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Allometry of *Urtica urens* in Polluted and Unpolluted Habitats

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The allometry of *Urtica urens* (small nettle), an important medicinal plant in many countries, growing in an area near pollution sources and an area away from pollution sources was determined. The allometric coefficients were determined for nonlinear relationships between plant height, stem width, root length, petiole length, leaf dry weight, petiole dry weight, leaf length, leaf width, leaf area and specific leaf area. The slopes of the linear equations were determined for the above parameters. The results showed that there is a difference in the allometry of different parts of *U. urens* growing in these two areas. Air pollutants reduced the plant height, stem width, root length and petiole length and increased leaf parameters. The same pattern of growth was reflected by comparing the slopes of the straight lines of the parts of the plants growing in the two areas.

Keywords: air pollution, allometric coefficient, medicinal plants, morphometry, small nettle, *Urtica urens*

Urtica urens (small nettle) is one of the important medicinal plants in Jordan and many other countries. It has been found growing throughout the temperate zones of both hemispheres worldwide (Europe, Africa, Asia and both Americas). It has been used as antiasthmatic, depurative, diuretic, haemostatic, hypoglycaemic, adrenal tonic, astringent, cholagogue, circulatory stimulant, expectorant, kidney tonic, mucolytic, nutritive, parturient, styptic and thyroid tonic (Saad et al., 1988). Its above ground part, roots and seeds are used for medicinal purposes. In Jordan, the habitat of this plant has been insulted by a number of air pollutants originating mainly from power plants and oil refineries. However, only a few studies have been carried out to evaluate the linkage between air pollution and plant allometry. Grantz and Yang (2000) studied the ozone impacts on allometry and root hydraulic conductance and reported that ozone induces an allometric shift in carbohydrate allocation. This shift is mediated by direct effects on phloem loading with consequent inhibition of translocation to roots and root system development. Kruse et al. (2003) studied the effects of elevated carbon dioxide partial pressure on growth, allometry, and nitrogen metabolism of poplar plants. The results indicated that elevated partial pressure of carbon dioxide increased total biomass and the root : shoot ratio in the nitrogen-deficient plants. In this context, Muzika et al. (2004) reported that O_3, NO_2 and SO_2 adversely influence the growth of *Picea abies* and *Fugus sylvatica*. Their results indicated that there is a negative correlation between these pollutants and the overall growth of these plants. Exposure to SO_2 elicits multiple events linked to metabolism, grain yield and defense and stress responses in plants (Farooq and Hans 1999; Deepak and Agrawal, 2001; Rakwal et al., 2003; Xiong et al., 2003; Prietzel et al., 2004).

Elevated CO_2 levels were reported to increase midday photosynthetic CO_2 exchange rate and water use efficiency and lower transpiration and stomatal conductance (Vu, 2005), increase fine root production and mortality and turnover (Dilustro et al., 2002), decrease the activity of ribulose bisphosphate carboxylase (Rubisco) (Perez et al., 2005), and resulted in larger leaves on short shoots and more leaves per shoot length on long shoots (Hamerlynck et al., 2002).

Considerable work has been carried out on the effects of O_3 on growth of annual plants and trees (Gimeno et al., 2004; Manning et al., 2004), leaf senescence-related processes and morphological changes in seedlings of Mediterranean trees (Ribas et al., 2005), leaf conductance of plant species grown in semi-natural grassland (Jaggi et al., 2005), stomatal response to light and leaf wounding (Paoletti, 2005), and pollen development in *Lolium perenne* L. (Schoene et al., 2004). Grantz et al. (2003) reported that O_3 resulted in reduced biomass production, leaf area development and biomass allocation to roots.

The aim of this study was to investigate the differences in the allometry of *U. urens* by comparing nonlinear and linear relationships of this species growing

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in polluted and unpolluted areas.

