GEOGRAPHICAL REPORTS
OF TOKYO METROPOLITAN UNIVERSITY 48 (2013) 25–35

A STUDY ON METALLIC ELEMENT COMPOSITION OF PETALS FROM YOSHINO CHERRY TREE AND ITS REGIONAL CHARACTERISTICS IN TOKYO

Yuki KUROSAWA*, Nobuo SAKAGAMI, and Makiko WATANABE**

Abstract We analysed the elemental composition of Yoshino cherry tree (*Prunus × yedoensis*) petals and soils from the Tokyo Metropolitan area to understand their regional variations and the environmental factors that affect these variations. Petal samples were collected from 130 sites during 2010–2011. K, Ca, S, P, Si, Fe, Mn, Zn and Rb were detected in petals using energy-dispersive X-ray spectroscopy (EDX). Based on the presence of five elements (Ca, Mn, Fe, Zn and Rb), the petal samples were classified into three areas: eastern Tokyo (downtown area), central Tokyo (upland area) and western Tokyo (mountainous and hilly area). Petals from eastern Tokyo contained relatively high concentrations of Fe and Zn, and low concentrations of Mn and Rb. Central Tokyo samples contained relatively high Rb, while western Tokyo samples contained high Mn, low Rb and Fe. Soil samples were collected from beneath Yoshino cherry trees at 35 sites and their elemental compositions were measured using EDX. Nineteen elements were detected in the soils. The compositions of the soil elements were analysed using principal components analysis, where the first and third principal components corresponded to mafic and felsic properties in the parent soils, respectively. Because some elements correlated with the second principal component and had a high elemental enrichment factor, this component was considered to represent anthropogenic influences. Ca and Rb in petals correlated with mafic soil properties, whereas Zn correlated with felsic soil properties. Fe in petals correlated with the anthropogenic component. We concluded that the elements in petals are not always influenced by the soil elemental composition, but changes in soil properties due to the soil parent material properties and human impacts also affect plant uptake of elements and their transfer to petals.

Key words: elemental composition, regional characteristics, Yoshino cherry tree, enrichment factor

1. Introduction

Yoshino cherry tree (*Prunus × yedoensis*) is the third most planted tree species in 2009, and was planted most in 2007 and 2008 in Tokyo Metropolitan parks (Bureau of Construction, Tokyo Metropolitan Government 2011). Also, it was the third most predominant tree species on roadsides in 2010, and there are currently more than 40,000 of these roadside trees in Tokyo. Katsuki *et al*. (1998) studied the elemental composition of Yoshino cherry trees and determined

* Chugai Technos Corporation , ** Ibaraki University, College of Agriculture

41 elements by multi-element quantitative analysis of petals, calyces and leaves from trees in the Nagoya University campus and Nagoya City. In recent years, the elemental composition of a plant has been cited as a method for identifying the district where the plant grew (Uchimura *et al*. 2007). The essential elements for plants, except C, H and O, which are assimilated from the atmosphere, are all absorbed from the soil, including the three major nutrients, N, P and K. The concentrations of these elements differ for different plants, but an excess or deficiency of any of these may show plant disease symptoms. Krzysztof *et al*. (2003) reported that elements such as Ba, Cd, Mn and Ni exhibited the greatest differences between deciduous tree leaves from different urban areas in south-western Poland. Because significant elemental composition differences have been reported between different sites, therefore, we hypothesised that multi-element analysis of specific trees could be a new environmental assessment indicator. In this study, we examined metallic elements in Yoshino cherry flowers collected from central and suburban Tokyo to investigate their regional variations and discussed the relationship between the spatial distribution factors and soil compositions, which supplies the plants with these metals.

2. Materials and Methods

Flower samples from 130 Yoshino cherry trees were collected at 80 sites between 27 March and 19 April 2010 and from 63 Yoshino cherry trees at 57 sites between 3 April and 19 April 2011. Surface soil samples were collected at 35 of these sites (Fig. 1). Ten flowers (five petals per flower) were collected randomly from a Yoshino cherry tree at each site. Flower samples were separated into calyx and petals in the laboratory and were immediately washed and stored frozen. Later, the samples were freeze-dried, and 20 freeze-dried petals for each sample were

