Asian Journal of Chemistry Vol. 19, No. 6 (2007), 4895-4902

Evaluation of Phytoremediation Potential of Rose Species

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The use of plants to remove heavy metals from soil (phytoremediation) is emerging as a cost-effective to conventional methods. The objective of this study was to investigate heavy metal uptake capacity of fruit flesh and seeds of 6 rose species (*Rose canina, Rosa dumalis* subsp. *boissieri*, *Rosa dumalis* subsp. *antalyensis*, *Rosa villosa* subsp. *villosa*, *Rosa pisiformis* and *Rosa pulverulenta*) of same age from a collection orchard in Erzurum city, Eastern part of Turkey. Results indicated that significant differences were found in terms of heavy metal uptake among species and fruit parts. Among species tested, *Rosa pulverulenta* were more effective for Cd, Al and Si uptake and *Rosa dumalis* subsp. *boissieri* for Ni uptake. According to results, *Rosa pulverulenta* could be useful for remediation of heavy metal from Cd, Al and Si contaminated area.

Key Words: Heavy metal, *Rosa* species, Turkey.

INTRODUCTION

The labile fraction of heavy metals in soils is the most important element for toxicity for plants and micro organisms. Thus, it is crucial to reduce this fraction to decrease the negative effects of heavy metals in contaminated soils. Heavy metals make a significant contribution to environmental pollution as a result of human activities such as mining, smelting, electroplating, energy and fuel production, power transmission, intensive agriculture, sludge dumping and military operations[1,2]. Some heavy metals, *e.g.*, Mn, Fe, Cu, Zn, Mo and Ni are essential or beneficial micronutrients for micro organisms, plants and animals while others have no known biological or physiological function. All heavy metals at high concentrations have strong toxic effects and environmental threat[3,4]. Excessive accumulation of heavy metal can have deleterious effects on soil fertility, affect ecosystem functions and constitute a health risk to animals and human beings.

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Contaminated soils can be remediated by physical, chemical and biological techniques[5]. Traditional treatments for metal contamination in soils are expensive and cost prohibitive when large areas of soils are contaminated. Treatments can be done *in situ* or *ex situ* which are both extremely expensive. These include high temperature treatments, solidifying agents and washing process. Many different remediation methods have been tried to address the rising number of heavy metal contaminated sites. Most of traditional methods are either extremely costly (*i.e.*, excavation, solidification and burial) or simply involve the isolation of the contaminated sites. Some methods, such as soil washing, can pose an adverse effect on biological activity, soil structure and fertility and incur significant engineering costs[6]. Therefore, the development of cost effective and *in situ* environmental friendly technologies for the remediation of heavy metal contaminated soils is much needed. Unlike the previously mentioned conventional methods, phytoremediation is inexpensive, effective, can be implemented *in situ* and is environmentally friendly. A special advantage of phytoremediation is that soil functioning is maintained and life is soil reactivated[7].

Over the last 10 years there has been increasing interest in developing a plant-based technology to remediate heavy metal contaminated soils[8]. Phytoremediation is an emerging technology that uses various plants to degrade, extract, contain or immobilize contaminants from soil and water. The success of phytoremediation depends on the ability of a plant to uptake and translocates heavy metals, a function of specific phenotype and genotype and the selection of soil amendments[8,9].

The genus *Rosa* contains *ca.* 100 species that are widely distributed in Europe, Asia, the Middle East and North America. The Anatolia region of Turkey is one of the major genetic diversity centers of *Rosa* species[10] and most of the rose species growing in this area have originated from seeds. 25 Rose species have been reported in Turkey[10], distributed over more than half the country with Eastern and central Anatolia regions have the largest native rose population[11]. In most parts of Anatolia, wild roses have been gathered for their fruits from scattered sites since ancient times.

