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SOLUBLE PHOSPHORUS RELEASE FROM ORGANIC SOILS*

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ABSTRACT

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Soluble P release during soil organic matter decomposition was measured under fluctuating seasonal temperatures in several of Florida's organic soils. Natural soil profiles obtained from seven locations in central and south Florida were used in the study. Soil columns were leached once every 25 days, followed by applying a suction of 100 cm. Soil columns were flooded for 25 days in the months of July and August (between 14 and 21 weeks after initiation of the study for central Florida organic soils and between 11 and 18 weeks for south Florida organic soils) to simulate normal agronomic practice.

The amounts of P released into effluent from Florida's organic soils were in the range of 2.9—26.2 μg P/cm^3 of soil per year (16—168 kg P ha^{-1} year^{-1}). This represents 2.2—20% of the total soil P for central Florida organic soils and 0.75—1.1% of total soil P for south Florida organic soils. Soluble ortho-P accounted for about 70—89% of total effluent P for central Florida organic soils and 54—57% of effluent P for south Florida organic soils. Estimated soil P mineralization during organic matter decomposition was about 38—185 kg P ha^{-1} year^{-1} for central Florida organic soils and 16—23 kg P ha^{-1} year^{-1} for south Florida organic soils. Seasonal temperature fluctuations had minimal influence on the P release into effluent. Flooding the organic soils, however, increased P release into drainage effluent by about 4—8 times, compared with drained conditions.

INTRODUCTION

Florida has approximately 1.5 million hectares of organic soils, which were formed by the accumulation of the decayed remains of sawgrass (*Cladium jamaicense* Crantz) and related wetland plants over the last 5000 years. These soils are generally adjacent to freshwater lakes. For example, Lake Okeechobee in south Florida and Lake Apopka in central Florida are associated with organic soils. These soils were drained for agricultural purposes resulting in enhanced carbon loss caused by aerobic microbial

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oxidation. As a result, these soils are subsiding at a rate of about 3 cm $year^{-1}$ (Stephens, 1969). During the summer months when crops are not planted, these soils are flooded as a management practice to control weeds, pests, and reduce soil subsidence. Following flooding they are drained, and drainage water is either pumped into recycle reservoirs or into adjacent lakes. In Florida, drainage water P discharge from organic soils used for agricultural purposes was in the range of 0.5—2.4 kg P ha^{-1} $year^{-1}$ in the Everglades agricultural area (Florida Sugar Cane League, 1978) and 7.7 kg P ha^{-1} $year^{-1}$ in central Florida (Reddy et al., 1982). Other studies reported a drainage water P discharge of about 2—37 kg P ha^{-1} $year^{-1}$ from organic soils of Ontario, Canada (Miller, 1979) and 0.6—31 kg P ha^{-1} $year^{-1}$ from organic soils in New York (Duxbury and Peverly, 1978).

The biochemical and physical processes controlling P release into drainage effluents include organic P mineralization and P adsorption—desorption. Management practices such as water table manipulation (Snyder et al., 1978) and flooding to control soil subsidence can also influence P release into drainage effluents. The purpose of this investigation was to measure the role of soil organic matter decomposition on the release of soluble P into drainage effluent under fluctuating seasonal temperatures. Natural soil profiles collected from various locations in Florida were used in the study.

TABLE I

Description of the organic soils used in leaching studies

Soil symbol	Soil series	New classification	Location	Associated lakes
Cultivated soils				
F	Oklawaha muck	Terric Medifibrists Clayey, mixed, Euic, hyperthermic	Eustis—Leesburg	Lake Yale—Lake Griffin
D	Monteverde muck	Typic Medifibrists Euic, hyperthermic	Zellwood	Lake Apopka
C	Lauderhill muck	Lithic Medisaprists Euic, hyperthermic	Zellwood	Lake Apopka
A	Brighton muck	Typic Medifibrists, Dysic	Zellwood	Lake Apopka
BC	Pahokee muck	Lithic Medisaprists Euic, hyperthermic	Belle Glade	Lake Okeechobee
Virgin soils				
EV	Monteverde muck	Typic Medifibrists Euic, hyperthermic	Zellwood	Lake Apopka
BV	Pahokee muck	Typic Medisaprists Euic, hyperthermic	Belle Glade	Lake Okeechobee