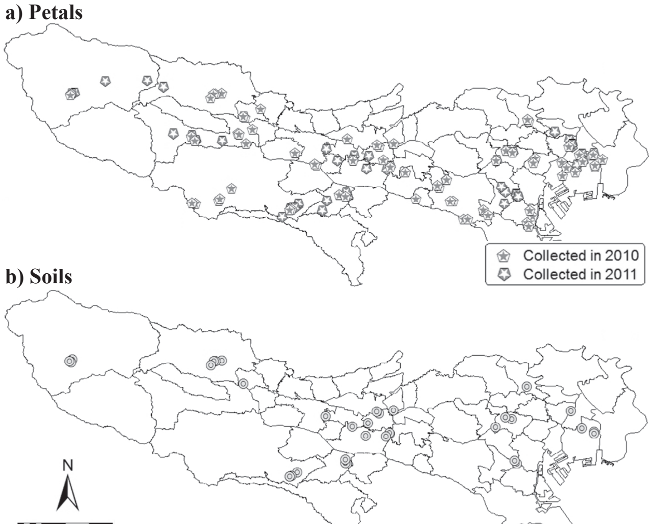

Fig. 1 Location of sampling points in Tokyo Metropolis. a) petals and b) soils.

covered with a 6-μm-thick Mylar film and pressed at 100 kN to form a tablet. Semi-quantitative analysis of the elements in the petals was performed on the tablet samples using energy-dispersive X-ray fluorescence (EDX-700H; Shimadzu Corporation, Kyoto, Japan). This measurement was repeated four times on each side of two tablets from each tree. Semi-quantitative values were obtained by multiplying the sensitivity coefficient with the peak intensity of each element, according to the Fundamental Parameter (FP) method in the instrument program.

Soils were sampled directly under the tip of the tree crown. Using a 100 cm^3 stainless steel cylinder, three samples (or two samples when space was exceptionally restricted) were collected under each tree, from the surface to approximately 8 cm below. Soil samples were air dried, and gravel and plant roots were carefully removed. The samples were then sieved to 250 μm, mixed with cellulose powder (approximately 15 wt.%), and then pressed at 100 kN to form a 10 mm × 5 mm tablet. The tablet samples were analysed by EDX under vacuum with an applied voltage of 50/15 kV, and an integration time of 200/200 s. Principal components analysis was performed on the elemental compositions using SPSS software version 10.0J.

3. Results and Discussions

Elemental composition of the petals

Katsuki *et al*. (1998) reported that 41 elements, besides S and Si, were analysed by inductively coupled plasma (ICP) emission spectrometry in petals from a Yoshino cherry tree collected in Nagoya City. In our study, nine elements were detected: K (70.6 ± 1.8 wt.%), Ca (15.5 ± 1.8 wt.%), S (5.4 ± 0.5 wt.%), P (5.2 ± 0.5 wt.%), Si (2.3 ± 0.2 wt.%), Fe (0.79 ± 0.29 wt.%), Mn (0.19 ± 0.08 wt.%), Zn (0.066 ± 0.011 wt.%) and Rb (0.023 ± 0.011 wt.%). K and Ca contributed 86 wt.% of the elements in the petals, S, P and Si contributed 13 wt.% and Fe, Mn, Zn and Rb contributed approximately 1 wt.%. The semi-quantitative analysis results of the petal samples, as the average, median wt.% and standard deviation (±1σ), are shown in Table 1. The rank order of the elements was almost the same at each site. The coefficients of variation (CVs) for Mn and Rb were high at 42.3 and 47.8 %, respectively. However, elements that were found at relatively high concentrations in the petals showed low CV values (K: 2.6 %, S: 8.4 % and P: 8.8 %). To compare the concentration of each element, its concentration was divided by that of K, which had the highest concentration and the lowest CV. These values were then logarithmically transformed. The mean and standard deviation of the log-transformed values were obtained for both samples collected in 2010 and 2011. The z-score for each element at each site was obtained by subtracting the average value from the data for each point and then

Table 1 Semi-quantitative value (wt.%) of the elements contained in the petals of Yoshino cherry trees (n = 130)

	Ca	Fe	K	Mn	P	Rb	S	Si	Zn
Average	15.5	0.79	70.6	0.19	5.2	0.023	5.4	2.3	0.066
Median	15.4	0.74	70.6	0.17	5.2	0.020	5.4	2.3	0.064
Standard deviation	1.8	0.29	1.8	0.08	0.5	0.011	0.5	0.2	0.011
Coefficient of Variation (%)	11.5	37.1	2.6	42.3	8.8	47.8	8.4	10.1	17.3