MATERIALS AND METHODS

Study Sites and Species

The study was conducted at two different sites in Jordan. The first was Zarqa which is in the vicinity of pollution sources, a petroleum refinery, a wastewater treatment plant and a thermal power plant. The collection site was about 100 m from the thermal power plant. Al-Hassan (1995) and Aqeel et al. (1990) reported that three types of air pollutants are found at this and nearby sites, namely: 1) high levels of SO_2 with an hourly averages ranging from 0.041 to 0.102 ppm, 2) H_2S with a daily averages ranging from 0.0086 to 0.0195 ppm, and 3) CO that reached a maximum of 11.06 ppm. All pollutant levels exceeded daily and hourly limits according to the Jordanian ambient air quality standard (JS1140/99). The effluent of the wastewater treatment plant is not used to irrigate this area. It is transferred to King Talal Dam about 25 km to the west of the treatment plant. The second site was Sukhneh, which is located 20 km away from the nearest pollution source. The two studied sites located at the same bioclimatic region, the Arid Mediterranean bioclimatic region, that is characterized by annual rainfall that ranges from 150-300 mm and mean maximum temperature of 28-39ºC in the hottest month (August) and mean minimum temperature of 1-11ºC in January, the coldest month. The prevailing wind direction in both sites is westerly to northwest in most times of the year (Al-Esawi, 1996).

The Middle East is divided into four vegetative regions, the Mediterranean, the Irano-Turanian, the Sudanian, and the Saharo-Arabian (Zohary, 1973). The two sites are located in the Irano-Turanian vegetative regions with the same soil type (the xerochryptic soil type) (Zohary, 1973) that is characterized with poor and eroded calcareous (loess) soil type. The vegetation is timberless with mostly shrubs and bushes. Soil pH is 7.8, concentration of soil Na is 1.5 meq/100 g, the exchangeable sodium percentage (ESP) is 6.2%, the cation exchange capacity (CEC) is 18.3 meq/100 g, electrical conductivity (EC) is 2.5 ms/cm, the percentage of calcium sulfate is 4.4%, and the percentage of calcium carbonate is 25% (Commission of European Communities, 1994).

Small nettle is a medicinal plant that is annual, monoecious with erect stem that is branching below. The leaves are broadly lanceolate or ovate, subcordate or tapering at base, and are acutely dentate-serrate. Their petioles are short. The plant is stipulate with spike like inflorescence and achene fruits (Zohary, 1972). This plant is abundant in both sites, the polluted and unpolluted areas.

Sampling and Measurements

A random sample of 563 healthy *U. urens* individuals were collected from an area of 0.5 km^2 during the growing season from January to May from both sites. Collected samples were placed in plastic bags, sprinkled with water and returned to laboratory within a few hours where they were submerged in water for 16 to 20 h. From each of the chosen plants one leaf was harvested by cutting the petiole at a point where it is completely separated from the main axis. Petioles were excised from leaf blade and their lengths were measured. Length, width and photosynthetic surface area of each blade were measured using a leaf area meter (AM 200, ADC Bioscientific, UK). These blades and their petioles were dried at 70°C to a constant weight and then dry weight was measured. Plant height for each sample was measured, and the specific leaf area (SLA, $cm^2\ g^{-1}$) was calculated (Nagashima and Terashima, 1995; Chang et al., 2004).

Statistical Analyses

Allometric analysis was carried out using nonlinear and linear regression analysis. The variables of plant height (PH), leaf area (LA), leaf length (LL), leaf width (LW), leaf dry weight (LDW), petiole length (PL), petiole dry weight (PDW), stem width (SW), root length (RL) and specific leaf area (SLA) were analyzed using the nonlinear equation $y = ax^k$ and the linear equation $y = a + bx$. In the case of the nonlinear equation, the relationship is allometric if the allometric coefficient (k) $\neq$ 1 and (a) represents the mean value of the ratio of y/x. In the linear equation (a) represents the y-intercept and (b) is the slope of the straight line. Correlation coefficients were calculated for each relationship. The calculations were carried out using STATISTICA software for windows (StatSoft, USA).

