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Full Length Research Paper

Determination of the accumulator plants in Kucukcekmece Lake (Istanbul)

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Soils are polluted by actions like using commercial fertilizers, pesticides, soil regulators and hormones to increase the amount and quality of agricultural production, discharge of soil and liquid wastes, performing wastewater sludge applications, using polluted waters in agricultural irrigation, atmospheric precipitations and radioactive sprays. It is an important environmental problem to reform and clean the soils polluted with heavy metals. Phytoremediation is a measure which uses several plants to remove the pollutants from water and soil to reduce, completely extract, control or immobilize them. The plants used for this reason are referred to as the accumulators. Metal accumulation can occur in several different families like small annual grass to perennial bushes and trees. For remediation or cleaning of the soils polluted with heavy metals, the ideal plant species are the ones which can produce high amounts of biomass, and can accumulate and tolerate the pollutants. In this study, the Cd and Zn contents obtained from Kucukcekmece Lake border were monitored on monthly basis and it was aimed at determining the plant species with accumulation ability. The plants chosen for this activity were *Labiatae galatica, Compositae cardueae, Cypereace carex,* and *Phragmites australis. Compositae cardueae* was the most efficient species in terms of mean heavy metal intake performance.

Key words: Heavy metals, accumulators, phytoremediation, soil pollution, Cd, Zn.

INTRODUCTION

A number of natural sources has been polluted by the combined action of modern agricultural applications, increased industrial activities, and rapidly growing global population. Hence soil pollution has now turned into another major environmental problem. Agricultural practices that result in soil pollution include among others: usage of commercial fertilizers, pesticides, soil regulators and hormones to increase the amount and quality of agricultural production, discharges of soil and liquid wastes, sludge applications, usage of polluted waters in agricultural irrigation, atmospheric precipitations and radioactive sprays (Chen et al., 2000). Due to the increasing sources of soil pollution, the ability of soils to be fertile and non-problematic is highly reduced. It is needful to mention also that "free" pollutants like asbestos also constitute another problem in soil pollution.

Cadmium and zinc are two elements whose chemical properties resemble each other and thus, cadmium can behave similarly like zinc regarding its intake and metabolic functions (Mengel and Kirkby, 1987). Cadmium and zinc are hazardous heavy metals for the environment. Excessive amounts of zinc in the soil are toxic to plants and microorganisms. Mobility of zinc increases when the acidity of soil goes down to pH 5.5. Cadmium is a powerful toxin for plants, animals and humans by impairing the enzyme activity (Caliskan, 2007). It is the second most toxic heavy metal after lead. It causes diabetic renal complications, high blood pressure, osteoporosis, renal calculi, leukemia, and carcinogenic activities in some organs like lungs, kidney, urinary bladder, pancreas, breasts and prostate (Saffron, 2001; Schwartz and Reis, 2000). This heavy metal mostly accumulates on kidneys, lungs, liver, thyroid gland and

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placenta (Muler et al., 1998; Starug et al., 2000). The negative effect caused by cadmium over immune system is explained by impairing the zinc metabolism in the body (Buchet, 1990). In addition to their useful effects, the majority of metals, especially the heavy metals, are toxic to plants and they cause the death of the plant. The extent at which the metals behave as toxic varies regarding the plant species and the metal in question.