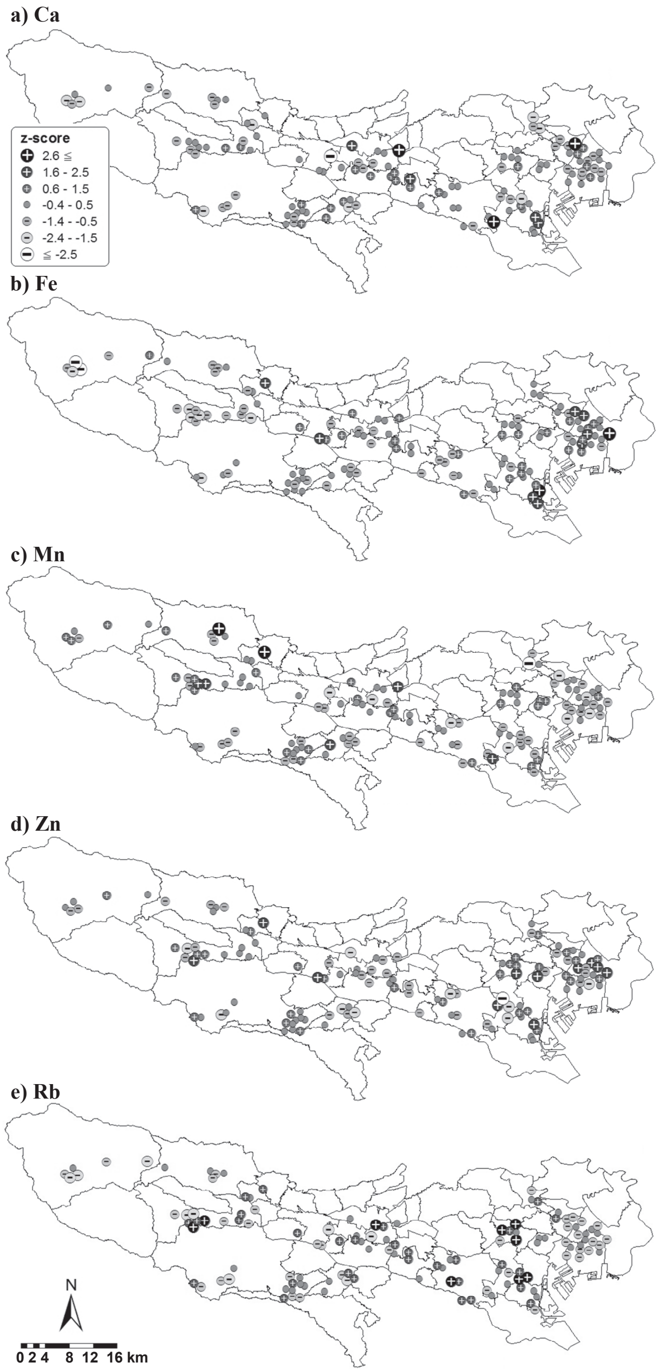

Fig. 2 Distribution of z-score of a) Ca, b) Fe, c) Mn, d) Zn and e) Rb contained in the petals of a Yoshino cherry tree.

dividing by the standard deviation to normalize the data. Since the most frequent z-score for Fe in 2011 was negatively biased, the logarithmic transformation was repeated twice.

Figure 2 shows the spatial distribution of the z-scores (n = 130) for Ca, Fe, Mn, Zn and Rb, all of which had relatively high CVs (see Table 1). Points of the figure are different from the actual position in order to avoid overlap. The z-scores for Ca tended to be high in eastern and central Tokyo and low in western Tokyo, while those for Fe were higher in eastern Tokyo and tended to decline towards the west. The z-scores for Mn were below average in central Tokyo and tended to be above average in western Tokyo, those for Zn were relatively high in the central district and north-eastern Tokyo. As for Rb, there here was a tendency towards high z-scores in central Tokyo, and below average scores in the central district and the mountainous area. Therefore, the z-score distributions differed for each element.

Figures 3a) and 3b) show the yearly difference in the distribution of z-scores for Ca, Mn, Fe, Zn and Rb between 2010 and 2011. The scores were compared by classifying the entire area into three regions: western, central and eastern Tokyo, as shown in Fig. 3c). Samples from eastern Tokyo had higher z-scores for Fe and Zn than that for the other elements, an average z-score for Ca and below average z-scores for Rb and Mn. This pattern was found in both years and was taken to be the characteristic of eastern Tokyo. Samples from central Tokyo typically had high z-scores for Rb in both years and z-scores within the average range for Fe, Mn and Zn. Samples from western Tokyo had relatively low z-scores for Fe and Rb and relatively high z-scores for Mn in both years.