The fruit of the wild rose, the rose hip has been gathered by peasants for a long time in Turkey and is an excellent source of vitamins A, B2, B3, C, D and E, as well as bioflavonoids, citric acid, flavonoids, fructose, malic acid, tannins and zinc[12]. The fruits (rose hip) include average 40 seeds per fruit. Approximately 30-35 % of fruit made up of seed while the remaining 65-70 % per cent is pericarp[13].

This paper aims to assess the potential of 6 *Rosa* species with high binary biomass yield for phytoextraction of heavy metals from moderately contaminated soils.

EXPERIMENTAL

This experiment was conducted under field conditions in Erzurum province (39º 55' N, 41º 61 E) of Turkey. In 1998 6 rosa species of *R. villosa, R. pulverulenta, R. dumalis* subsp. *boissieri, R. pisiformis, R. dumalis* subsp. *antalyensis* and *R. canina* were planted in the a collection plot in Ataturk University. In 2005, rose hips were harvested manually from shrubs from the 6 species. All fruits were picked at ripe stage. The fruits selected according to uniformity of shape and colour then the fruit flesh and seeds obtained from these fruits. After harvest, fruit samples were divided into two groups: seeds and fruit flesh. Each sample was washed in deionized water, blotted dry with paper toweling, placed in a paper bag and dried in a forced air drying oven at 68ºC for 48 h and then they were ground for chemical analysis. After fruit ripening, soils samples were collected from each plot, air-dried and sieved (2 mm) for soil analyses.

Total nitrogen was determined using the micro-Kjeldahl method. Protein contents of fruit parts (seed and flesh) of species were determined by multiplying N contents by a coefficient[14] of 6.25. K^+, Ca^{2+} and Mg^{2+} were determined after wet digestion of dried and ground sub-samples in a HNO_3 -$HClO_4$ (v:v, 1:3) acid mixture. In the diluted digests, P was measured in the indophenol-blue method with a spectrophotometer at 660 nm and after reaction with ascorbic acid. Potassium and Ca^{2+} were determined by flame photometry and Mg^{2+} by atomic absorption spectrometry. Fe, Mn, Cu, Zn, Cd, Al, Si and Ni were determined by atomic absorption spectrometry[15] after wet digestion of dried and ground sub-samples in 1 M NH_4NO_3-extractable mixture.

Particle size distribution of soil was determined by Gee and Bauder[16]. Carbonate, phosphorus, potassium, pH and electric conductivity of soil were determined by Page *et al.*[17]. Total Fe, Mn, Zn, Cu, Cd and Pb contents of soil were determined by digesting 2 g of soil in a mixture of concentrated HNO_3/HCl (v:v, 1:3)[18,19]. Digested samples were analyzed by atomic absorption spectrophotometer. Some physical and chemical properties of soil are given Table-1.

Each plot was considered as a replicate and all of the treatments were repeated 3 times. All data were separated by LSD were performed using (SAS) statistical software[20].

RESULTS AND DISCUSSION

The maximum protein content (5.8 g 100 g^{-1}) was observed in seeds of *R. antalyensis*, while *R. pulverulenta* had the highest (9.06 g 100 g^{-1}) protein value in fruit flesh. Nitrogen content was the highest in seed of *R. antalyensis* (0.92 %) and flesh of *R. pulverulenta* (1.45 %), respectively (Table-2). N content was generally higher in fruit flesh than in seeds.

