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SHORT COMMUNICATION

TOTAL AND LEACHABLE PHOSPHOROUS IN URBAN STREET TREE LEAVES

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ABSTRACT. Leaves of different tree species were leached with distilled water (pH 7.0 ± 0.2) and rain water (pH 5.7 ± 0.3) in laboratory glass cylinders to simulate the release of phosphorous (P) pollutant to urban runoff. An average of 106 ± 52.1 μg g^{-1} and 143 ± 72.7 μg g^{-1} (air dried weight) of P were leachable from entire leaves in 2½ hours in distilled water and rain water, respectively; these represented 7.21% and 11.36%, respectively, of the total P in the leaves analyzed. The amount of leachable and total leaf P varied significantly ($p < 0.05$) among tree species but were not significantly ($p < 0.05$) affected by tree diameters. Fragmented leaves released more than twice as much phosphorous as intact leaves. These findings point to leaves as a source of urban runoff P.

INTRODUCTION

Water is a good solvent of many atmospheric pollutants. Whipple *et al.* [1] reported that runoff from urban areas contains a wide variety of nutrients, heavy metals, synthetic organic chemicals and sediments. Urban land runoff has been cited as the main source of lake P [2,3]. Sources of this P have not been much examined but reported to include automobile exhaust, minerals, lawn fertilizer, atmospheric deposition, detergent (from domestic wastes) and tree leaves and seeds.

Halverson *et al.* [4] found that rain falling through an urban tree canopy *(Acer negundo L.)* had enhanced concentrations of several elements including P. Tree foliage present a large surface area for collection of elements through dry fall out. The transport of nutrients and elements from soil to leaves occurs via the trees, where they are subject to leaching and eventual transfer to urban surfaces. Therefore, contribution of P from leaf fall and leaching may be important source of P in urban areas.

Total concentration of P in tree leaves has been reported for various natural ecosystems [5,6]. Gosz *et al.* [7] reported substantial amounts of calcium, magnesium, potassium, sodium and total nitrogen leached from leaves of several species of forest trees. In urban areas, Cowen and Lee [8] and Dorney [9] have examined leachable tree leaf P using distilled water as solvent. However, determination of leachable leaf P using rain water has not been much investigated. Thus, this research was conducted to determine the content of P in various tree species in the city of Ogbomoso (Nigeria) street trees, considering: the amount of P leachable from tree leaves at the leaching period of 2½ hours in distilled water and rain water, total leaf P content, differences among species in total and leachable P, and effect of tree diameter on leaf P levels. This study demonstrates the importance of urban street leaves as a source of urban runoff P.

EXPERIMENTAL

Freshly fallen, dry tree leaves (representing 10 species, Table 1) were collected along the street in the city of Ogbomoso. Leaves were air-dried to constant weight at laboratory temperature (approximately 27±2°C) for two weeks. Rain water used for this study was collected from Lagos.

Analysis of leachable P was done as described by Dorney [9]. Samples of leaves were weighed, placed in acid-washed and detergent free 1500 cm^3 glass cylinders, and 500 cm^3 of distilled water ($pH = 7.0 \pm 0.2$) were added. The leaves were soaked for 2½ hours to simulate the natural contact time with urban runoff. The distilled water was poured off and leaves were washed with an additional 500 cm^3 of distilled water. The identical sequence of steps were also followed using the rain water. Total leachable P in the distilled water and rain water were determined using perchloric acid digestion followed by vanadomolybdate determination using a Spectronic 20D Spectrophotometer [10]. Leaves of selected tree species were cut into pieces, and the total leachable P were determined following the same procedure described for the intact tree leaves. Calibration curves were prepared daily using distilled water and prepared standards of 0, 2, 4, 10, 20 and 50 $\mu g\ dm^{-3}$ of phosphorous. Using the levels of total P in the distilled water and rain water as blanks and calibration curves, the amount of leachable P per gram of air-dried leaf tissue was determined. The reproducibility of the method of leaching was checked by analyzing duplicate leachate samples. Duplicate results did not differ by more than 5% of the mean.

