Rainfall Simulator Study of the Movement of Agrochemicals in Soils from Farmland Near Everglades National Park, Florida

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Abstract: Non-point source water pollutants from agricultural areas have been implicated as a source of water quality degradation in south Florida. Nutrient loading from agricultural and urban areas has increased nutrient concentrations, particularly phosphorus, in the Everglades National Park. This could have an adverse affect on natural vegetation types and patterns. The objective of this study was to investigate wash-off phosphorus in the soils from south Florida under simulated rainfall. Three typical soils, covering about 85% of the region, were selected for this study. A rainfall simulator was used to simulate regional rainfall characteristics. The results indicate that phosphorus transport from the soil depends not only adsorption coefficient but on the soil erodibility and permeability.

1 Introduction

Agro-chemical loading from agricultural and urban areas has increased nutrient concentrations, particularly phosphorus, in the Everglades National Park (EPA, 1996). The location of three national parks (Everglades, Biscayne and Big Cypress) in south Florida poses a major challenge for agriculture sector to develop satisfactory techniques that optimize crop production along with environmental protection. Soils in south Florida overlay a porous limestone bedrock and the shallow, unconfined Biscayne aquifer. The soils have low water holding capacity and high permeability and when large amounts of water and fertilizers are applied to crops there is a potential danger of agrochemicals (nutrients and pesticides) leaching into the aquifer (Savabi, 2001).

Frossard *et al.,* (2000) reported that long-term, intensive agriculture can cause a marked increase in loss of phosphorus and other agrochemicals through increased runoff, erosion, and leaching and have an adverse affect on water quality. Soil texture and the manner of leaching are the most common variables affecting the transport of surface-applied phosphorus (Lauer, 1988). Phosphorus movement is greater in sandy textured soils than in heavier textured soils, although downward movement of P is not much in either case (Lauer, 1988). Over a range of agricultural soils, 90% of the P added through fertilizer remained in the soil profile. Almost 95% of the ^{32}P-labeled phosphorus added in solution to four Oklahoma agricultural soils remained within the top 5 cm, and no movement was observed below 15 cm (Sharpley, *et al.*, 1986). One study with P applied in sprinkler water found that P moved down to 7 cm in a silt loam, but down to 11 cm in a sand (Lauer, 1988). Another study found that after 12 years of P application on a sandy loam, some of the extractable P had moved to 60 cm, the deepest sampling taken (Sommers *et al.*, 1979). Lauer (1988) found that a calcareous silt loam had a higher P sorption index, and therefore greater reactivity toward triple superphosphate than a noncalcareous silt loam and a sand. Triple superphosphate was, however, less reactive than ammonium polyphosphate or monoammonium phosphate. Accordingly, at a given P rate, the phosphorus penetrated deeper in the noncalcareous silt loam (mean depth of 5.5 cm) and sand (5.4 cm) than in the calcareous silt loam (3.1 cm) (Lauer, 1988). In the calcareous soil, most of the P remained in the top 2 cm, due most likely to the greater interaction of this soil with P. Previous research has shown that the amount of phosphorus in runoff is directly related to the P content in the surface soil (e.g., Sharpley *et al.*, 1986).

The objective of this study was to investigate the mobility of phosphorus (applied through super phosphate) in the soils found in farmland east of Everglades National Park, south Miami-Dade County, Florida.

2 Methods and materials

2.1 Soil collection and rainfall simulator

The three common soils from agricultural areas in south Miami-Dade County, Florida, used in this study were: Chekika gravelly loam (loamy-skeletal, carbonatic, hyperthermic Lithic Udorthents), Krome (loamy-skeletal, carbonatic, hyperthermic Lithic Udorthents) and Perrine marl (coarse-silty, carbonatic, hyperthermic Typic Fluvaquents) (Table 1). These soil associations cover approximately 85% of the area in Miami-Dade County, Florida. The important physical and chemical properties of these soils that influence agro-chemical sorption and transport are listed in Table 1. The rainfall simulator houses a set of oscillating nozzles (VeeJet No. 80100), spaced 1.07 m apart, located 3.5 m above the soil surfaces.