TABLE 1
SOME PHYSICAL AND CHEMICAL PROPERTIES OF SOIL

Parameter		
Particle size distribution (%)	Sand	35.40
	Silt	31.00
	Clay	33.60
Organic C	g kg^{-1}	7.00
pH	(1:2.5 soil/water)	7.20
Total N	g kg^{-1}	1.25
Available P	P_2O_5 Olsen (mg kg^{1})	13.20
CEC	$cmol_{(+)}$ kg^{-1}	15.20
EC	dS m^{-1}	1.10
Exchangeable		
K	$cmol_{(+)}$ kg^{-1}	2.10
Ca	$cmol_{(+)}$ kg^{-1}	10.70
Mg	$cmol_{(+)}$ kg^{-1}	2.40
Na	$cmol_{(+)}$ kg^{-1}	0.36
Available Heavy Metal		
Zn	mg kg^{-1}	1.30
Cu	mg kg^{-1}	1.00
Cd	mg kg^{-1}	0.13
Ni	mg kg^{-1}	0.28
Al	mg kg^{-1}	0.14
Total Heavy Metal		
Zn	mg kg^{-1}	30.10
Cu	mg kg^{-1}	14.60
Cd	mg kg^{-1}	10.51
Ni	mg kg^{-1}	8.65
Al	mg kg^{-1}	10.12

Phosphorus contents of fruit parts was fairly variable. *R. antalyensis* had the highest phosphorus content (485 mg 100 g^{-1}) in the seed whereas the highest phosphorus content in the fruit flesh was obtained in *R. pulverulenta* (536 mg 100 g^{-1}) plant (Table-2). Potassium content was the highest in *R. antalyensis* (524 mg 100 g^{-1}) in the seed whereas the highest potassium content in the fruit flesh was obtained in *R. pulverulenta* (770 mg 100 g^{-1}) plant (Table-2). Calcium and Mg content was the highest in *R. pulverulenta* (110 mg 100 g^{-1} Ca, 104 mg 100 g^{-1} Mg) seeds whereas the highest Ca and Mg contents in fruit flesh were obtained in *R. canina* (287 mg 100 g^{-1} Ca, 125 mg 100 g^{-1} Mg) (Table-2).

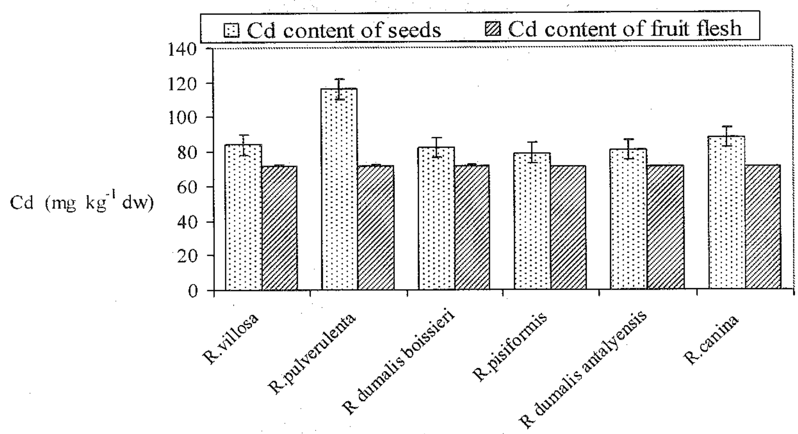
TABLE-2
MACRO AND MICRO ELEMENT CONTENTS OF SEED AND FLESH PART OF FRUITS OF DIFFERENT ROSA SPECIES

	N	P	K	Ca	Mg	N	Fe	Cu	Mn	Zn
Species	%	Fruit seed content mg kg^{-1} (dw)								
R. villosa	0.82	4582	3619	854	968	432	27	21	16	24
R. pulverulenta	0.75	4687	3311	1098	1012	468	27	24	24	24
R. dumalis subsp. boissieri	0.86	4725	4389	793	968	396	36	21	14	36
R. pisiformis	0.85	3985	3850	793	1012	450	27	27	16	30
R. dumalis subsp. antalyensis	0.92	4850	5236	976	1012	270	18	18	16	24
R. canina	0.85	4200	3311	1098	1056	234	18	12	26	18
		Fruit flesh content mg kg^{-1} (dw)								
R. canina	0.98	4860	5467	2867	1254	990	27	27	56	30
R. dumalis. subsp. boissieri	1.22	4950	5775	1952	1188	252	18	9	16	24
R. dumalis subsp. antalyensis	1.30	5260	6468	1647	1166	252	27	12	16	18
R. villosa	1.24	5250	6314	1525	1056	288	27	12	12	18
R. pisiformis	1.35	5120	6622	1220	990	1116	72	12	6	42
R. pulverulenta	1.45	5360	7700	2562	1210	414	27	15	24	24