Duplicate portions of the leaf tissue were pulverized to unifrom size and the total P was measured following nitric (800 cm^3) and sulphuric (200 cm^3) acids digestion [11]. Data were analyzed statistically using regression analysis to determine significant effects of tree diameter on total leaf P and leachable P. The analysis of variance ($p < 0.05$) was used to determine significant differences in total P, leachable P and percent of total P leachable between tree species.

RESULTS AND DISCUSSION

The analytical results given in Table 1 are the means (and standard deviations) for 2 to 6 samples taken from each tree specie at weekly intervals. Concentrations of leachable P in distilled water from intact tree leaves ranged from 39.8 to 345 $\mu g\ g^{-1}$ air-dry weight with means ranging from 52.1 to 190 $\mu g\ g^{-1}$ (Table 1). Leaves averaged 106 $\mu g\ g^{-1}$ of leachable P in distilled water. These levels are less than those reported by Dorney [9] for leaves of different tree species in distilled water. Similarly, the concetnrations of leachable P in rain water from intact tree leaves ranged from 44.7 to 482 $\mu g\ g^{-1}$ air-dry weight with means ranging from 69.6 to 241 $\mu g\ g^{-1}$ (Table 1). Leaves averaged 143 $\mu g\ g^{-1}$ of leachable P. The leachable P levels were higher with rain water than with distilled water for leaves of different tree species analyzed. This might be attributed to the presence of dissolved substances in the rain water [12], which increase the rates of leaching. The mean total tree leaf P ranged from 0.10 to 0.45% (Table 1), with overall mean of 0.25% for all tree species studied. Only small fractions (means 7.21% and 11.36%) of the total leaf P were leached in 2½ hours test period in distilled and rain waters, respectively.

In order to simulate fragmentation which occurs as the leaves weather *in-situ*, the leaching study was carried out on the cut-up leaves. It was found out from our study that the fragmented leaves released more than twice as much phosphorous as intact leaves. For example, *Azadirachta indica* leaves cut into small pieces leached 273 μg P/g and 397 μg P/g of leaves soaked in distilled and rain waters, respectively (Table 2), which are more than two times the level for intact leaves (106 μg P/g and 156 μg P/g, respectively). These observations are in agreement with those reported by Cowen and Lee [8], and might be due to exposure of vein surfaces of the fragmented leaves.

Table 1. Total P, leachable P, and % of total P leachable from urban street leaves.

Common name	Scientific name	T.D. (cm)	Total P (%)	Leachable (P), $\mu g\ g^{-1}$ of dry leaves		% of total (P) leachable		No. of sample (n)	
				D_{Water} (pH=7.0 ±0.3)	R_{Water} (pH=5.7 ±0.2)	D_{Water}	R_{Water}	Leachable P	Total P
Mango	*Mangifera indica L.*	35.9	0.11[a] (0.02)[b]	71.6 (31.0)	95.3 (39.4)	6.70 (1.23)	8.40 (0.67)	5	3
Dongoyaro	*Azadirachta indica*	85.1	0.10 (0.02)	106 (22.2)	156 (31.4)	8.70 (0.80)	15.9 (1.25)	4	3
Shear butter	*Vilellaria paradoxa*	54.7	0.39 (0.11)	190 (45.0)	241 (104)	3.90 (0.73)	6.20 (1.83)	6	3
Orange	*Citrus sinensis*	43.8	n.d	153 (36.7)	214 (53.7)	n.d	n.d	4	0
Purple alamander	*Alamander sp.*	39.6	0.45 (0.16)	90.4 (31.5)	108 (27.7)	13.5 (1.83)	22.2 (1.87)	6	4
Pawpaw	*Carica papaya Linn.*	31.2	0.09 (0.02)	122 (27.1)	158 (44.1)	5.60 (0.70)	8.20 (1.00)	5	2
Cashew	*Anarcadium occidentale L.*	44.6	0.14 (0.02)	52.1 (18.5)	69.6 (22.3)	2.80 (0.66)	4.10 (0.79)	3	3
Guava	*Psidium guajava L.*	36.3	n.d	59.6 (20.4)	83.3 (35.7)	n.d	n.d	3	0
Gmelina	*Gmelina arborea roxb.*	32.9	n.d	96.3 (28.5)	133 (49.2)	n.d	n.d	4	0
Avocado pear	*Persea grattisima*	41.4	n.d	74.5 (23.4)	117 (48.0)	n.d	n.d	5	0
	Mean (All leaves)		0.25 (0.15)	106 (52.1)	143 (72.7)	7.21 (3.85)	11.36 (6.67)	45	18