RESULTS AND DISCUSSION

The maximum and minimum plant heights in the unpolluted site (Sukhneh) were 25 to 765 mm with a

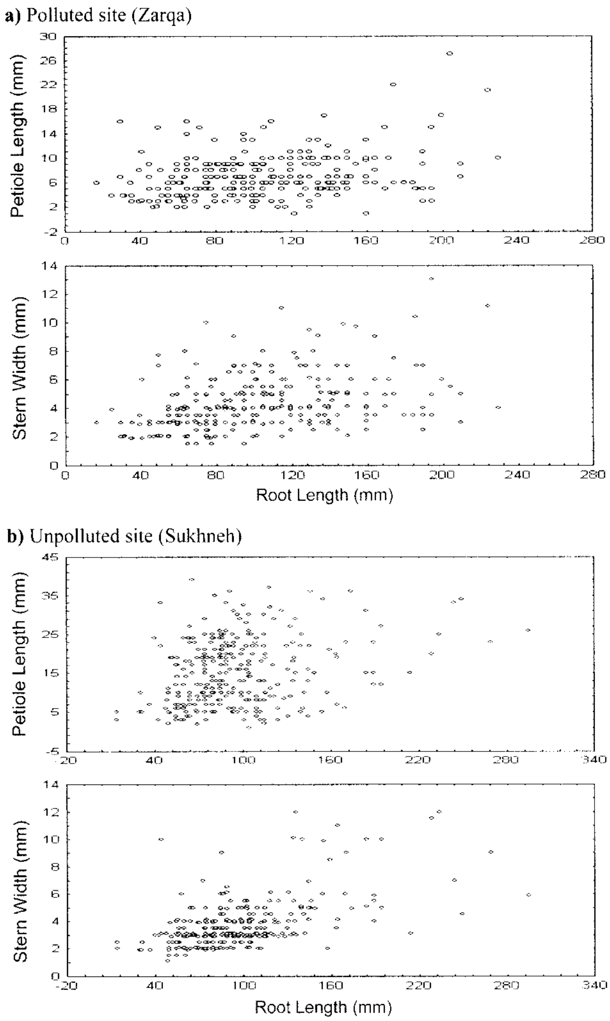

Figure 1. Differences of petiole length and stem width related to the root length between the polluted site and the unpolluted site.