The first applications of phytoremediation started in the 1990s and artificial marshy areas and oil spillage areas were investigated (USEPA, 2000). The main idea of this application is to use several plants to remove pollutants from water and soil by extracting completely, controlling, or immobilizing them (Salt et al., 1998, 1995). The plants used for this purpose are referred to as hyper accumulators. Metal accumulation can occur in several different families like small annual grass to perennial bushes and trees. For remediation or cleaning of the soils polluted with heavy metals, the ideal plant species are the ones which can produce high amounts of biomass, and can accumulate and tolerate the pollutants (Wu et al., 2007). However, this combination may not always be possible. It may require choosing plants with hyper accumulation ability combined with poor biomass (or vice versa), and forsaking something in order to receive another effect. In addition, growing hyper accumulative plants only in the polluted area may also result in a potentially hazardous biomass production. To remove a pollutant from soil, the plants must find acceptable soil conditions. The most important parameter in this subject is the soil pH value. There are, however, many other factors affecting the heavy metal intake capacity of the plant (Martens and Boyd, 1994; Fergusson, 1990; USDA, 2000). After gaining mobility, the elements are retarded by the root cells of the plant. They are first bound to the cellular wall, then passed through the membrane with transport systems and intracellular binding regions. It is considered that the intake of element ions is carried out by the channel and/or carrier proteins. The negative charge of inner plasma membrane provides a way for the cation intake (Clemens et al., 2002).

Toxic symptoms observed with excessive heavy metal presence are caused by interactions on cellular and molecular level. Besides, oxidative stress originating from this excess amount of heavy metals is caused by the promotion of free radicals and reactive oxygen species (Hall, 2002). The heavy metal-tolerant plants can be classified as those plants which survive in the toxic soils more successfully than the others. This is possible with an interaction between the environment and the plant genotype (Hu et al., 1999).

In this study, a study area with ca. 6 km Kuçukçekmece Lake border was chosen which also embraces Istanbul University Avcilar campus and Avcilar military region. Cd and Zn contents were monitored for a 3-month period on samples taken from the common plant species and on soil specimens taken from the roots of these plants.

MATERIALS AND METHODS

Investigated area

Kucukcekmece Lake is a lagoon lake situated at the northern side of Marmara region, 15 km west of the city center, whose length is ca. 7500 m, width is 900 m (at the narrowest place) and 4500 m (at the broadest place). The industry and residence activities around the lake grow very rapidly, especially the south-eastern region of the lake (close to the Marmara Sea) which contains a dense residence area. The lake is connected with three rivers to the north and east. It also has a short connection to the Marmara Sea (Figure 1). The total drainage area belonging to the Kucukcekmece Lake is estimated to be 5600 ha and the connecting rivers have the following areas: Ispartakule River, 15700 ha; Sazlıdere, 8400 ha; and Meneksedere (Nakkasdere), 4300 ha; all of which add up to an area as large as 34000 ha. This area has a slope of ca. 5%. The height is zero from the coast but 100 m in Sazlidere. The vegetation is mainly composed of grass but there are bare areas as well. The lake is fed from the sea according to the meteorological conditions, and from the land with the involvement of fresh water transported from the stream. Sazlidere is the most important stream feeding the lake.

Plants used in the study

Sideritis galatica

The species *Sideritis* is a member of Labiatae family and is common in mainly western and southern Anatolian regions. There are about 40 species of this type growing in Turkey with a high endemism ratio (Kocaer and Baskaya, 2003). It blossoms between July and September. The plant is light green or yellowish in color, perennial, and has a simple or branched structure.

Compositae cardueae serratula

Compositae is a filum also known as the daisy family. Some of them are grassy plants which contain milky fluids. Their leaves are generally simple or combined. The flowers are capitulums, that is, looks like a ball-like anther (daisy, chrysanthemum, etc.).

Phargmites australis

It belongs to the wheat family, which are monocotyledons and grassy and have branched roots in common. They do not have flowers. Wheat, oat, rye, rice and barley are also members of this family. *Phragmites australis* is also known as reed and grows especially in marshy areas, near lakes and inside water.

Cyperace carex

It can not only grow in semi-deserts, steppes, dry hillsides and pastures but also in swamps, river shores and mountain slopes. They are grassy perennial plants.