[a]Means of duplicate analysis and `n' sampling, where n = number of sample; [b]standard deviation, σ_{n-1}; n.d. = not determined; D_{Water} = distilled water; R_{Water} = rain water; T.D. = tree diameter.

Table 2. Leachable (P) from fragmented leaves.

Common name	Scientific name	Leachable P, $\mu g\ g^{-1}$ of dry leaves		No. of sample (n)
		D_{Water}	R_{Water}	
Dongoyaro	*Azadirachta indica*	273[a] (82.5)[b]	397 (168)	5
Orange	*Citrus sinensis*	396 (187)	570 (234)	4
Guava	*Psidium guajava*	189 (92.6)	260 (101)	7
Cashew	*Anarcadium occidentale L.*	110 (34.6)	156 (44.7)	3

[a]Means of duplicate analysis and `n' sampling, where n = number of sample; [b]standard deviation, σ_{n-1}.

Tree diameter did not have a significant ($p < 0.05$) effect on total or leachable P. It is apparent from these results that urban street tree leaves contain relatively high amount of total P and that only small fractions (about 7.21% and 11.36%) are readily leached from entire leaves in 2½ hours in distilled and rain waters, respectively. Also any physical damage to the leaves would tend to increase their contribution to runoff phosphorous loads. Exposure of vein surfaces by cutting the leaves of selected tree species was shown to result in large amounts of leachable P compared with intact leaves.

However, levels of leachable ($p = 0.05$, $F = 2.12$), total ($p = 0.05$, $F = 2.64$), and percent of total P leachable ($p = 0.05$, $F = 2.64$) did vary significantly among species. Leave from shear butter (*Vilellaria paradoxa*) and orange (*Citrus sinensis*) had significantly more leachable P than average in both solvent media while cashew (*Anarcadium occidentale L.*) had significantly less. Total P levels in tree leaves also showed variation with purple alamander (*Alamander sp.*) and shear butter (*Vilellaria paradoxa*) having significantly higher levels than overall mean while mango (*Mangifera indica L.*), dongoyaro (*Azadirachta indica*) and pawpaw (*Carica papaya Linn.*) had significantly less. For the percent of total P which was leachable, only purple alamander (*Alamander species*) had significantly higher levels than average in both solvent media while cashew (*Anarcadium occidentale L.*) had significantly less. The observed differential levels of total P in tree species studied might be due to different transport mechanism of elements including P from soil to leaves by tree species, and also on the amount of P available in the soil.

CONCLUSION

As evidenced from our study, the leachable P levels were higher with rain water than distilled water, and this might be attributed to the presence of dissolved ions and gases in rain water. Therefore, in industrialized cities like Lagos, where varied human activities such as fossil fuel combustion, volcanic emissions, biomass burning, anthropogenic emissions, tropospheric aircraft, transport and stratosphere [13] result in the emissions of various substances (principally SO_2, NO_x, NH_3, hydrocarbons and particulate matter) to the atmosphere, which lead to a number of environmental problems such as poor air quality and acidic deposition or acid rain, the leaching rate of P will be expected to be higher than that of urban areas with little or no industrial activity.

Burning and storing of leaves in the street gutter or roadsides prior to pick up should be discouraged as they evolve gases that lead to acid formation and may facilitate nutrient including P transport to lakes and streams from urban runoff.

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