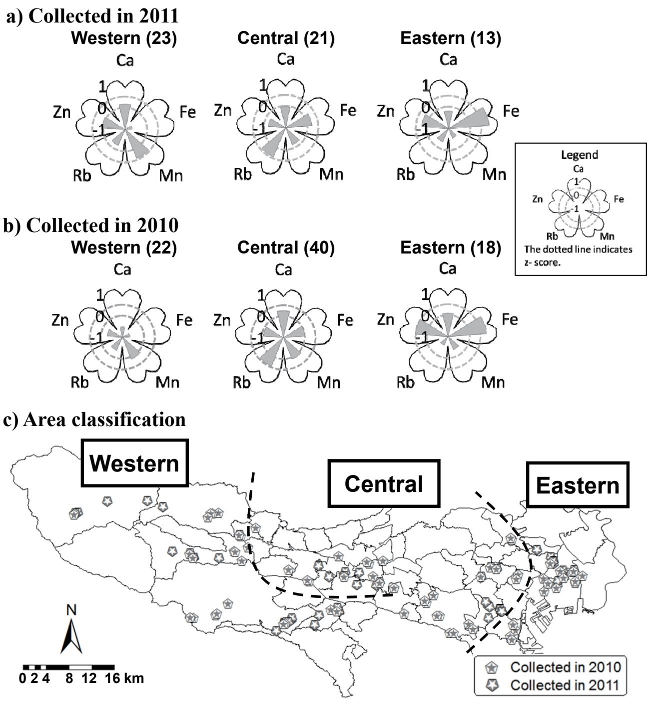

Fig. 3 Comparisons of z-score of Ca, Fe, Mn, Zn and Rb of petals.
a): collected in 2001, b):collected in 2010, c): area classification of Tokyo

Table 2 Semi-quantitative value (wt.%) of the elements contained in the soil (n = 35)

	Al	Br	Ca	Cr	Cu	Fe	K	Mg	Mn	P
Average	19.1	0.038	5.0	0.036	0.14	29.5	2.6	1.3	0.57	0.84
Median	19.8	0.036	4.3	0.037	0.13	30.0	1.9	1.3	0.58	0.72
Standard deviation	3.1	0.019	2.7	0.009	0.03	5.2	2.2	0.4	0.07	0.56
Coefficient of Variation (%)	16.0	49.0	54.7	26.5	22.9	17.6	85.0	30.8	12.7	67.2

	Pb	Rb	S	Si	Sr	Ti	V	Zn	Zr
Average	0.23	0.030	0.40	37.9	0.070	2.3	0.10	0.12	0.060
Median	0.21	0.022	0.36	36.7	0.070	2.4	0.10	0.11	0.053
Standard deviation	0.12	0.020	0.15	5.4	0.023	0.3	0.02	0.06	0.018
Coefficient of Variation (%)	52.7	65.7	38.1	14.3	33.8	14.5	16.5	47.6	30.5

Elemental composition of soils

Table 2 shows the semi-quantitative EDX analysis results of 35 soil samples. Nineteen elements were detected in the soil (given as the mean weight content wt.% ± the standard deviation): Si (37.9 ± 5.4), Fe (29.5 ± 5.2), Al (19.1 ± 3.1), Ca (5.0 ± 2.7), Ti (2.3 ± 0.3), K (2.6 ± 2.2), Mg (1.3 ± 0.4), P (0.84 ± 0.56), Mn (0.57 ± 0.07), S (0.40 ± 0.15), V (0.10 ± 0.02), Zn (0.12 ± 0.06), Cu (0.14 ± 0.03), Sr (0.070 ± 0.023), Rb (0.030 ± 0.020), Zr (0.060 ± 0.018), Pb (0.23 ± 0.12), Br (0.038 ± 0.019) and Cr (0.036 ± 0.009). Si was the most abundant element at most sites, although Fe was the most abundant at some sites. The CV for K was relatively high (85 %). Pb and Br were detected at 4 and 30 sites, respectively. Ca (55 %), P (67 %), Pb (53%), Rb (66 %), Br (49 %) and Zn (48 %) were all relatively variable and we considered them to be the most suitable elements for characterising the sites. We attempted to extract the sites affected by intensive anthropogenic activities using an enrichment factor (EF) because heavy metal pollution is characteristic of soils in urban areas (Asami 2001; Inada *et al*. 2009).