Analytical procedure

In the study, the plants were collected from the flora and their heavy metal concentrations were measured. In order to determine the phytoremediation performances, the plants, collected in December, March and May were examined in terms of Cd and Zn concentrations on their roots, stems and leaves, and also on the

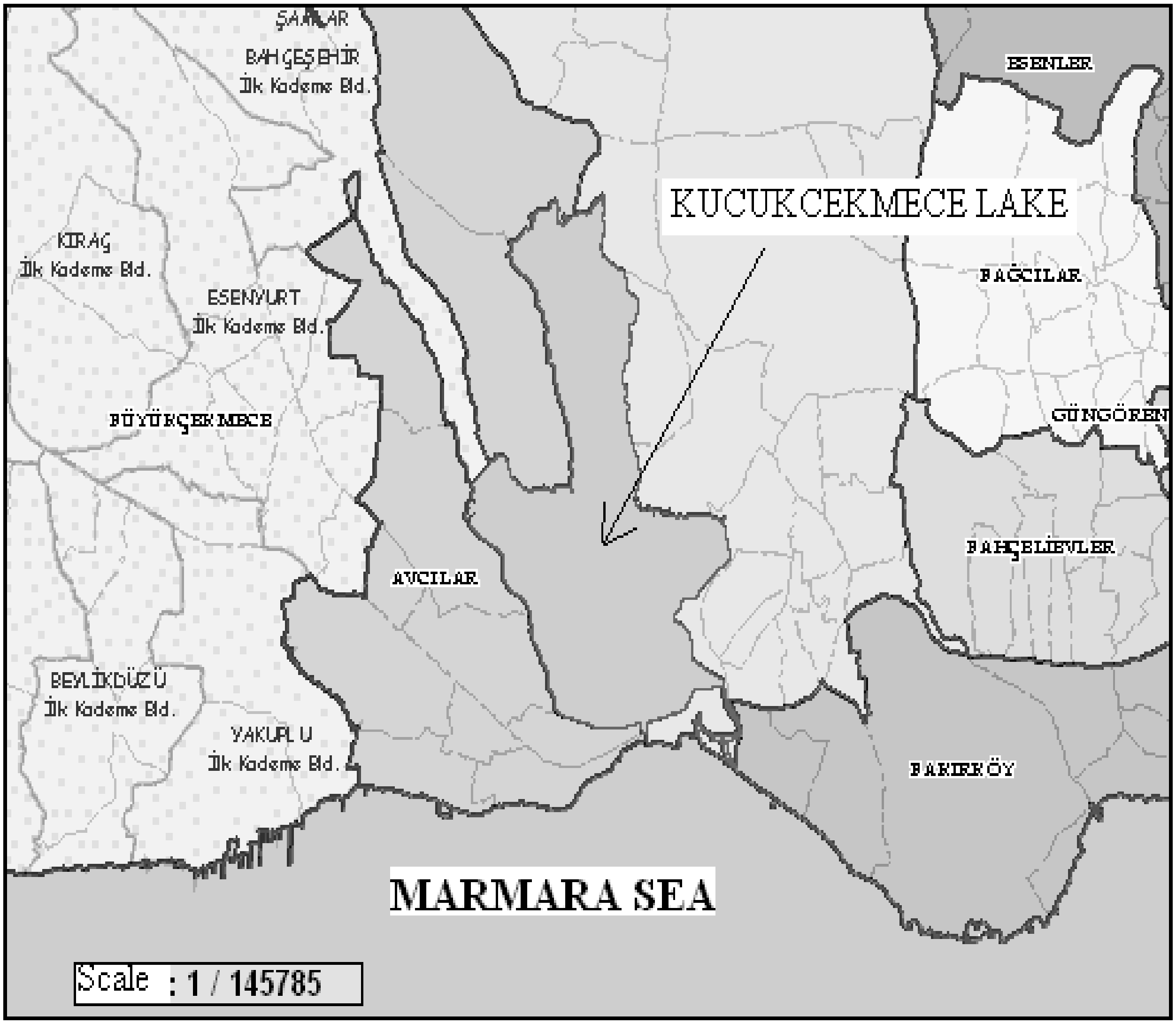

Figure 1. Map of investigated area.

soil and lake water they were collected. The plant and soil samples obtained from the land were sampled as described in this section and the heavy metal analyses were carried out with ICP (ICP-OES, Perkin Elmer, Optima 2100DV).