ₗS AND METHODS

oil columns from seven locations across Florida (Table I) were
ɔy slowly driving a polyvinyl chloride (PVC) pipe (7.5 cm ID)
ı of about 70 cm. This procedure resulted in very little or no
ıction. Three soil columns were obtained from each of seven
five of which were areas used for growing crops and two areas
ı. One of the virgin sites and four of the cultivated sites were
Florida; the remaining sites were in south Florida. All soils ob-
closely associated with lakes. At the same locations, soil sam-
ılso obtained at depth increments of 0—30, 30—60, and 60—90
ɛd characteristics of the soils are shown in Table II. Soil col-
sealed with PVC caps and stored at 4°C until used. Maximum
od was 3 weeks for south Florida soils and 2 weeks for central
ı.

cteristics of the soils used in the study

Bulk density (g cm^{-3})	pH	Phosphorus (μg/cm^3 of soil)				Total C (%)
		Water-soluble	Dilute acid extract	Organic	Total	
0.31	5.7	13.02	14.14	80.3	170.5	36.7
0.20	5.7	2.26	8.16	74.8	133.0	35.7
0.16	5.5	0.67	2.88	26.6	42.4	36.5
0.33	6.5	0.89	17.03	369.9	601.6	36.6
0.34	6.4	0.79	17.96	272.0	445.4	37.2
0.12	6.0	0.23	5.62	26.2	52.8	35.4
0.32	6.4	1.15	15.74	345.5	392.0	43.5
0.32	6.5	1.20	17.50	340.2	380.0	42.1
0.92	6.9	1.10	9.38	333.9	427.8	6.7
0.33	5.9	6.83	10.49	53.6	72.6	38.5
0.12	4.8	3.02	4.39	22.9	32.4	37.2
0.13	4.9	3.59	5.30	18.6	25.3	36.4
0.36	6.3	0.69	2.07	207.2	276.4	46.9
0.30	6.2	0.52	1.90	201.2	251.5	42.1
0.14	5.5	5.25	8.82	121.9	203.0	36.4
0.12	6.3	1.73	7.56	31.9	67.2	36.5
0.48	7.4	0.63	16.13	47.6	69.6	7.4
0.34	5.4	0.63	4.18	381.5	[illegible]	[illegible]

Incubation procedure

Soil columns were incubated in a greenhouse shaded with wooden lattice. Temperatures in the greenhouse were maintained at the same level as encountered outside the greenhouse by allowing the outside air to be blown in by cross ventilation and an electric fan. The temperature in the greenhouse was monitored continuously using a thermograph (Table III). Incubation of central Florida soils was initiated on 11 April 1980, while the south Florida soils were incubated on 16 May 1980.

The bottom portion of the PVC column was sealed to a porous plate, and glued to a PVC cup provided with an outlet. Glass wool and a thin layer of pre-washed sand was placed on top of the soil column. Initially, each soil column was leached with 2 l of 0.01 M $CaCl_2$ followed by one liter of de-ionized distilled water. Soils were allowed to drain naturally followed by applying 100 cm suction. Soil water content at 100-cm suction was found to be optimum for soil organic matter decomposition (Terry, 1980). Leachate was collected for chemical analysis. After 25 days of incubation, soils were leached with one liter of de-ionized distilled water (3 cm h^{-1} for a period of 7.5 h) and were allowed to drain naturally followed by applying 100-cm suction. This procedure was repeated once every 25 days for a period of 1 year. During the summer months (July and August), soil columns were flooded for two 25-day periods to represent summer flooding and draining (between 14 and 21 weeks after initiation of the study for central Florida organic soils and between 11 and 18 weeks for south Florida organic soils). At the end of the flooding period, a similar leaching procedure described above was followed. After every

