



Assessment risk of phosphorus leaching from calcareous soils using soil test phosphorus



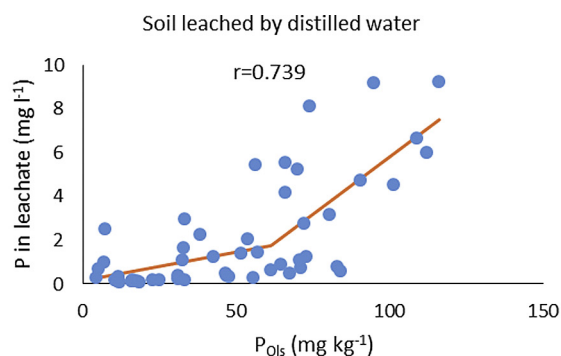
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HIGHLIGHTS

- Accurate estimation of phosphorus (P) leaching in soil is important.
- Phosphorus extracted by CaCl_2 was accurately predicted P leaching.
- Change points of water extractable P and Olsen P against P leaching was found.
- Soils were classified for potential P leaching loss.

GRAPHICAL ABSTRACT



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ABSTRACT

Accurate estimation of phosphorus (P) leaching is important because excess P may reduce surface and ground water quality. Little attention has been paid to estimate P leaching from soil tests in calcareous soils. The relation between different soil tests P (STP), P sorption index (PSI) and degree of P saturation (DPS) and leaching of P were examined for assessing the risk of P loss from calcareous soils. Columns leaching repacked with native soils were leached with either distilled water or 10 mM CaCl_2 solutions, separately. Four leaching events were performed at four days, and 28.7 mm of distilled water or 10 mM CaCl_2 solutions was applied at each leaching events. Compared with distilled water, CaCl_2 had a small ability to solubilize P from soils. Concentration of P in leachate in both leaching solutions was exceeding 0.1 mg l^{-1} associated with eutrophication. Cumulative P leached P was ranged from 0.17 to $18.59 \text{ mg P kg}^{-1}$ and $0.21\text{--}8.16 \text{ mg P kg}^{-1}$, when distilled water and 10 mM CaCl_2 solutions were applied, respectively and it was higher in sandy clay loam soils compared with clay soils. Among evaluated environmental soil P tests, $P_{\text{CaCl}_2\text{-3h}}$ (P extracted by 10 mM CaCl_2 for 3 h), $P_{\text{CaCl}_2\text{-1h}}$ (P extracted by 10 mM CaCl_2 for 1 h) were more accurate than other soil P tests for predicting P concentration in the leachates in both leaching solutions and accounting for 83% and 72% of variation of P concentration, respectively. The water extractable P (WEP) ($r = 0.771$) and Olsen-P (P_{Ols}) ($r = 0.739$) were significantly related to the leached P concentration using distilled water solution in a split line model, with a change point of $27.4 \text{ mg P kg}^{-1}$ and $61.5 \text{ mg P kg}^{-1}$, respectively. Various DPS were calculated and related to the leached P concentration. Based on P extracted by Mehlich-3 (P_{M3}) and HCl (P_{HCl}) and PSI, the change point of the relationship between leached P concentration and $\text{DPS}_{\text{M3-3}} \left(\frac{P_{\text{M3}}}{(P_{\text{M3}} + \text{PSI})} \times 100 \right)$ and $\text{DPS}_{\text{HCl-2}} \left(\frac{P_{\text{HCl}}}{(P_{\text{HCl}} + \text{PSI})} \times 100 \right)$ for both leaching solutions was approximately the same, thus a mean value of 49% for $\text{DPS}_{\text{M3-3}}$ and 73% for $\text{DPS}_{\text{HCl-2}}$ was obtained. Soils were grouped into four categories of increasing P leaching potential

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based on WEP, P_{OIS}, and DPS_{M3-3}. The results indicated that 8.00%–25.50% of the soil grouped in no risk category whereas 8.00%–13.70% of the soils fell into the high risk category.

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1. Introduction

Runoff can be considered a major way of phosphorus (P) losses compared with P leaching, but recent investigation indicated that P leaching from soils is a matter of concern (Qin et al., 2010; Li et al., 2015). Several researchers (Eghball et al., 1996; McDowell and Sharpley, 2001; Maguire and Sims, 2002a; Dao et al., 2005; Abdala et al., 2015) indicated that accumulation of P in the surface soil may intensify risk of P losses and increase movement of P below the plough layer. Many factors such as soil P sorption saturation and soil texture can affect leaching of P from soils. Significant leaching of P have been reported from P-saturated soils (Breeuwsma and Silva, 1992), sandy soils (Sims et al., 1998), soils that are poorly drained and high in organic matter (Cogger and Duxbury, 1984), structured clay soil (Djodjic et al., 2004) and where soils have received large amounts of manure or compost (Jalali and Ostovarzadeh, 2009).

