of supplemental irrigation and fertilizer treatments on yield and nutrients balance in wheat by using modified DRIS. Ph.D. Thesis Coll. of Agric. Univ. of Salahaddin.

7- Esmail, A. O., Ali, O. O. and Abdurrahman, N.M. (2011). Effect of forest exposure on nutrient balance in oak. Journal of Kirkuk University.6 (1) 170-175.

8- Galaly, T. F. S. (2010). Interaction effect of phosphorus and sulfur on phos -phorus availability and some growth parameters of corn plant grown in calcareous soil. M.Sc. University of Salahaddin College of Agriculture, Department of Soil and Water.

9-Hassan J.K. (1985). Effect of pyrophosphate on the availability of phosphorus to corn plant in some Iraqi soils. M.Sc. thesis, University of Baghdad, College of Agriculture.

10-Havlin, J.L.,Beaton ,J. D.,Tisdal, S. l. and Nelson W.L. (2007).Soil fertility and management seventh edition. Pearson Education Inc. Singapore, pp: 1-515.

11-Hundal, H. S. and Agoro, C. L. (1995).DRIS approach for nitrogen,phosphorus and potassium foliar diagnosis norms for Lychee. Journal of the Indian Society of Soil Science. 43 :(1)58-63.

12-Jackson, M. L. (1954).Soil chemical analysis. Prentice Hall, Inc. London.
13-Kahraman L.M. (1989) The study of phosphorus compounds ransformation in gypsiferous and calcareous soil and its availability for plant.M.Sc.thesis , University of Mousl,College of Agriculture.
14-Lindsay, W .l. and Morenol, E .C. (1960). Phosphate phase equilibrium in soils .Soil Sci. Soc. of Am. Proc. 24:177-82.
15-Roberto,A.R. and Pedro H.M.(2002) Sugercane nutritional diagnosis with DRIS norms established in Brazil South Africa and United States.Journal of Plant Nutrition. 25(12):2831-2851.
16-Rowell, D. L. (1996). Soil Science. Methods and Application. Reading Univ. UK. pp: 1-220
17-Saeed, K. S. (2008).The effects of orthophosphate, pyrophosphate and magnesium on the availability of phosphorus to corn plants using new DRIS methodology .Ph.D. Dissertation, Univ. of Sulaimani, College of Agriculture, Department of Soil and Water.
18-Summner,.M.E.(1979) Interpritation of foliar analysis for diagnosis purposes. Agronomy JournaL.45:87-90.

تأثير التوازن الكيميائي للفسفور في التربة على جاهزيته لنبات الحنطة بأستخدام مخطط الاذابة ومخطط دريس

الخلاصة

شملت الدراسة مقارنة المخطط الاذابة و مخطط DRIS في دراسة جاهزية الفسفور وحالته في تربة كلسية. تشير النتائج الى الحصول على النتائج المتشابهة في كلا الطريقتين، وان افضل معاملة لحصول اعلى الانتاج للحنطة و جاهزية الفسفور هي اضافة 90 كغم هكتار $^{-1}$. ومن ناحية اخرى افضل توازن غذائي بين الفسفور وجميع المغذيات المدروسة (النايتروجين، البوتاسيوم، الكالسيوم و المغنسيوم) تم تدوينها من اضافة 90 كغم هكتار $^{-1}$ من الفسفور.