Plant samples

The plants were dried at 60°C and then ground in a mixer to obtain a powder. 0.2 grams of the samples were weighed and 4 ml of nitric acid was added and kept for 10 - 15 min. The tubes were then sealed and burned in a Berghof Speedwave MWS-2 microwave oven. The procedure was carried out in three steps, each for 10 min, at 150, 175 and 90°C. After burning, the samples were taken in 30 ml of solution and filtered.

Soil samples

The soil samples were dried in dry air, sieved, and 0.2 grams were weighed. 3 ml of nitric acid and 1 ml of hydrochloric acid were added and kept for 15 - 20 min. It was then burned in a microwave oven at 180°C for 15 min. The soil sample was dissolved in 30 ml of water and filtered.

RESULTS

In the study, plants growing on the shore of Kucukcekmece Lake namely *P. australis, C. carex, L. sideritis, C. cardueae* were sampled and the Zn and Cd concentrations on their roots, stems and leaves were measured. The measurements were also performed for their soil samples that were taken. The results obtained for plant and soil samples taken on three different times (December, March, May) are presented in Tables 1 - 3.

The current literature about the concentration interval of heavy metals in soil reveals that cadmium is present in soil between 0.005 – 181 ppm (Alloway, 1990; Brummer et al., 1991; Leita et al., 1989). Cadmium concentration in plants varies in 0.1 – 1 ppm range (Mengel and Kirkby,

Table 1. Heavy metal analysis results for soil and plant samples collected in December.

Parameter	***Phragmites australis***		***Cyperace carex***		***Labiate sideritis galatica***		***Compositae cardueae***	
	Cd (ppm)	**Zn (ppm)**	**Cd (ppm)**	**Zn (ppm)**	**Cd (ppm)**	**Zn (ppm)**	**Cd (ppm)**	**Zn (ppm)**
Soil	0.14	0.55	0.31	0.21	0.31	0.90	0.40	1.20
Root	0.25	0.34	0.27	0.18	0.28	0.86	0.22	0.90
Body	0.20	0.47	0.11	0.47	0.5	0.94	0.24	0.76
Leaves	0.28	0.88	0.09	0.32	0.27	0.87	0.14	0.62

Table 2. Heavy metal analysis results of plant and soil samples for March.

Parameter	***Phragmites australis***		***Cyperace carex***		***Labiate sideritis galatica***		***Compositae cardueae***	
	Cd (ppm)	**Zn (ppm)**	**Cd (ppm)**	**Zn (ppm)**	**Cd (ppm)**	**Zn (ppm)**	**Cd (ppm)**	**Zn (ppm)**
Soil	0.27	1.02	0.42	0.52	0.41	0.70	0.51	1.12
Root	0.16	0.94	0.32	0.42	0.22	0.62	0.34	0.99
Body	0.14	0.82	0.21	0.30	017	0.38	0.24	0.82
Leaves	0.12	0.66	0.11	0.18	0.10	0.15	0.13	0.62

Table 3. Heavy metal analysis results for plant and soil samples collected in May.

Parameter	***Phragmites australis***		***Cyperace carex***		***Labiate sideritis galatica***		***Compositae cardueae***	
	Cd (ppm)	**Zn (ppm)**	**Cd (ppm)**	**Zn (ppm)**	**Cd (ppm)**	**Zn (ppm)**	**Cd (ppm)**	**Zn (ppm)**
Soil	0.25	1.00	0.31	0.41	0.31	0.46	0.21	0.51
Root	0.19	0.91	0.27	0.31	0.17	0.36	0.19	1.35
Body	0.15	1.01	0.19	0.95	0.21	0.63	0.18	0.30
Leaves	0.12	0.98	0.15	0.52	0.24	0.37	0.10	0.25

1987). Tables 1 - 3 show that cadmium level in the studied plants was between 0.12 – 0.34 ppm, whereas the range in the soil was 0.21 – 0.51 ppm.

