Available online at www.sciencedirect.com
SCIENCE DIRECT®
Environmental Pollution 139 (2006) 176–182
ENVIRONMENTAL POLLUTION
www.elsevier.com/locate/envpol

Use of dolomite phosphate rock (DPR) fertilizers to reduce phosphorus leaching from sandy soil

G.C. Chen[a], Z.L. He[a,b,*], P.J. Stoffella[b], X.E. Yang[a], S. Yu[b], D. Calvert[b]

[a]Department of Natural Resource Science, College of Environmental and Resource Sciences, Huajiachi Campus, Zhejiang University, Hangzhou 310029, China
[b]IFAS, Indian River Research and Education Center, University of Florida, 2199 South Rock Road, Fort Pierce, FL 34945, USA

Received 13 August 2004; accepted 13 December 2004

Fertilizers developed from dolomite phosphate rock (DPR) reduce phosphorus leaching from sandy soil

Abstract

There is increasing concern over P leaching from sandy soils applied with water-soluble P fertilizers. Laboratory column leaching experiments were conducted to evaluate P leaching from a typical acidic sandy soil in Florida amended with DPR fertilizers developed from dolomite phosphate rock (DPR) and N-Viro soil. Ten leaching events were carried out at an interval of 7 days, with a total leaching volume of 1183 mm equivalent to the mean annual rainfall of this region during the period of 2001–2003. Leachates were collected and analyzed for total P and inorganic P. Phosphorus in the leachate was dominantly reactive, accounting for 67.7–99.9% of total P leached. Phosphorus leaching loss mainly occurred in the first three leaching events, accounting for 62.0–98.8% of the total P leached over the whole period. The percentage of P leached (in the total P added) from the soil amended with water-soluble P fertilizer was higher than those receiving the DPR fertilizers. The former was up to 96.6%, whereas the latter ranged from 0.3% to 3.8%. These results indicate that the use of N-Viro-based DPR fertilizers can reduce P leaching from sandy soils.

Keywords: Phosphorus leaching; DPR fertilizers; Water-soluble P fertilizer; Sandy soils

1. Introduction

Nutrients from applied fertilizers are positive assets if retained in the soil for uptake by plants, but become environmental pollutants if leached into watercourses or groundwater (Lewis and McGechan, 1998; McGechan and Wu, 1998; McGechan and Lewis, 2000). In the past, much attention was paid to nitrogen as a nutrient and pollutant, due to its high solubility and leachability into groundwater (Wu et al., 1998). However, more attention has been recently paid to the potential contamination of phosphorus to surface water (He et al., 2003; Zhang et al., 2002, 2003, 2004) because phosphorus is a limiting nutrient in most freshwaters (Sharpley and Beegle, 1999).

Application of P fertilizers can enhance agricultural production in soils with low P availability, especially in the tropical and subtropical region. However, P application in excess of plant requirements often results in contamination of aquatic systems. It has been reported that leaching of P contributes to eutrophication of fresh water bodies due to the availability of

* Corresponding author. Institute of Food and Agricultural Sciences, Indian River Research and Education Center, University of Florida, 2199 South Rock Road, Fort Pierce, FL 34945-3138, USA. Tel.: +1 772 468 3922x109; fax: +1 772 468 5668.
E-mail address: zhe@mail.ifas.ufl.edu (Z.L. He).

0269-7491/$ - see front matter © 2005 Elsevier Ltd. All rights reserved.
doi:10.1016/j.envpol.2004.12.016

soluble P to algae (Sonzogni et al., 1982; Izuno et al., 1991; Sharpley et al., 1994; Grobbelaar and House, 1995; Correll, 1998; Daniel et al., 1998; Parry, 1998; Sims et al., 1998). There has been an increasing interest in developing slow release P fertilizer to reduce P leaching losses from agricultural soils.

Water-soluble P fertilizers applied to sandy soils, which are widespread in Florida, are readily subjected to leaching, especially during the rainy season. Phosphorus leakage from agricultural soils has been suspected to be one of the major nonpoint sources for pollution of surface waters (Calvert, 1975; Calvert et al., 1981). Therefore, there is an urgent need for new types of P fertilizers that are agronomically effective and environmentally friendly. Phosphate rock (PR) has been directly applied to P-deficient acidic soils because it is nearly as effective as water-soluble P fertilizer but more cost-effective for correcting P deficiencies (Rajan et al., 1991; Wright et al., 1991; Chien and Menon, 1995). Phosphorus fertilizers developed from phosphate rock may also be superior to water-soluble P fertilizer for acidic sandy soils due to their slow release characteristics of P in terms of pollution of surface water.