In Hamedan, western Iran, about 65% of the cultivated soils are light texture soils (Jalali and Jalali, 2016) and have received P fertilization for more than 40 years. Intensive fertilization leads to accumulation of P in soils, increasing the risk of pollution of the aquatic environment by dissolved P losses in surface runoff (Sharpley and Withers, 1994) and leaching (Kolahchi and Jalali, 2013).

Soil column or field lysimeters can be used to simulate P leaching, but P leaching studies are time-consuming, labour intensive, expensive, and difficult to manage (Li et al., 2015; Pizzeghello et al., 2011). Many researchers attempted to predict leaching of P from soil properties and soil indices. Therefore, recognizing soils that are at risk of P losses using soil P tests are very important (Wang et al., 2015). As reported in previous published works (Heckrath et al., 1995; McDowell et al., 2002; Maguire and Sims, 2002a, 2002b; Wang et al., 2012) the soil P tests and degree of P saturation (DPS) developed for agronomic and environmental purposes can also be used to evaluate potential risk of P loss from agricultural soils (Sims et al., 2000; Hooda et al., 2000).

Although the risk for P leaching in calcareous soils was studied by a number of researchers (Mahmood-UI-Hassan et al., 2010; Jalali and Naderi, 2012; Ige et al., 2005; Djodjic et al., 2004; Zheng et al., 2015), relatively few research studied have been conducted to determine the relationship between P concentration in the leachates and various soil tests for P and DPS. Thus, this study was conducted to quantify P leaching from soils with different textures by using a wide range of soil testing P concentrations and to classify soils for potential P leaching loss.

2. Materials and methods

2.1. Soil extractable P

Five soil textures, including clay (n = 6), sandy (n = 8), sandy clay loam (n = 16), sandy loam (n = 9) and mixed loam (a mixture of loam, clay loam, silt loam, and silty clay loam) (n = 12) for a total of 51 soils, were selected as representative soils in the agricultural production areas of Hamedan, western Iran. Data of physical and chemical soil properties, and P extracted by different methods were analyzed previously by Jalali and Jalali (2016) and their mean values

were tabulated in Table 1. In addition, calcium chloride extractable P (PCaCl₂), water extractable P (WEP) and ammonium oxalate extractable P (P_{ox}) were adopted on all soils.

Calcium chloride-extractable P was obtained by shaking 2.0 g soil sample with 20 ml of 10 mM CaCl₂ solution for 1 h (P_{CaCl2-1h}) (Kuo, 1996). Water extractable P was obtained by equilibrating 2.0 g soil with 10 ml deionized water for 30 min. Acid ammonium oxalate-extractable P (P_{ox}), Al (Al_{ox}) and Fe (Fe_{ox}) were determined using a 0.1 M oxalic acid + 0.175 M ammonium oxalate solution, equilibrated at a pH of 3.0 and 1:60 soil-to-solution ratio and 4-h reaction time in darkness (McKeague and Day, 1966). Phosphorus in the extracts was determined colorimetrically by the procedure of Murphy and Riley (1962). Iron and Al in oxalate solution were determined using Varian, SpectraAA-400, and spectrophotometric method, (Pansu and Gautheyrou, 2006), respectively. The relationships between the DPS obtained from maximum P sorption (Q_{max}) and Olsen extractable-P (P_{OIS}), Mehlich-3-P (P_{M3}), calcium chloride extractable-P (P_{CaCl2-3h}), citrate extractable-P (P_{citrate}), and HCl extractable P (P_{HCl}) were reported elsewhere (Jalali and Jalali, 2016). The above data were also used here to compare and calculate new DPS values based on PSI.

2.2. P sorption index

Wang et al. (2016) presented three ways for calculating PSI and in this study only one of them was used. Phosphorus sorption index was calculated as the difference between initial (75 mg P l⁻¹, equivalent to 1500 mg P kg⁻¹) and final concentration of P at equilibrium (Pautler and Sims, 2000; Sims, 2000). The soil to solution ratio was 1:20 and suspensions were shaken for 18 h at room temperature, followed by centrifugation, filtration, and P was measured calorimetrically. The various DPS values were then calculated using following equations:

$$DPS_{ox} = \frac{P_{ox}}{(Fe_{ox} + Al_{ox})} \times 100 \quad (1)$$

$$DPS_{M3-1} = \frac{P_{M3}}{(Al_{M3} + Fe_{M3})} \times 100 \quad (2)$$

$$DPS_{M3-2} = \frac{P_{M3}}{(P_{M3} + Q_{max})} \times 100 \quad (3)$$

$$DPS_{M3-3} = \frac{P_{M3}}{(P_{M3} + PSI)} \times 100 \quad (4)$$

$$DPS_{CaCl2-1} = \frac{P_{CaCl2-3h}}{(P_{CaCl2-3h} + Q_{max})} \times 100 \quad (5)$$

$$DPS_{CaCl2-2} = \frac{P_{CaCl2-3h}}{(P_{CaCl2-3h} + PSI)} \times 100 \quad (6)$$

$$DPS_{CaCl2-3} = \frac{P_{CaCl2-1h}}{(P_{CaCl2-1h} + Q_{max})} \times 100 \quad (7)$$

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