The values for zinc were given by Bergmann (1993) and the allowable maximum Zn value is for fresh weight 5 and 15 ppm for fruits and vegetables, respectively. The tolerable and excessive Zn amounts for tomato leaves as dry matter was measured to be 21 – 120 ppm and >120 ppm, respectively (Mengel and Kirkby, 1987). The allowable zinc concentration for tomato fruit however remains controversial; one group measured 24 – 28 ppm (Moauro et al., 1993) whereas another group reported 12 – 67 ppm (Hobson and Davies, 1971). Tables 1 - 3 indicate that the heavy metal concentrations in our study lie within 0.15 – 1.01 ppm range.

Cd and Zn intake performances according to the sampling date for four different plant species used in our study are presented in Figures 2 and 3.

DISCUSSION

This study was aimed at determining the accumulation of plant species by monitoring Cd and Zn levels from soil and plant samples collected from Kucukcekmece Lake shore in monthly basis. Figures 2 and 3 show the concentrations of heavy metals stored by the plants in their roots, stems and leaves. According to these figures, *L. galatica* was found to be the best plant in terms of storing cadmium and zinc on its leaves and in its stem, respectively. The storing capacity of this plant was found to be at the maximum in December and at the minimum in March. *C. cardueae* was found to use its roots to store cadmium and zinc and its performance increased dramatically in May for zinc and March for cadmium. *C. carex* stored zinc in its stem and cadmium in the roots, and the intake performances for cadmium and zinc was at the maximum level in March and May, respectively. *P. australis* used its leaves to store both heavy metals. May and December were the best months for zinc and cadmium intakes, respectively.

The main source of heavy metal for plants is the flora, that is, soil, feed liquor, and air. The most important factor determining the biological intake possibility of a heavy metal is its attachment or adsorption onto the soil