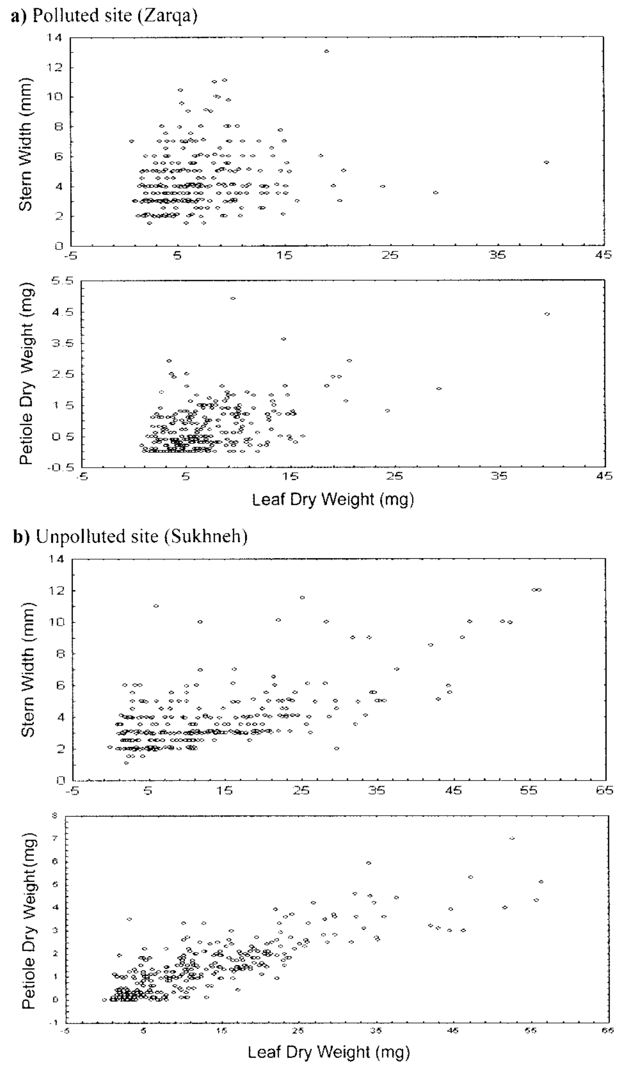

Figure 2. Differences of stem width and petiole dry weight related to the leaf dry weight between the polluted site and the unpolluted site.

mean ± standard error of 232.9 ± 7.32 mm while those in the polluted site (Zarqa) were 14 to 910 mm with a mean ± standard error of 216.3 ± 9.19 mm (Fig. 1, 2, 3, 4). The values for root length were 15 to 910 mm (103.4 ± 4.65 mm) in the unpolluted site and 17 to 230 mm (103.6 ± 2.56 mm). Furthermore, the maximum and minimum stem widths were 1.1 to 12 mm (3.7 ± 0.1 mm) in the unpolluted site and 1.5 to 13.1 (4.9 ± 0.14 mm) in the polluted site. The values for leaf length were 5.3 to 93.7 mm (33.8 ± 0.96 mm) in the unpolluted site and 9.1 to 64.3 (21.1 ± 0.51 mm) in the polluted site. The values for leaf width were 3.3 to 49.5 mm (22.2 ± 0.56 mm) in the unpolluted site and 6.9 to 32.5 (14.2 ± 0.26 mm) in the polluted site, and the values for leaf dry weight were 0.1 to 57.2 mg (12.0 ± 0.63 mg) in the unpolluted site and 0.9 to 39.7 mg (7.2 ± 0.28 mg) in the polluted site. Overall the results showed that allometric coefficient (k) is higher in the unpolluted site than in the polluted site. For example:

$RL = 49.67 * SW^{0.530}$ (Sukhneh)
$RL = 61.09 * SW^{0.371}$ (Zarqa)

The results indicate that root length will increase in the unpolluted site with each increment of stem width more than in the polluted site. The same pattern of growth was also found in leaf dry weight, petiole dry weight, plant height and stem width increase. For example:

$PH = 9.98 * RL^{0.716}$ (Sukhneh)
$PH = 15.32RL^{0.584}$ (Zarqa)