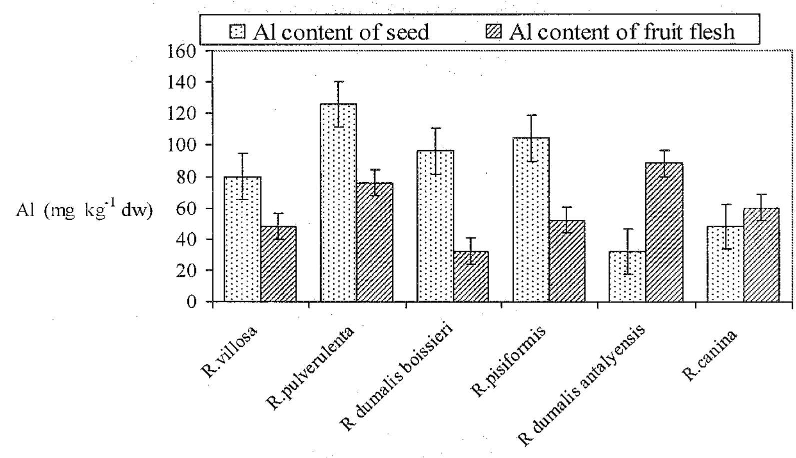
Na content changed significantly among the species. The highest Na content in the seed part of fruit was determined in *R. pulverulenta* (47 mg 100 g^{-1}) whereas the highest Na content in the fruit flesh part of plant was obtained in *R. pisiformis* (112 mg 100 g^{-1}) (Table-2).

The highest contents of Fe, Cu, Mn and Zn in the seed part of fruits were obtained in the *R. boissieri* (36 mg kg^{-1}) *R. pisiformis* (27 mg kg^{-1}), *R. pulverulenta* (24 mg kg^{-1}) and *R. pisiformis* (30 mg kg^{-1}), respectively. The highest contents of Fe in the fruit flesh part of plant were obtained in the *R. pisiformis* (27 mg kg^{-1}) and the highest Cu, Mn and Zn contents were obtained in the *R. canina* at 27, 56 and 30 mg kg^{-1}, respectively (Table-2). Similar observations were made by Adriano *et al.*[21], Mears *et al.*[22], Quartacci[23], Celemente *et al.*[24], Martinez *et al.*[25], Gubta and Sinha[26] and Yanai *et al.*[27] indicating scavenging potential of heavy metals of different plant species.

The different concentration of heavy metals (Cd, Al, Si and Ni) measured in the different parts (seed and flesh) of plants were statistically significant. Heavy metal concentrations in seeds were about 4-6 times higher than in flesh part of fruit (Figs. 1 and 2). These results suggest that seed parts that inedible of rosa fruits had greater heavy metal uptake than edible fruit flesh in all species. That rose hip seeds are believed toxic for livestock. This could be due to its higher heavy metal contents.



Cd seed LSD .05: 3.20
Cd fruit flesh LSD .05: 4.10



Al seed LSD .05: 4.35
Al fruit flesh LSD .05: 3.07

Fig. 1. Cd and Al content in seed and flesh part of Rose species

A statistically significant difference among species was evidenced in the phytoextraction of heavy metals. *R. pulverulanta* was the more effective for Cd, Al and Si, while *R. dumalis* subsp. *boissieri* for higher Ni uptake. Similar result were reported by McGrath *et al.*[28], Epstein *et al.*[29], Kirkham[30], Shu *et al.*[31], Liphadzi *et al.*[32], Thayalakumaran et al.[33].