TABLE III

Maximum and minimum ambient temperature ranges (°C) during the study period

Incubation time (weeks)	Central Florida organic soils		South Florida organic soils	
	Minimum	Maximum	Minimum	Maximum
0—5	19.3	34.2	21.9	34.9
5—10	21.9	34.9	22.1	34.3
10—15	22.1	34.3	22.4	34.1
15—20	22.4	34.1	20.9	32.4
20—25	20.9	32.4	16.5	28.3
25—30	16.5	28.3	11.3	21.7
30—35	11.3	21.7	4.9	16.2
35—40	4.9	16.2	7.4	19.3
40—45	7.4	19.3	8.9	23.8
45—50	8.9	23.8	—	—

volume of the leachate (effluent) was measured. A portion nt was filtered through 0.2 μm filter paper and analyzed for the end of the study period, soil columns were sectioned into increments and analyzed for extractable P.

thods

le, extractable and organic fractions of P in the soil samtermined. Water-soluble P was measured by extracting 5 g -dry basis) with 25 ml of de-ionized distilled water for 30 was determined in the extract after filtration through 0.2 er. Extractable P was measured by extracting 5 g of soil with ble acid (0.05 N HCl + 0.025 N H_2SO_4) for 30 min. Ortho-P ed in the extract following filtration through 0.2 μm filter and total P in the soil samples were measured by the proed by Olsen and Dean (1965). Ortho-P in the extracted effluents was analyzed by the single-reagent method (Murphy 32) and total P in the effluent was determined by persulfate wed by the single-reagent method (APHA, 1971).

ISCUSSION

s of central Florida released more P into drainage water n south Florida. Under aerated conditions, total P released as in the range of 0.37—11.2 μg P/cm^3 of soil per 25-day for central Florida organic soils and 0.03—0.42 μg P/cm^3 of for south Florida organic soils. Total amount of P released y period (including two flooding periods in July and August) μg P cm^{-3} year^{-1} (2.2—20.0% of total soil P) for central soils and 2.9—3.9 μg P cm^{-3} year^{-1} (0.75—1.1% of total Florida organic soils (Fig. 1). This represents about 16—168 $^{-1}$ released into effluent during organic matter decomposia's Histosols.

of ortho-P released into effluent was 70—89% of the total rganic soils of central Florida and 54—57% of the effluent h Florida organic soils (Fig. 2). This represents an annual —128 kg P ha^{-1} year^{-1} from all soils studied. Phosphorus fluent was derived from: (1) solubilization of inorganic lization of organic P.

f P solubilized as a result of chemical and biological proe incubation period was estimated using the following

P_0

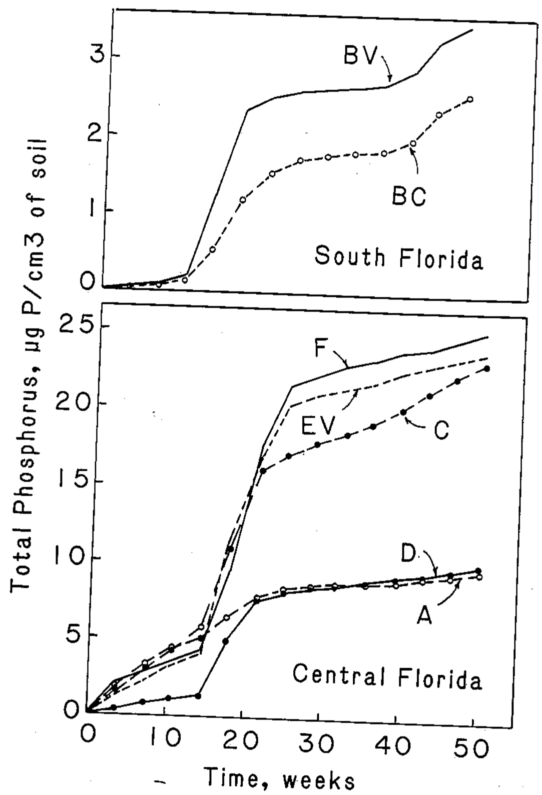


Fig. 1. Cumulative total P release into drainage effluent from several organic soils during 50 weeks for soils A, C, D, EV and F and 46.4 weeks for soils BC and BV, respectively. A = Brighton; C = Lauderhill; D = Monteverde; EV = Monteverde (virgin); F = Oklawaha; BC = Pahokee; BV = Pahokee (virgin).