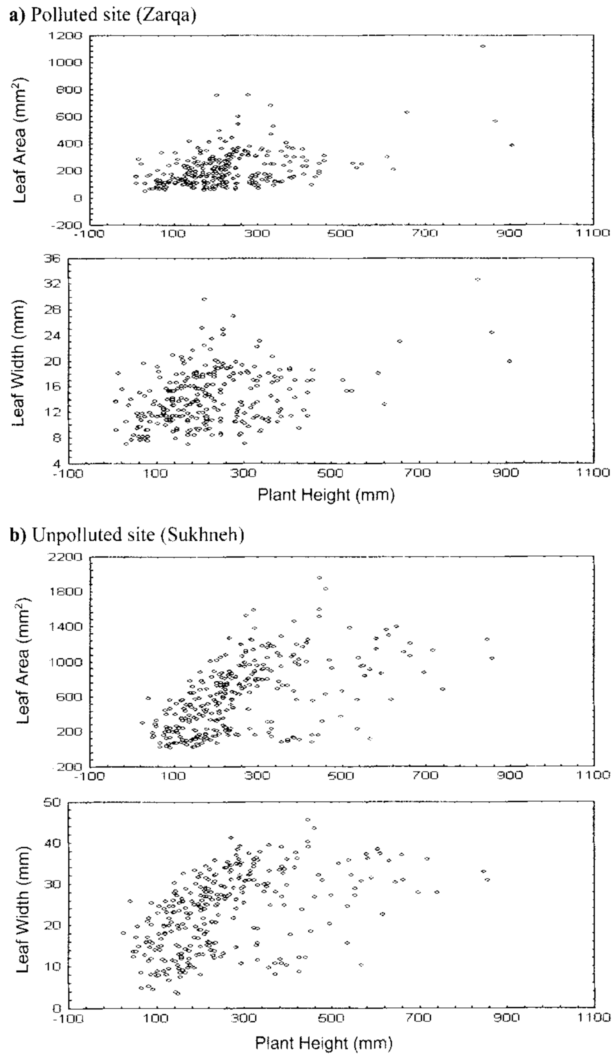

Figure 3. Differences of leaf area and leaf width related to the plant height between the polluted site and the unpolluted site.

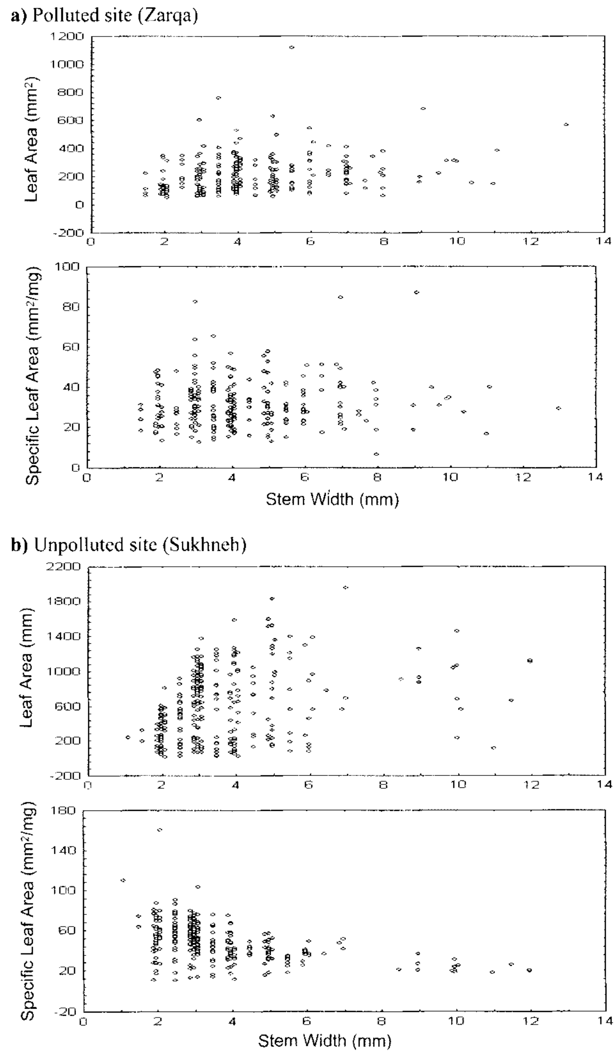

Figure 4. Differences of leaf area and specific leaf area related to the stem width between the polluted site and the unpolluted site.

However, plant height increase with each increment of leaf area in the unpolluted site was lower than the increase in the plant weight with each increment of leaf area in the polluted site.

The linear relationships shown in the tables reflect the same growth patterns apparent in the nonlinear equations. The slope of the straight line shows the relationships that the allometric coefficient illustrated and thus confirms the nonlinear results.