Soils were placed in 144 cm^2 boxes on a 2% slope. Fine sand was placed below each soil to simulate the porous limestone bedrock that exists in south Florida. The depth of soil in each box was about 5 cm and packed to it's field observed bulk density (1.2 g/cm^3—1.4 g/cm^3). A plumbing system similar to Savabi (2001) was designed to saturate the soil from the bottom, prior to each rainfall simulation test. Triple Super Phosphate was mixed with the top few centimeters of soil. The rate of applications was 118 kgs P_2O_5/acre. This is equal to 33 mg of P per kg of soil (evenly distributed) on each box. Each box was placed beneath the rainfall simulator and subjected to a one hour rainfall event. The rainfall intensity was between 11—13 cm hours. Rain gages were used to determine the rainfall application. Runoff and sediment samples were taken manually at 3—5 minute intervals. Sediment lost from each simulated rainfall test was determined as the product of runoff volume and soil loss, integrated over the entire rainfall simulation period. This procedure was repeated three times for each soil and agro-chemical treatement.

Table 1 Soil physical and chemical properties

Soil Name	Soil Texture	Soil Depth cm	% Sand	% Silt	Saturated hydraulic conductivity (falling head method)	%OM	CECmeq/ 100g of soil	pH	%Rock >2 mm
Krome	Sandy Loam	20	59	31	23.9	2.1	12.2	7.8	11.4
Perrine Marl	Silty Clay Loam	12.5	5	63	16.9	1.3	8.7	7.6	1.4
Chekika	Sandy Loam	30	61	25	25.8	3.1	14.7	7.9	20.2

2.2 Phosphorus reactivity index (PRI)

In order to characterize P in the soil water solution, Phosphorus Reactivity Index (PRI), and water extractable P were measured. An index of P sorption as reported by Bache and Williams (1971) has often been used as a measure of the reactivity of forms of phosphorus with a particular soil. The index is the ratio, $x/\log c$, where x is the amount of P sorbed and c is the equilibrium concentration of P in solution. This ratio is correlated with P sorption maxima calculated from a Langmuir sorption plot, and is also a measure of the reactivity of a particular fertilizer with a particular soil. The PRI was measured for each soil. Each 1 gram sample of soil received 1.5 mg P from KH_2PO_4, and was shaken in a 1:20 soil suspension of 0.02 M KCl for 40 h. After centrifuging and filtering, the P remaining in the supernatant was determined by the ascorbic acid method and the amount of P sorbed (x) and the equilibrium concentration of P in solution (c) were measured. In addition, water extractable soil P was determined for each soil. A centrifuge tube with one gram of soil and 25 mL of distilled water was shaken for 1 h, centrifuged, and filtered through a 0.45 mm polycarbonate membrane. The supernatant was analyzed for P using chromatography method.

3 Results

The amount of water extractable soil P (mg per kg of soil) was the highest for Perrine, followed by Chekika soil. The Krome soil had the lowest water extractable soil P (Table 2). The average total *P* concentation and average water extractable P for nine soil samples (three samples for each soil type) were 2200 and 0.42 respectively. Our measured P concentation and average water extractable P are within the range of value reported by other investigators in south Miami-Dade County soils. Li *et al.* (1997) measured the water soluable P in soil samples from various vegetables and fruit groves in south Dade county. They reported that the range of water extractable P concentation of P from 0.3 to 7.9 and total P of about 2200ppm. Therefore, the soils used in this study may be considered atypical for the region.

Table 2 P status for various soil types in south Miami-Dade County

Soil Type	$CaCO_3$ %	Total P (mg/kg of soil)	P Index (mg/kg of soil)	H_2O Extracted P (mg/kg of soil)
Chekika	66	3,200	410	0.455
Krome	62.5	1,700	530	0.131
Perrine	87.5	1,700	250	0.700

The amount of soluable P concentration in storm runoff is shown in Fig. 3. Soluble P in runoff was the highest for Perrine, followed by Chekika. Krome soil had the lowest soluble P concentration (Fig 3). This is the same ranking as the water extractable P that is shown in Table 2. Pote *et al.*, (1996) indicated this relationship between water extractable soil P and dissolved P in runoff in their extraction study. In addition, the Perrine soil has the lowest infiltration rate and the highet runoff rate (Fig. 1).

