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Evaluation of absorbable phosphorus in some of soil samples from the county of bahar using various extractants

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Abstract

This research was performed with the purpose of evaluating 4 methods of extraction of absorbable phosphorus and to determine the appropriate extractant for estimation of absorbable soil phosphorus in 15 samples of soil. The physical and chemical characteristics of soils were determined using prevalent experimental methods. Pot plantation was performed in the form of factorial experimentation in the framework of a completely random project in 9 sample of soil with two levels of phosphorus (zero and 150 milligrams per Kg soil) with three repetitions and plant indices including: absorbed phosphorus and relative performance were measured. Evaluation of the results of the correlation coefficient between various extractants and relative performance, concentration and absorption of phosphorus by the maize plant shows that Olsen extractants have meaningful correlation with relative performance, phosphorus absorption and Mehlich 3 extractants with relative performance. Yet, regarding Bray and AB-DTPA extractants meaningful correlation with relative performance and concentration of absorbed phosphorus was not found.

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Introduction

Awareness of the capacity to absorb phosphorus in soil has important role in determination of the amount of use of phosphorus fertilizers. The absorption capacity of phosphorus is a function of numerous factors. In acidic soils, this element forms sediments in the form of iron and aluminum phosphates and in neutral and calcareous soils in the form of calcium phosphates. Due to presence of calcium with high activity in calcareous soils, with addition of phosphorus containing fertilizers, calcium phosphate is formed and changes to insoluble forms with passage of timeand this process is termed phosphorus stabilization (Barrow and Shaw, 1976)). For appropriate fertilizer recommendation for every nutrient element including phosphorus, performance of the soil test project is a necessity. In the soil test project for a nutrient element, selection of the extractant and correlation tests between the amount of the nutrient element extracted fromsoil and the amount absorbed by the plant has special priority(Hamilton *et al.*1993). In most soils, phosphorus forms complexes with calcium, iron and aluminum. Due to high capacity of some soils for phosphorus stabilization, its mobility in soil is very little compared to other elements. In calcareous soil, the precipitation of phosphorus as calcium phosphate is the main factor in decreasing its absorbtivity in soil.

Soleimani Darcheh (1994) showed that when phosphorus fertilizer is added to the soil, part of it leads to increase soluble phosphorus and the rest is precipitated and is strongly stabilized and is not easily in balance with the soluble phosphorus (1). Additionally, in the study of effect of curing on the capacity of extraction of phosphorus, it has been reported that after passage of 45 to 90 days,up to 80 percent of the available phosphorus turns into an labile form and is not extractable by the Olsen method thus to increase available phosphorus from 10 milligram to 40 milligram of phosphorus in each Kg of soil, 55 Kg of phosphorus rich fertilizer needs to be used. Results show that on the average, 78 percent of the available phosphorus fertilizer changes to labile form in a period of three weeks.In the past years and for evaluating available phosphorus in soil, researchers have suggested numerous methods. The method of Olsen or sodium bicarbonate by Olsen *et al*(1982) advanced for prediction of the plant response to use of phosphorus fertilizer in calcareous soils. The method of Olsen compared to other methods is more sensitive to the soil buffering capacity. Barrow and Shaw (1976) have reported that with increased buffering capacity of soil, the amount of phosphate in the solution of the extractant decreased. They also stated that the effect of buffering capacity on extruded phosphorus by the method of Olsen is higher than the method of Colwell. This issue has repeatedly been reported that the method of Olsen for prediction of the absorbable phosphorus by plants is less effective in regions that the soil has great changes in chemical characteristics such as pH, mineralogy and phosphorus buffering capacity (Delgado and Torrent, 1997). Zalba and Gallantini (2007) have reported that when the Olsen method was modified by Colwell (1963), the effect of the phosphorus buffering capacity decreased. Van Rotterdam *et al.* (2012) have reported that to calculate the potential for phosphorus availability, at least two parameters are needed: one is the absorbed phosphorus on the soil which is reversibleto the solution of soils or the factor of quantity (Q) and the other is the concentration of phosphorus in the soil solution or the factor of intensity. The best prediction is obtained when Q is measured by the Olsen method and the factor of I by the method of calcium chloride 0.001 Molar. The I factor shows the ratio of phosphorus that can exit the soil. The ratio Q/I shows the capacity of soil for buffering I factor. Van Rotterdam and colleagues (2012) used this method and were able to improve the prediction of phosphorus containing fertilizer for grass lands.