The results showed that there are differences in the values of plant parameters such as plant height, root length, stem width, leaf length and width and leaf dry weight and in the allometry between the plants growing in Zarqa near pollution sources and those growing in Sukhneh away from pollution sources. The allometry of plant parts, namely plant height, stem width, root length, petiole length and dry weight indicated that in the unpolluted site these plant parts grow more than their growth in the polluted site. On the other hand, the allometry of plant parts with leaf parameters, namely the area, length, width, and specific leaf area showed that these plant parts grow more in the polluted area than in the unpolluted area. These relationships indicate that air pollution might have influenced the growth of plant parts in two different ways: 1) an increase in the area of the leaf and thus the leaf length and width, and 2) a decrease in plant height, stem width and root length.

There have been reports on the change of allometry of plant parts by environmental influences (Huber et al., 1999). The results of Muzika et al. (2004) are also in agreement with our results. They indicated that NO_2

Table 1. Parameters of nonlinear relationships for plants from Zarqa and Sukhneh sites.

Relationship	Zarqa			Sukhneh		
	a	k	R	a	k	R
RL-SW	61.09	0.371	0.392	49.67	0.530	0.575
LDW-PDW	8.49	0.319	0.221	9.87	0.863	0.812
PH-RL	15.32	0.584	0.401	9.98	0.716	0.485
SW-LDW	3.26	0.166	0.233	1.54	0.364	0.524
PH-LA	23.05	0.435	0.421	21.95	0.398	0.508
SW-SLA	3.55	0.064	0.051	18.95	-0.434	0.440
PH-LL	41.75	0.562	0.379	39.78	0.536	0.441
PH-LW	34.28	0.716	0.353	30.44	0.689	0.469
SW-LA	1.47	0.209	0.279	1.608	0.137	0.231

Table 2. Parameters of linear relationships for plants from Zarqa and Sukhneh sites.

Relationship	Zarqa			Sukhneh		
	a	b	r	a	b	R
RL-SW	67.35	8.238	0.378	51.23	12.360	0.567
LDW-PDW	4.91	3.031	0.808	2.91	7.396	0.824
PH-RL	93.40	1.279	0.411	83.96	1.823	0.489
SW-LDW	3.84	0.079	0.190	2.27	0.108	0.620
PH-LA	136.09	0.434	0.434	142.21	0.201	0.549
SW-SLA	0	0.115	0.820	0	0.049	0.688
PH-LL	107.97	5.6618	0.360	118.39	4.046	0.432
PH-LW	69.06	11.150	0.357	80.35	7.824	0.483
SW-LA	3.66	0.004	0.245	2.92	0.001	0.292

and SO_2 had a negative effect on plant growth. Deepak and Agrawal (2001) also reported that SO_2 exposure resulted in reductions in plant growth, biomass and yield. Olszyk (1989) reported that SO_2 reduced number and size of fruits and growth of individual leaves. Above studies indicate that the negative effects of pollutants are mainly on shoots and roots which are in agreement with our results.

Tausz et al. (2003) reported that pedospheric sulfur could integrate into the atmospheric sulfur as a sulfur source for plant growth that was shown in needles and roots of spruce seedlings. Stuiver and De Kok (2001) reported that atmospheric H_2S acts as a sulfur source for *Brassica oleracea*. Moreover, Collins and Cunningham (2005) stated that sulfur as an air pollutant can be readily assimilated into crops during vegetation. These reports indicate that plants when subjected to a high concentration of atmospheric sulfur will tend to use it as a source of sulfur instead of soil sulfur. This uptake can be the physiological bases for the effects of air pollutants on the allometry of plants.

The results indicate that there is a difference in the allometry and thus growth of different parts of *U. urens* between an area subjected to air pollutants and an area away from pollution sources. Air pollutants have adverse effects on the shoot and root systems but positive effects on the leaves. Thus, air pollutants reduced the plant height, stem width, root length and petiole length. But, air pollutants increased leaf parameters. The results suggest that use of these plant parts for medicinal purposes can be affected by the air pollution. Further studies are needed to examine the biochemical and physiological changes in this plant due to the effects of air pollution.

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