Phytoextraction efficiency is related to both plant metal concentration and dry matter yield. Thus, the ideal plant species to remediate a contaminated site should be a high yielding crop that can both tolerate and accumulate the target contaminants. The data obtained in our experiment confirmed that Rosa species are tolerant to heavy metals, especially of *R. pulverulenta* is more tolerant than the other species.

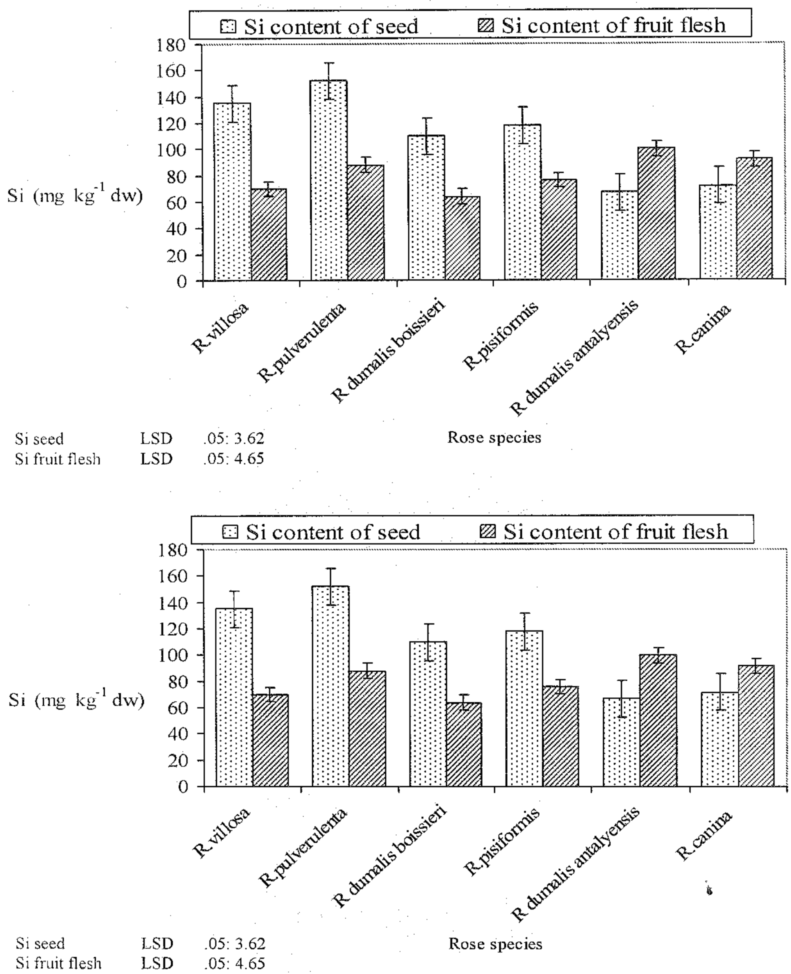


Fig. 2. Si and Ni content in seed and flesh part of fruits of Rose species

REFERENCES

1. N. Herawati, S. Susuki, K. Hayashi, I.F. Rivai and H. Koyama, *Bull. Environ. Contamin. Toxicol.*, **64**, 33 (2000).
2. L.A. Brun, J. Maillet, P. Hinsinger and M. Pepin, *Environ. Pollut.*, **111**, 293 (2001).
3. J. Chatterjee and C. Chatterjee, *Environ. Pollut.*, **109**, 69 (2000).
4. S.O. Kim, S.H. Moon and K.W. Kim, *Water, Air Soil Pollut.*, **125**, 259 (2001).
5. S. McEldowney, D.J. Hardman and S. Waite, in eds.: S. McEldowney, D.J. Hardman and S. Waite, Pollution Ecology and Biotreatment, In Treatment Technologies, Longman Scientific and Technical, Singapore, pp. 301-337 (1993).
6. I.D. Pulford and C. Watson, *Environ. Intern.*, **29**, 529 (2003).
7. S. Trapp and U. Karlson, *J. Soil Sediments*, **1**, 37 (2001).
8. E.A. Elkhatib, A. Mahdy and A.Y. Thabet, *Land Contamin. Reclam.*, **9**, 359 (2001).