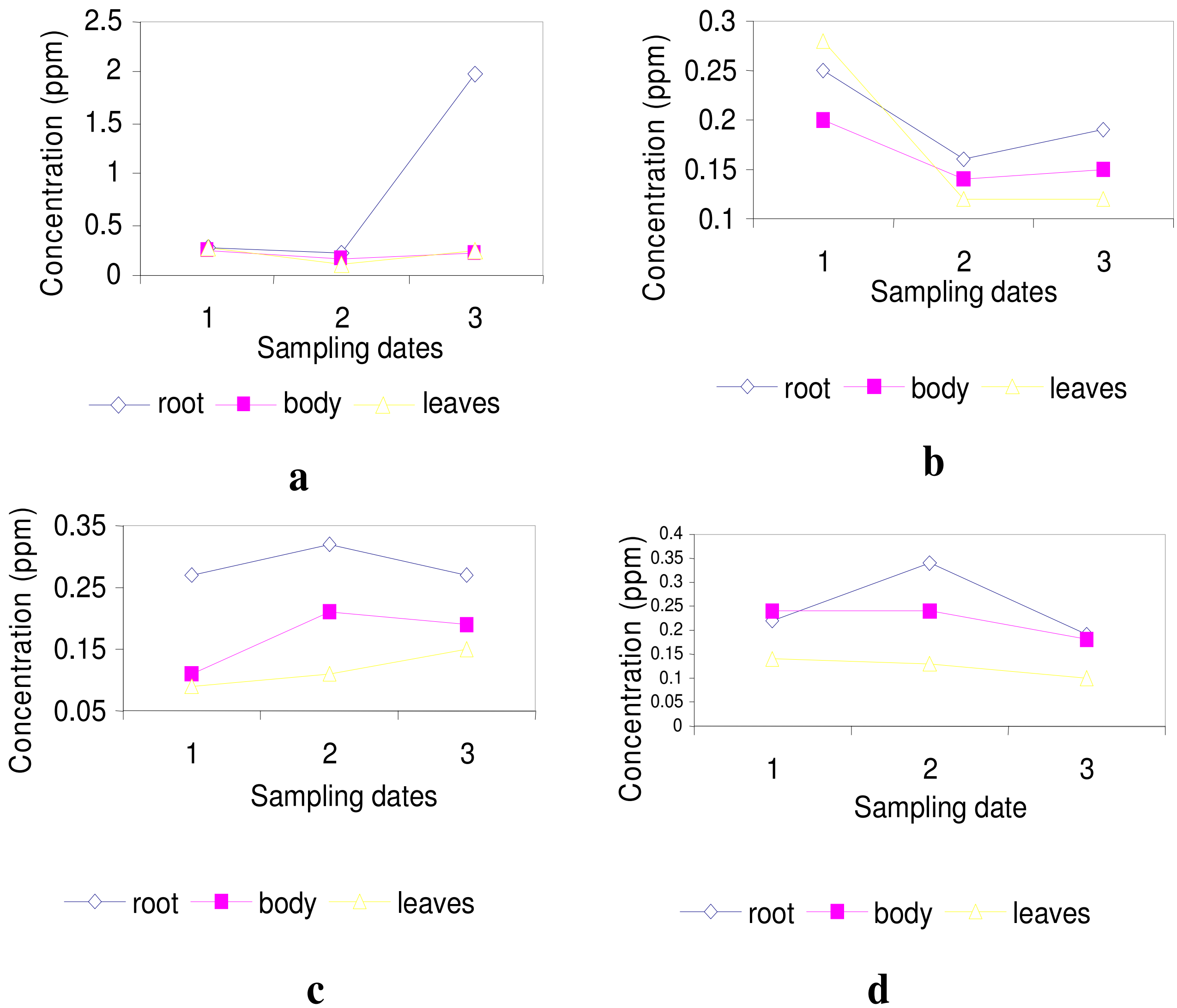

Figure 2. Monthly distribution of Cd intake performances of the plants used in the study (December to May) a: *L. galatica* b: *P. australis* c: *C. carex* d: *C. cardueae.*

elements. The biological intake capacity of heavy metals coming from emission sources via atmospheric means plays an important role. Plants are more sensitive to excessive amounts of Zn and Cd than animals. Therefore plants can be used as an indicator for alerting against possible dangers for humans and animals. The high concentrations for humans and animals can be tolerated by the plants quite efficiently. Soil pH value, microbial activities and temperature play important roles on seasonal changes of heavy metal levels stored by the plants. In our study, *C. cardueae* was the most efficient plant for mean heavy metal intake. Its roots were the main storage medium for heavy metal intake. *C. carex* was the least efficient plant in terms of mean heavy metal intake, as seen from Figures 2 and 3. As a result, it could be useful for soil remediation if *C. cardue* species is grown around soils polluted with Zn and Cd.

In order to reduce heavy metal-originated soil pollution, new aims, models, techniques and methods must be chosen, but they must not cause environmental problems for industry, agriculture and urbanization. In this context, resident industrial facilities must finish their refinement plants; if finished, they must be operated efficiently, and new facilities must be planned along side with their refinement plants. In addition, industrial facilities must not be allowed to be established near fertile agricultural areas and urban places. Therefore *C. cardue* could be very useful in reducing pollution if the environmental regulation plans based on river basins are obeyed. As a last remark, by using phytoremediation methods, which are cost-effective on soils suffering heavy metal pollution and by applying accumulative plants storing heavy metals in their bodies, successful results for exterminating heavy metal pollution would be created.