This method has been used in numerous researches and has been appropriate in a wide range of soils for prediction of the capacity to use phosphorus for the plant. The method of Colwell is similar to the method of Olsen; yet, Colwell changed the time period for contact of sodium bicarbonate solution from half an hour to 16 hours. With increased time of extraction with sodium bicarbonate, the ability of the extractant is doubled and almost all the available phosphorus is extruded from soil. Yet, the correlation coefficients between the plant responses and the phosphorus extracted by this method and the method of Olsen are close to each other. The ammonium bicarbonate-DTPA method which is also known as the method of Soltanpour and Schwab regarding prediction of the situation of accessible phosphorus is similar to other methods. Since this method extracts multiple elements at the same time, its use leads to saving time and expenses(Soltanoour and Schwab 1977). Ammonium bicarbonate as an extractant that has good correlation with phosphorus absorption by the plant and the total phosphorus amount was introduced. The Mehlich 2 method is a multipurpose extractant that is used in wide sections of soil both acidic and basic and shows high correlation with the Bray method in acidic and neutral soils (Peter *et al.* 2002**).**

The following goals were evaluated and attended to in this research

1-Comparison of various extractants for phosphorus extrusion from agricultural soil in the county of Bahar , west of Iran and introduction of the most appropriate extractant with attention to ease of preparation, speed of extraction, economizing and acceptable relationship with the amount of concentration and absorption of phosphorus and the relative performance of the maize plant 2-Evalaution of the correlation coefficients between various extractants for determination of the relationship between the methods in the capacity to extract phosphorus 3-Evaluation of the correlation coefficients between extruded phosphorus by various methods of extraction with the amount of concentration and absorption of phosphorus and its relative performance in plants and determination of appropriate indices for evaluation of extractants.

Materials and methods

Sample collection and analysisFor performing this research, 15 samples of superficial soil were selected from various areas of the Bahar county. Physical and chemical characteristics of the soil such as itspH, percent organic carbon by the method of Walkley-Black, phosphorus by the method of Olsen, cation exchange capacity and percent clay, silt and sand by the hydrometric method were determined. In thisstudy, it was endeavored that the evaluated soils be different regarding physical and chemical characteristics particularly amount of extractable phosphorus from them.

Experiment design

Pot plantation was performed in the form of factorial experimentation in the framework of a completely random plan in 15 samples of soil with two levels of phosphorus (zero to 150 mg in Kg of soil) in three repetitions.

Plastic pots with appropriate drainage were filled with 3 Kg soil. Since the soil in the pots should not have deficiency in other nutrient elements, amount s of 5, 5 and 100 mg in Kg zinc, iron and potassium respectively were added to the soil of all pots from sources of zinc sulfate, sequestrin and potassium sulfate. After implementation of the care and addition of nutrient elements, three maize seeds that had previously formed a sprout in wet material were planted in each pot (midsummer) and the pots were placed in open air. The element of nitrogen was added to each pot in the form of urea after one month past from the plantation at the amount of 150 mg per Kg. During the growth season, necessary care was taken. At the end of the growth season (midautumn) the plants were removed from the pots and were washed with diluted acid and distilled water. After drying them at 70 degrees centigrade, their dry weight was determined and they were powdered with electric mill. One gram of the plant samples was burned in electric oven for 2 hours at 550 degrees centigrade and was extracted with 10 milliliter hydrochloric acid 2 Molar. The concentration of phosphorus was determined in the extractions using colorimetry and plant indices: absorbed phosphorus, relative performance and plant response were calculated using the following formulas:

Phosphorus absorption (mg in the pot)=bulb weight x concentration of phosphorus in the plant.

Relative performance (percent)=(performance of the cared for plant/performance of control plant) x 100
The method of extraction.

Four methods that used for extracting of soil phosphorus were

Olsen
Using sodium bicarbonate 0.5 Molar in pH=8.5 on 2.5 g of soil with a ratio of 20:1 and half an hour agitation.

Bray and Kurtz
using hydrochloric acid 0.025 Molar, ammonium fluoride 0.03 Molar in pH of 3.5 on 2 g of soil with a ratio of 7:1 and one minute agitation.