into effluent at the end of each leaching period; P_1 = P in the soil column present in available form (as determined by 0.05 N HCl + 0.025 N H_2SO_4 extraction) at the end of the incubation period; and P_0 = P in the soil column present in available form at the start of the incubation. Phosphorus concentrations in the above equation are expressed in μg P/cm^3 of soil.

Among the central Florida organic soils, soils EV (virgin) and F (cultivated) were found to be most productive with about 185 and 150 kg P ha^{-1} $year^{-1}$, respectively, solubilized during organic matter decomposition (Table IV). These soils have about 45–52% of total P in organic fraction compared with 62–73% in soils A, C, and D. This suggests that in soils EV and F, a significant amount of P was either solubilized from insoluble inorganic P or they contain more easily decomposed organic matter, thus more organic P was mineralized. Cultivated soils A, C, and D were obtained from the same general area as soil EV, and these soils are used intensively for vegetable production. Soils C and D have relatively

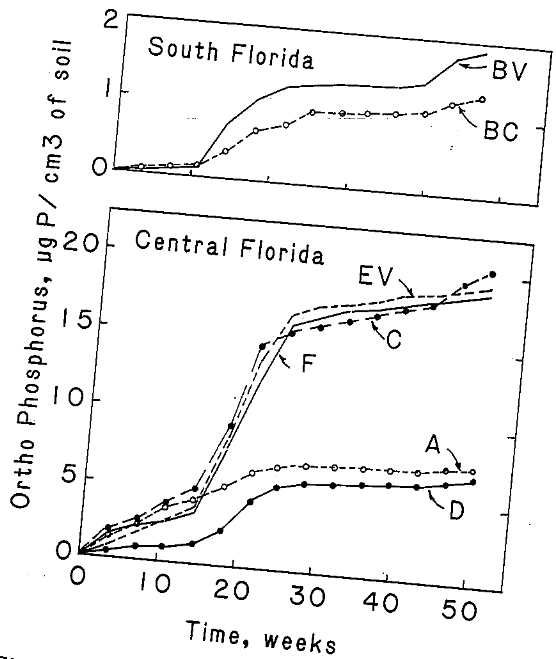


Fig. 2. Cumulative soluble ortho-P release into drainage effluent from several organic soils during 50 weeks for soils A, C, D, EV and F and 46.4 weeks for soils BC and BV, respectively. A = Brighton; C = Lauderhill; D = Monteverde; EV = Monteverde (virgin); F = Oklawaha; BC = Pahokee; BV = Pahokee (virgin).

TABLE IV

Phosphorus solubilization rates of Florida's organic soils

Soil	Initial amount of soil P available ($\mu g/cm^3$ of soil)	P leached into effluent[a] ($\mu g/cm^3$ of soil)	Final amount of soil P available ($\mu g/cm^3$ of soil)	P potentially solubilized	(kg P ha^{-1} $year^{-1}$)
Cultivated soils					
F	11.3	25.2	8.5	22.4	149.6
D	16.8	10.2	17.3	10.7	71.5
C	8.8	23.3	15.2	29.7	105.4
A	7.3	9.7	2.6	5.0	33.9
BC	2.1	2.6	3.5	4.0	24.4
Virgin soils					
EV	8.7	23.9	12.6	27.8	185.7
BV	4.2	3.5	3.1	2.4	15.0

[a]Values shown are the total amounts of P leached after 350 days in soils A, C, D, EV and F, and 325 days for soils BC and BV, respectively.

re total P (62—78% in organic fraction) than soil EV, but the amount P mineralized was less than soil EV, probably due to the slow rate of anic P mineralization. Soil A had lower total P (73% in organic frac- ı) than other soils and the amount of P mineralized represents about ͅ of the total soil P in 1 year.