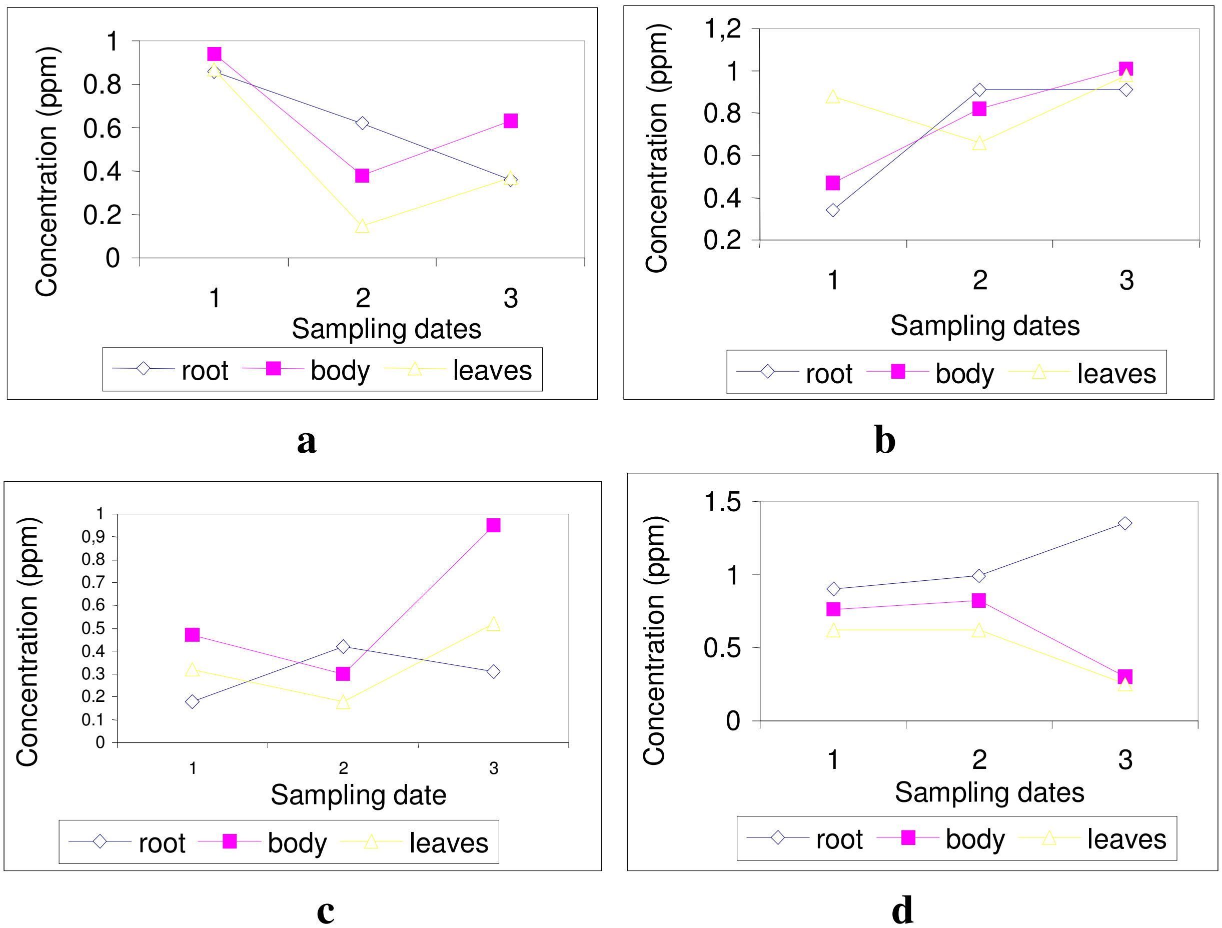

Figure 3. Monthly distributions of Zn intake performances of the plants used in the study (December to May) a: *L. galatica* b: *P. australis* c: *C. carex* d: *C. cardueae.*

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