Mehlich
using acetic acid 0.2 Normal + ammonium nitrate 0.25 Molar + ammonium fluoride 0.015 Normal + Normal acid nitric + EDTA 0.001 Molar on 2.5 g soil with a ratio of 10:1 with 5 minute agitation and 10 minute centrifugation.

AB-DTPA
Combination of ammonium bicarbonate 1 Molar and DTPA 0.005 Molar in a ratio of 20:1 of liquid to soil and shaking for half an hour.

Statistical analysis
To evaluate the relationship between the extruded phosphorus with various extraction methods with each other and with the concentration and amount of phosphorus absorption by the maize plant and relative performance, correlation coefficients and their significance were determined by SPSS software (ver.16) and indices that had meaningful and higher coefficients of the extracted phosphorus were selected as appropriate indices for evaluation of the extractants.

Results and discussion
The physical and chemical characteristics of soils are shown in Table 1.

Table 1. Physical and chemical characteristics of the soils samples.

Soil sample	Calcium carbonate	Silt	Clay	Organic carbon	Electric conductance	pH	Cationic exchange capacity
		%	dS m^{-1}				Cmol$_c$ kg $^{-1}$
1	20.0	36	45	0.59	0.34	7.7	29
2	8.3	18	39	1.00	0.26	7.8	22
3	6.5	26	31	0.38	0.15	7.5	20
4	10.0	31	31	0.48	0.17	7.5	9
5	9.5	21	28	0.79	0.29	7.5	22
6	1.5	21	38	0.73	0.14	7.1	24
7	13.0	14	29	1.40	0.23	8.1	24
8	3.8	19	31	0.88	0.17	7.4	24
9	16.0	26	42	0.63	0.23	7.6	18
10	24.0	19	32	0.64	0.28	7.8	22
11	8.8	13	29	0.92	0.27	7.9	25
12	2.5	19	50	0.37	0.15	7.4	29
13	2.5	15	35	0.39	0.14	7.3	17
14	7.8	21	25	0.75	0.19	7.5	20
15	2.8	16	22	0.87	0.28	7.4	21

According to this Table, the evaluated soils were diverse regarding physical and chemical characteristics. The range of changes of EC and pH of the soils was between 0.14 to 0.36 dSm^{-1} and 7.1 to 8.1. The calcium carbonate percentage was between 1.5 and 20. The least amount of organic carbon percentage of the soil was related to soil 12 and the most amount was related to soil 7. Cationic exchange capacity of the soils was between 17 to 29 Cmol$_c$Kg^{-1}. The Olsen phosphorus had a range of 10 to 37 mg Kg^{-}

[1]. The name of the extractants and mean amounts of phosphorus extracted from the soil samples is shown in Table (2) and the correlation coefficients between the phosphorus extracted by various extractants are shown in Table (3).

Table 2. Range of changes in the amounts of phosphorus extracted by each extractant.

	Extracted phosphorus (mg Kg^{-1})		
Extractant	Minimum	Maximum	Mean
Mehlich 3	5	100	52.50
Bray	0.5	18	9.25
Olsen	6.5	37	21.75
AB-DTPA	0.2	15	7.60

Based on Table (2) mean phosphorus extracted by the mentioned methods decreases as follows Mehlich 3 > Olsen > Bray > AB-DTPA. Results well show that due to difference in the various forms of phosphorus in the soil and the ability of various extractants in solving various forms of phosphorus and various mechanisms of extraction of extracting absorbable phosphorus, the amount of phosphorus extracted by various methods is different (Roberts 2008). Difference in the time of extraction of absorbable phosphorus and ratio of soil and extractant solution are also influential on the amount of phosphorus extracted (Sarawat 1997). Additionally, in various soils also the amount of phosphorus extracted by each method is different which shows the difference in the absorbable phosphorus in the soils and the effect of soil characteristic on the amount of phosphorus extracted. In the Mehlich 3 method, phosphorus is extractedby reaction with acetic acid, nitric acid and fluorine compounds. Strong acids such as nitric acid and weak acids such as acetic acid extract phosphorus in soil in all three inorganicforms and have an order of solubility (Olsen 1954). Fluorine by forming complexes with iron and aluminum and Calcium, causing the release of phosphorus is absorbed (Fe-P<Al-P<Ca).Additionally, fluoride by forming precipitation of calcium fluoride leads to solution of calcium phosphate (Kamprath and Watson 1980). Therefore, the Mehlich 3 method due to higher acidic nature compared to the other acidic extractants such as Bray in addition to extracting labile phosphorus is also able to extract some of the inaccessible phosphorus as well. Therefore, the amount of phosphorus extractable with the Mehlich 3 method is significantly higher (Mehlich 1984). Yet, in calcareous soils, it does not show meaningful correlation with the Bray method. Zibral and Nemec (2002)also reported high correlation between the amount of phosphorus extruded by the Olsen method and the methods of calcium chloride and Mehlich 3. In numerous studies performed globally by researchers, the Olsen method has had meaningful and high correlation with other extractants in a wide range of soils.