EFs for each element relative to the Ti concentration were calculated using the following equation, where $(E/Ti)_{sample}$ is the ratio of the element of interest and Ti in each sample and $(E/Ti)_{soil;\ Kanto\ Plain}$ is the ratio of the element of interest and Ti in reference data for soils in the Kanto Plain (Terashima *et al*. 2004).

$$EF = (E/Ti)_{sample}/(E/Ti)_{soil;\ Kanto\ Plain}$$

Ti was used as a reference element because it has previously been shown to be suitable for that role. Obiajunwa (2001) used Ti as a reference element for calculating EFs for X-ray fluorescence analysis results. Terashima *et al*. (2004) calculated EFs to characterise background soils on the basis of regions from the average elemental concentration profiles in samples from the southern Kanto Plain. Table 3 shows the elemental composition of soils from the southern Kanto Plain (Terashima *et al*. 2004).

According to Golchert *et al*. (1991), EFs were divided into three categories: (1) data indicating no significant human impact on heavy metal concentrations (EFs of 2 or less); (2) data indicating a possible increase in concentrations caused by human influences (EFs between 2 and 10); and (3) data clearly indicating substantially increased concentrations caused by human influences (EFs > 10).

Table 3 Elemental concentrations in soils of southern Kanto plain from Terashima *et al*. (2004) research

Sampling site		Soil type	Elements (ppm)									
			Al	Br	Ca	Cr	Cu	Fe	K	Mg	Mn	P
Iruma c.	Saitama pref.	Kuroboku soils	105500	-	5400	-	146	82400	4100	11600	1394	775
Niiza c.	Saitama pref.	Kuroboku soils	99400	-	9000	-	144	76100	4000	11200	1378	1015
Kashiwa c.	Chiba pref.	Kuroboku soils	113600	-	5700	-	139	82600	4800	11700	1460	711
Sagamihara c.(a)*	Kanagawa pref.	Kuroboku soils	91900	-	16600	-	202	81300	1800	21500	1398	n.d.
Sagamihara c.(b)*	Kanagawa pref.	Kuroboku soils	94400	-	20900	-	172	81000	1800	22800	1363	n.d.
Yokohama c.	Kanagawa pref.	Brown forest soils	86200	-	10900	-	52	54500	6500	8900	900	287
Chonan t.	Chiba pref.	Brown forest soils	99700	-	6500	-	51	61700	6400	7500	950	238

Sampling site		Soil type	Elements (ppm)								
			Pb	Rb	S	Si	Sr	Ti	V	Zn	Zr
Iruma c.	Saitama pref.	Kuroboku soils	-	24	1800	-	49	6900	321	111	102
Niiza c.	Saitama pref.	Kuroboku soils	-	21	1500	-	79	6800	304	138	97
Kashiwa c.	Chiba pref.	Kuroboku soils	-	31	1800	-	53	6900	327	124	111
Sagamihara c.(a)*	Kanagawa pref.	Kuroboku soils	-	8	n.d.	-	98	8600	364	99	81
Sagamihara c.(b)*	Kanagawa pref.	Kuroboku soils	-	8	n.d.	-	121	8000	324	82	74
Yokohama c.	Kanagawa pref.	Brown forest soils	-	29	300	-	109	4500	171	111	63
Chonan t.	Chiba pref.	Brown forest soils	-	29	300	-	106	4200	194	90	51

*Sagamihara c.(a) is Horinouchi, and Sagamihara c.(b) is Shinisono in Sagamihara City.

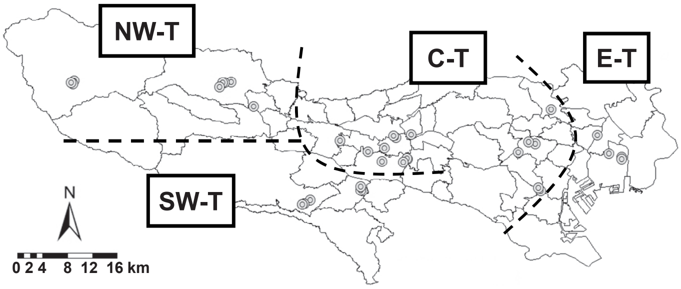

Fig. 4 Area classification of Tokyo for soils.

We divided the region into four areas, eastern Tokyo (E-T), central Tokyo (C-T), north-western Tokyo (NW-T) and south-western Tokyo (SW-T), as shown in Fig. 4. Background soil concentration data has been published by Terashima (2004), from which we used soil profiles from Kashiwa City, Chiba Prefecture for E-T, the average of Niiza and Iruma, Saitama Prefecture for C-T, and average data for Sagamihara City, Kanagawa Prefecture for SW-T. The background value for NW-T was obtained by averaging the felsic profiles from Chonan-cho, Chiba Prefecture and Yokohama, Kanagawa Prefecture. Table 4 shows the average EFs for each region. The EF values of elements such as Cu, P, Rb and Zn were higher than 2 in all areas. The EF values were higher than 2 for Ca in E-T, K in SW-T and NW-T, S in NW-T, Sr in E-T and C-T, and Zr in SW-T and NW-T. From these results, Ca, Cu, P, Rb, S, Sr, Zn and Zr were found to reflect anthropogenic impacts.