9. Y.X. Chen, Q. Lin, Y.M. Luo, Y.F. He, S.J. Zhen, Y.L. Yu, G.M. Tian and M.H. Wong, *Chemosphere*, **50**, 807 (2003).
10. S. Ercisli, *Genetic Resour. Crop Eval.*, **51**, 419 (2004).
11. S. Ercisli, *Genetic Resour. Crop Eval.*, **55**, 787 (2005).
12. K. Szentmihalyi, P. Vinkler, B. Lakatos, V. Illes and M. Then, *Bioresour. Technol.*, **82**, 195 (2002).
13. S. Ercisli and M. Guleryuz, *Asian J. Chem.*, **18**, 239 (2006).
14. A.L. Frank, Basic Food Chemistry, Westport: The Avi Publishing Company Inc. (1975).
15. AOAC, K. Helrich, Official Methods of Analysis of the Association of Official Analytical Chemists. Washington, DC (1990).
16. G.W. Gee and J.W. Bauder, Particle-Size Analysis, In Methods of Soil Analysis, Part 1. Physical and Mineralogical Methods, pp. 383-441 (1986).
17. A.L. Page, R.H. Miller and D.R. Keeney, Chemical and Microbiological Properties, Methods of Soil Analysis, Part 2, pp. 300-313 (1982).
18. D. Baker and M. Amacher, Nickel, Copper, Zinc and Cadmium, Methods of Soil Analysis Part 2, Chemical and Microbiological Properties, pp. 323-334 (1982).
19. R.G. Burau, Lead, Methods of Soil Analysis, Chemical and Microbiological Properties, pp. 347-362 (1982).
20. Institute SAS, SAS Users Guide, SAS Institute, Cary, N.C. (1982).
21. D.C. Adriano, W.W. Wenzel, J. Vangronsveld and N.S. Bolan, *Geoderma*, **122**, 121 (2004).
22. E. Meers, A. Ruttens, M. Hopgood, E. Lesage and F.M.G. Tack, *Chemosphere*, **61**, 561 (2005).
23. M.F. Quartacci, A. Argilla, A.J.M. Baker and F. Navari-Izzo, *Environ. Pollut.*, (In press) (2007).
24. R. Clemente, D.J. Walker and M.P. Bernal, *Environ. Pollut.*, **138**, 46 (2005).
25. M. Martinez, P. Bernal, C. Almela, D. Velez, P. Garcia-Agustin, R. Serrano and S. Navarro-Avin, *Chemosphere*, (In press) (2007).
26. A.K. Gupta, S. Sihna, *Bioresour. Technol.*, (In press) (2007).
27. J. Yanai, F. Zhao, S.P. McGrath and T. Kosaki, *Environ. Pollut.*, **139**, 167 (2006).
28. S.P. McGrath, Z.G. Shen, F.J. Zhao, *Plant Soil*, **188**,153 (1997).
29. A. Epstein, C.D. Gussman, M.J. Blaylock, U. Yermiyahu, J.W. Huang, Y. Kapulnik and C. Orser, *Plant Soil*, **208**, 87 (1999).
30. M.B. Kirkham, *Int. J. Phytoremediation*, **2**, 159 (2000).
31. W.S. Shu, H.P. Xia, Z.Q. Zhang, C.Y. Lan and M.H. Wong, *Int. J. Phytoremediaiton*, **4**, 47 (2002).
32. M.S. Liphadzi, M.B. Kirkham, K.R. Mankin and G.M. Paulsen, *Plant Soil*, **257**, 171 (2003).
33. T. Thayalakumaran, B.H. Robinson, I. Vogeler, D.R. Scotter, B.E. Clothier and H.C. Percival, *Plant Soil*, **254**, 415 (2003).

(*Received*: 1 March 2007; *Accepted*: 4 May 2007) AJC-5639