Table 3. Linear correlation coefficients of various methods of extraction with each other.

Method of extraction	Olsen	Bray	Mehlich 3	AB-DTPA
Olsen	1	0.85^{**}	0.52^{*}	0.25^{ns}
Bray		1	0.28^{ns}	0.37^{ns}
Mehlich 3			1	0.4^{ns}
AB-DTPA				1

Correlation of the extracted phosphorus by extractants with plant indices

Correlation coefficients related to the extracted phosphorus by various extraction methods and plant indices of relative performance, concentration and absorption of phosphorus have been shown in Table (4). Olsen found an acceptable correlation with relative performance and amount of absorption and concentration of phosphorus by the plant. The methods of Bray also have high correlation with relative performance and Mehlich 3 does not show meaningful correlation with relative performance. It appears that extract part of the inaccessible phosphorus are not appropriate for prediction of relative performance. The results of research by Ghanei and Hosseinpour (2004) show that the phosphorus extracted by the Olsen, Colwell, Soltanpour, and Mehlich 1 has meaningful correlation with relative performance of the maize plant, but do not show meaningful correlation with the indices of absorption and phosphorus concentration. Laxminarayana (2003) also reported meaningful correlation between the phosphorus extracted by the Olsen method and the rice plant relative performance. The correlation of the Olsen extractants and absorption of phosphorus by the seeds is meaningful (Table 4).

Table 4. Linear correlation coefficients of various extraction methods with plant indices.

Dependent variable extractant	Relative performance	Concentration of phosphorus in seeds	Seed phosphorus absorption
Olsen	0.6^{**}	0.51^{**}	0.42^{*}
Bray	0.32^{ns}	0.32^{ns}	0.24^{ns}
Mehlich	0.74^{**}	0.25^{ns}	0.26^{ns}
AB-DTPA	0.22^{ns}	0.20^{ns}	0.28^{ns}

* and **significant at 5 % and 1 % levels.

It appears that methods that have close relationship with soluble phosphorus or easily usable phosphorus in comparison to other extractants have higher correlation with concentration and absorption of the phosphorus by the plant seed. Halford (1980) showed that meaningful correlation exists between phosphorus extracted and the two methods of Colwell and Olsen and the concentration of phosphorus in alphalpha. In evaluation of the correlation coefficients between concentration and absorption of phosphorus by hay and various methods of extraction only the method of Colwell showed meaningful correlation with the concentration of phosphorus in hay. Mehlich 3 was introduced as an extractant with good correlation with phosphorus absorption by the plant (1984). Laximinaryana (2003) and Sarawat *et al.* (1997) also found meaningful correlation between the phosphorus extracted by Olsen and phosphorus absorbed by the plant.

Based on the values of the correlation coefficient between the extracted phosphorus form soil and plant indices by the Olsen and Mehlich 3methods in order were the most appropriate among the extractants used in this research and correlation of extractants that are related to inaccessible phosphorus and extract part of it such as Bray andAB-DTPA are weaker than other extractants. Therefore, the mentioned extractants are not appropriate representative of the accessible phosphorus and cannot be recommended.

Conclusion

The aim of this study was to determine the amount of phosphorus taken up by maize plants and to set this in relation to the amount of available P predicted by different soil P extracting methods.Mean phosphorus extracted by the mentioned methods decreases as follows Mehlich 3 > Olsen > Bray > AB-DTPA. The Olsen andMehlich 3 methods in order were the most appropriate among the extractants. Owing to the different extraction mechanisms utilized, the tested extraction methods extracted different pools of soil P with strongly varying extractability and varying dependence on soil properties. Further research is needed to examine the relation of P extractability by these methods to plant P uptake in contrasting soil types.

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