Principal component analysis

Table 5 shows the results of principal components analysis of the soil elemental compositions using the varimax rotation method. Concentrations of 15 elements (excluding Br, Pb and Mg because of their large variances) were divided by the Si (the most abundant element

Table 4 Regional enrichment factor in Tokyo

Region	Enrichment Factor									
	Al	Br	Ca	Cr	Cu	Fe	K	Mg	Mn	P
E-T	0.6	-	4.7	-	3.5	1.1	1.6	0.4	1.1	6.9
C-T	0.6	-	2.0	-	3.0	1.1	1.3	0.3	1.2	2.8
NW-T	0.8	-	0.6	-	2.5	1.4	3.2	0.2	1.5	2.6
SW-T	0.4	-	1.6	-	4.6	0.9	2.2	0.4	1.4	5.8

Region	Enrichment Factor								
	Pb	Rb	S	Si	Sr	Ti	V	Zn	Zr
E-T	-	2.6	0.6	-	4.6	1.0	1.0	3.6	1.5
C-T	-	3.8	0.8	-	2.7	1.0	1.0	3.2	1.7
NW-T	-	8.0	0.8	-	2.2	1.0	1.1	3.1	2.3
SW-T	-	4.8	2.5	-	2.1	1.0	1.0	3.0	3.4

Table 5 Factor loadings, eigenvalues, and cumulative contribution of principal component analysis of the elements in the soil

The principal component	Factor loading of elements														
	Al	Ca	Cr	Cu	Fe	K	Mn	P	Rb	S	Sr	Ti	V	Zn	Zr
Factor 1	0.91	-0.15	0.89	0.72	0.98	-0.66	0.94	0.28	-0.28	0.68	-0.31	0.97	0.95	0.21	0.20
Factor 2	-0.08	0.75	0.25	0.51	0.06	0.03	0.07	0.76	0.04	0.57	0.39	0.09	0.05	0.78	0.18
Factor 3	-0.23	0.12	-0.19	-0.11	-0.11	0.61	0.14	-0.03	0.92	-0.04	0.44	-0.06	-0.10	0.33	0.91

The principal component	Eigenvalue	Cumulative contribution (%)
Factor 1	7.0	46.9
Factor 2	2.6	64.2
Factor 3	2.5	80.9

in most samples) concentration. A logarithmic transformation was applied to Ca, K, S, P, Zn, Cu and Rb concentrations because of their relatively large variances, and a double logarithmic transformation was applied to K and P, to normalize the score distributions. Eigenvalues and the cumulative contributions of the first to third principal components were 7.0, 2.6 and 2.5, and 46.9, 64.2 and 80.9, respectively. The first component showed strong positive loadings for the mafic elements: Fe, Al, Ti, Mn, Cu, Cr and V, while the third component showed large positive loadings for the felsic elements:K, Rb, Sr and Zr (Japanese Society of Soil Science and Plant Nutrition 2005). Consequently, the first and third components were interpreted as representing mafic and felsic properties of the soil parent materials, respectively.

A high positive factor loading for the second principal component was found for Ca, Cu, P, S and Zn. Because EFs of these elements were higher than 2 (Table 4), the second principal component was interpreted as reflecting anthropogenic impact. Figure 5 shows the spatial distribution of the principal component scores of the soils analysed and Fig. 6 shows the relationships between elemental compositions of the petals and the principal component scores. Comparing these two figures allows the assessment of the relationship between the elemental compositions of the petals and soils.

The first principal component, interpreted as the mafic properties of the parent material, was higher in C-T and E-T, and out of the five elements (Ca, Fe, Mn, Zn and Rb) the Ca and Rb concentrations in the petals corresponded with such tendency, as shown in Fig. 3. Therefore, the Ca and Rb z-scores for the petals were plotted against the first principal component scores for