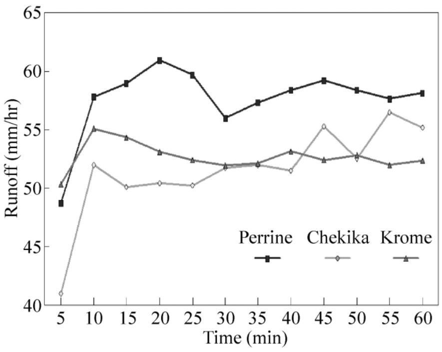

Fig. 1 Average storm runoff from plots with Perrine, Krome and Chekika soils

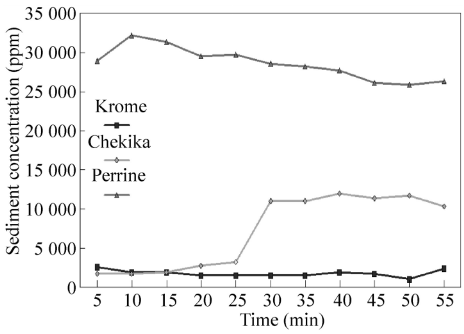

Fig.2 Average sediment losses from plots with Perrine, Krome and Chekika soils

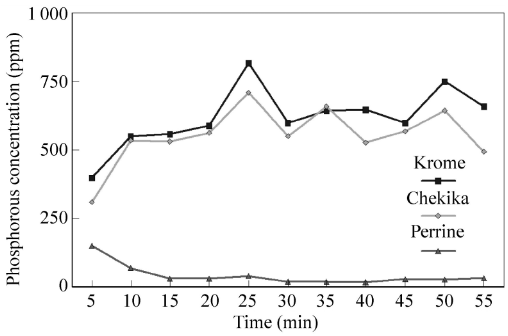

Fig.3 Average soluable phosphorus in storm runoff

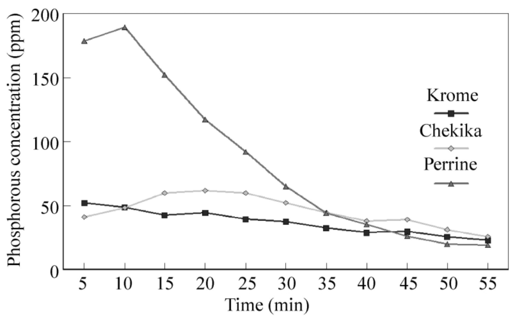

Fig. 4 Average attached phosphorus to sediments for the soils

The PRI for soils was highest for Krome, followed by Chekika, and Perrine (Table 2). This indicates that phosphorus would interact and be retained more by the Krome and Chekika soils than by the Perrine soil, although all the soils have high PRI values. This is consistent with the concentrations of soluble P attached to sediment and was detected in the storm runoff. The smallest amount of P is extracted from the Krome soil, which has the highest PRI. The amount of attached P found in the runoff soil samples was highest for Krome soil followed by Chekika soil. Perrine soil had the lowest amount of attached P in runoff samples

4 Conclusion

Perrine soil has the lowest organic matter content and the highest soluble phosphorous. Phosphorous attached to sediments and washed out of the runoff plots is highest for Krome soil. This phenomenon needs further investigation. Present results indicate that three soils in south Florida have different sorption capacities that should be considered while applying agro-chemicals, such as phosphorous and pesticides, as part of an agricultural operation. Our results concour with the developers of P indices (Sharpley *et al*. 1994) that soil test P levels are not enough to judge and guide P management and applications. Characteristics such as topography, management, as well as soil type, must be considered.

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