Large amounts of dolomite phosphate rock (DPR) materials are produced as by-products during processing of PR to phosphoric acid in Florida. They contain substantial amounts of P, Ca, and Mg, and can be used for developing slow-release P fertilizers. Organic materials that may be used with the DPR material to produce slow release P fertilizers are wastewater residuals, i.e. biosolids, which are generated during the treatment of domestic sewage and contain high organic matter content and moderate amounts of nutrients needed by plants (USEPA, 1994). Greenhouse studies demonstrated that application of the DPR fertilizers made from the DPR materials and N-Viro soil consisting of biosolids and fly ash (50:50) significantly improved the growth of millet (*Setaria italica*), used as an indicator crop (He et al., 2002). DPR fertilizers also have other desired properties such as provision of Ca, Mg, and other nutrients. DPR fertilizers were observed to enhance growth of citrus and vegetable crops (He et al., 2004). However, environmental impacts of the DPR fertilizers need to be evaluated for field application, especially P leaching from sandy soils, which is a public concern in Florida.

The major objective of this study was to evaluate P leaching from sandy soil amended with DPR fertilizers, as compared with water-soluble P fertilizer. This information is needed to develop best management practices for citrus and vegetable crop production.

2. Materials and methods

2.1. Soil and N-Viro-based DPR fertilizers

A typical acidic sandy soil (Wabasso, sand 96.1%, silt 2.3%, and clay 1.6%) classified as hyperthermic Alfic Haplaquods, was collected at the 0–30 cm depths in Fort Pierce, Florida. Wabasso sand is a representative agricultural soil of commercial citrus and vegetable production systems in the Indian River area. Selected properties of the soil were 5.0 g kg^{-1} organic C, 0.23 g kg^{-1} total N, pH 4.1 (1:1 H_2O), pH 3.2 (1:1 KCl), 5.1 mg NaOH extractable P kg^{-1} soil, 0.6 mg Olsen-P kg^{-1} soil.

The DPR source selected for this study was from an IMC facility in Central Florida because of its relatively higher concentrations and availability of P and other nutrients such as Ca and Mg than other DPR sources. The N-Viro soil was provided by the Florida N-Viro, L.P. Company. It was made of biosolids and fly ash (1:1) and has been increasingly used in citrus groves, gardens, and vegetable fields in Florida and other states in the USA. The DPR was ground to <100 mesh and then mixed with N-Viro soil at the proportions of 0, 10, 20, 30, 40, 50, and 100% DPR. The DPR fertilizers were incubated at room temperature for 10 days prior to use. Some chemical properties and nutritional values of these DPR fertilizers are presented in Table 1.

Total C and N in the DPR fertilizers were determined by dry combustion using a CN analyzer (Vario Max CN, Macro Elemental Analyzer System GmbH, Hanau, Germany). The pH was measured in water at the solid/water ratio of 1:2 (w/w) using a pH/ion/conductivity meter (Accumet Model 50, Fisher Scientific Inc., Atlanta, GA). Electrical conductivity (EC) was measured in solution at a solid:water ratio of 1:2 using a pH/ion/conductivity meter (Accumet Model 50, Fisher Scientific). Available P was extracted using either 0.5 M

Table 1
Relevant properties of tested DPR fertilizers

DPR fertilizers with DPR%	pH (H_2O)	Total C (g kg^{-1})	Total N (g kg^{-1})	Total P (g kg^{-1})	Total Mg (g kg^{-1})	$CaCO_3$ (%)	Olsen-P (mg kg^{-1})	Mehlich-1P (g kg^{-1})
0	11.7	88.2	7.24	4.93	1.96	25.3	326	0.21
10	11.5	79.4	6.52	15.7	2.56	29.7	546	1.38
20	11	70.6	5.79	26.4	3.16	34.1	608	3.60
30	10.7	61.8	5.07	37.2	3.77	38.6	583	4.64
40	10.5	52.9	4.34	47.9	4.37	43.0	528	5.21
50	10.4	44.1	3.62	58.7	4.97	47.4	527	6.31
100	7.2	0.00	0.00	112.4	7.98	69.5	307	21.20