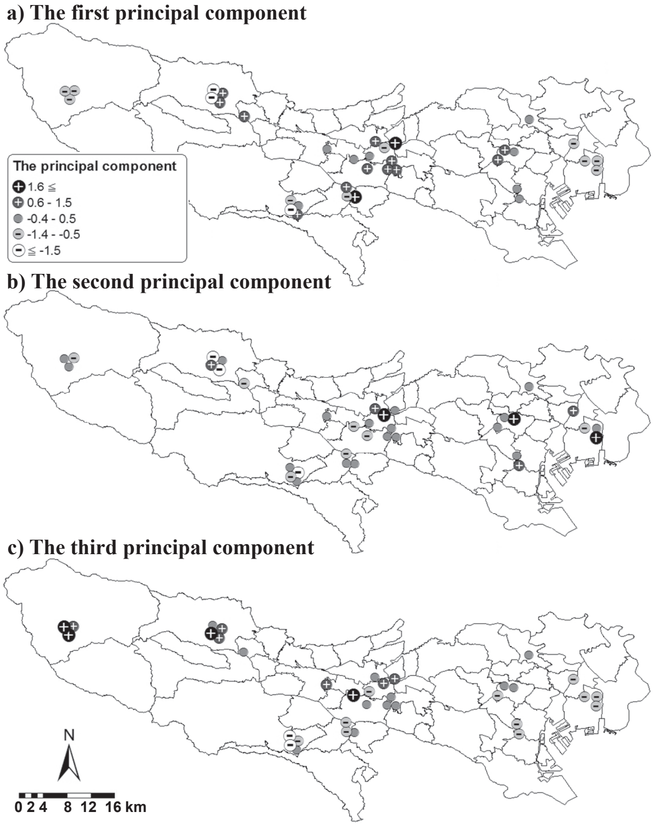

Fig. 5 Distribution of factor score of a) the first, b) the second, and c) the third principal component.

the soils, as shown in Figs. 6a) and 6b). Prior to this procedure, the z-scores of the petals were recalculated using the average value of all 130 points and the standard deviation. Higher the score in the first principal component (the mafic component), higher was the Ca and Rb concentration in the petals, and lower the score in the first principal component, lower was the Ca and Rb petal concentration. The relatively low K content of mafic soils compared with felsic materials may cause a relative increase in Ca uptake by plants from the soil because of the relative decrease in K uptake.

Drobner and Tyler (1998) reported that secondary effects of high soil acidity, such as leaching losses of K^+ and increased solubility of potentially interfering metal ions (such as Al^{3+}), might be important in accounting for the high uptake of Rb^+ from such soils. This could also explain the behaviour of Rb in our study.

The third component (the felsic component) score tended to rise in a westerly direction across Tokyo, excluding SW-T (Fig. 5c)). Only Zn, out of the five relevant elements, correlated (negatively) with this tendency. Figure 6c) is a plot of the z-scores for Zn in petals against the third principal component scores. It can be seen that for higher third component scores, lower is

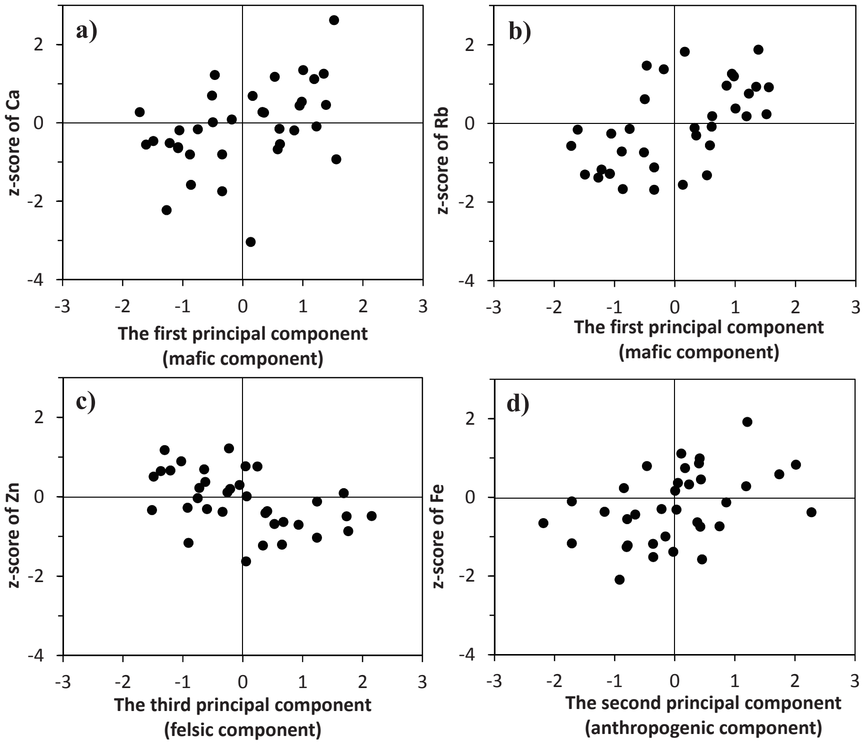

Fig. 6 Relationships between z-score of some metals in petals and each principal component scores of soils.

the z-score for Zn. This could be explained by the possibility of Zn being supplied from street dust (Asami 2001) and also by the decline in felsic properties in eastern Tokyo.