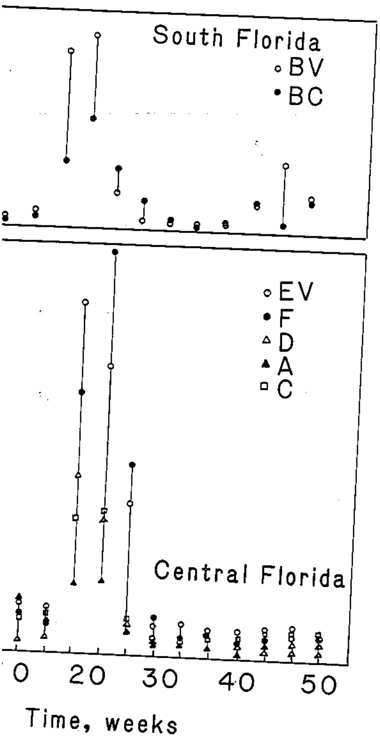
hosphorus release rates in south Florida organic soils were 24.4 and) kg P ha^{-1} $year^{-1}$, respectively, for soils BC (cultivated) and BV (vir- . About 74% of the total P in these soils was in the organic fraction. v P mineralization probably resulted in the slow rate of soluble P leached ı these soils. Results reported by other researchers (Gascho and Kidder, 9) show significant response to high rates of P application to agricul- l crops grown on south Florida organic soils. Similar response to P ication was not observed in central Florida soils. In the Everglades (south Florida), drainage water P discharge from organic soils used agricultural purposes was reported to be in the range of 0.5—2.4 kg $^{-1}$ $year^{-1}$ (Florida Sugar Cane League, 1978), compared with 7.7 kg $^{-1}$ $year^{-1}$ (Reddy et al., 1982) from the organic soils located in the vood area (central Florida), indicating a slow release of P from south da organic soils.

led vs. drained conditions

ta in Fig. 3 show the total P release rates under flooded and drained tions. Under flooded conditions, the amount of total P released from al Florida soils (36—208 mg P cm^{-3} day^{-1}) was about 4—8 times higher that released from the soils of south Florida (8—25 mg P cm^{-3} day^{-1}). P release into drainage effluent was about 4—6 times higher under ed conditions compared with drained conditions. Ortho-P accounted oout 28—97% of the total P under flooded conditions and 82—93% al P under non-flooded conditions. Increased P release under flooded ions was probably due to the solubilization of organic matter during bic decomposition and increased release of inorganic P as a result ubilization of iron, aluminum and calcium phosphate (Mahapatra trick, 1969).

omic and environmental significance

onomically, soluble P released from central Florida organic soils imately meets the requirement of crop needs, whereas the P release outh Florida organic soils does not satisfy the crop needs. In Florida, been estimated that vegetable crops (two to three crops a year) re- bout 50—70 kg P ha^{-1}, while a crop of sugar cane would remove about kg P ha^{-1} (Barnes, 1974; Andreis, 1975). In south Florida, crops l to the application of P fertilizers (Gascho and Kidder, 1979) indi-



horus release rates under flooded and drained conditions from several
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ctively. A = Brighton; C = Lauderhill; D = Monteverde; EV = Monteverde
:lawaha; BC = Pahokee; BV = Pahokee (virgin).

ow P-releasing capacity of those soils. However, crops grown on
of central Florida do not respond to P application.
oils of Florida are naturally poorly drained and are artificially
eep the water table at optimum level by establishing mole
ut 90 cm depth, and excess drainage water is either pumped
retention ponds or lakes. This results in an annual discharge
—7.7 kg P ha^{-1} year^{-1} (Florida Sugar Cane League, 1978;
1982). Summer flooding of organic soils accounted for 25—
P solubilized during the year. Flooding the organic soils re-
ubsidence (Snyder et al., 1978), but increased the soluble
ainage effluents, resulting in P loads to adjacent bodies of

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