Figure 6d) is a plot of the z-scores for Fe in petals against the second principal component which indicates anthropogenic influence. The z-score of Fe tended to be higher with higher second component scores. This could also be explained by the high probability of supply of Fe from street dust in eastern Tokyo (Asami 2001). In addition, more intensive human activities such as reclamation that are carried out in the eastern part of Tokyo may reduce the permeability of the soils and cause the reduction of Fe(III) to Fe(II), which is more soluble.

4. Conclusion

Nine elements, K, Ca, S, P, Si, Fe, Mn, Zn and Rb, were detected in the Yoshino cherry tree petals by semi-quantitative analysis. By taking the ratio of each element to K, five representative elements (Ca, Mn, Fe, Zn and Rb) were used to characterize the petals by their source area within the Tokyo region. Yoshino cherry tree petals in eastern Tokyo were characterised by high Fe and Zn and low Rb and Mn, petals from central Tokyo were characterised by high Rb, and petals from western Tokyo were characterised by high Mn and low Fe and Rb.

Nineteen elements were detected in surface soil samples from beneath the Yoshino cherry trees. Using principal components analysis and enrichment factors for each element, regional patterns in the metallic elemental composition of the petals were explained by the soil parent material properties and anthropogenic influences on the soil. We conclude that elements in petals are mainly influenced by the elemental composition of the soil originating from the soil parent materials, although changes in soil properties due to grading, soil compaction and heavy traffic influence the transfer of elements to petals, which was found to be significant in the central Tokyo area.

References

Asami, T. 2001. *De-ta de Shimesu Nihon Dojou no Yugaikinzoku Osen (Toxic Metal Contamination of Soil in Japan — Shown in the Data)*. Tokyo: AGNE Gijutsu Center.*

Bureau of Construction, Tokyo Metropolitan Government. 2011. *Ryokka ni Kansuru Chosa Houkoku, 38 (Survey Report on the Greening, vol. 38)*. Tokyo: Tokyo Metropolitan Government.*

Drobner, U., and Tyler, G. 1998. Conditions controlling relative uptake of potassium and rubidium by plants from soils. *Plant and Soils* **201**: 285–293.

Golchert, B., Landsberger, S., and Hopke, P. K. 1991. Determination of heavy metals in the Rock River (Illinois) through the analysis of sediments. *Journal of Radioanalytical and Nuclear Chemistry Articles* **148**: 319–337.

Inada, S., Kuno, K., and Watanabe, I. 2009. Trace element levels in the street dusts from major arterial highways of Tokyo, Japan from 2000 to 2003. *Ningen to Kankyo* **35**: 121–130.*

Japanese Society of Soil Science and Plant Nutrition. 2005. *Dojoseisei to Jukinzoku-Doutai (Behavior of Heavy Metals on the Process of Pedogenesis)*. Tokyo: Hakuyusya.*

Katsuki, F., Hokura, A., Iwahata, D., Ikuma, T., Oguri, S., and Haraguchi, H. 1998. Multielement determination of major-to-ultratrace elements in cherry samples by ICP-MS and ICP-AES after acid digestion. *Bunseki Kagaku* **47**: 835–844.**

Krzysztof, P., Anna, L., and Wiesiaw, Z. 2003. Metal concentrations in deciduous tree leaves from urban areas in Poland. *Environmental Monitoring and Assessment* **86**: 273–287.

Obiajunwa, E. I., Pelemo, D. I., Owolabi, S. A., Fasasi, M. K., and Johnson-Fatokun, F. O. 2002. Characterisation of heavy metal pollutants of soils and sediments around a crude-oil production terminal using EDXRF. *Nuclear Instruments and Methods in Physics Research (Section B)* **194**: 61–64.

Terashima, S., Imai, N., Ota, A., Okai, T., and Mikoshiba, M. 2004. Geochemistry of soils from the southern Kanto district, Japan: Preliminary study for the soil geochemical mapping (part 5: Generalization). *Bulletin of the Geological Survey of Japan* **55**: 1–18.**

Uchimura, K., Katsuda, M., and Miura, N. 2007. Determination of the geographical origin in different soil parent materials of tea with inorganic element composition. *Japanese Society of Tea Science and Technology* **103**: 51–60.**

(*: in Japanese, **: in Japanese with English abstract)