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ORIGINAL RESEARCH PAPER

Taraxacum officinale (Asteraceae) in the urban environment: seasonal fluctuations of plant traits and their relationship with meteorological factors

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Abstract

Plants can be used as effective bioindicators of the quality of the urban habitat. In this study, physiological traits were examined in plants growing outdoors, in the proximity of a road. All material was collected from robust, well-grown plants. All measurements were performed during the generative phase. Here, the evaluations of some gravimetric parameters (fresh weight, turgid weight, dry weight, water content, ash content) and physiological parameters (initial water content, mineral content, organic content, organic content/mineral content ratio, succulence, mineral deposition in tissues, tissues density, leaf relative water content, specific leaf area) were calculated for *Taraxacum officinale* from urban unmanaged areas, across the different seasons (winter, spring, summer, fall). One-way analysis of variance (ANOVA) was used to compare these traits in leaves, scapes, and roots. Initial water content and relative water content are good indicators of water status in *T. officinale*. With regard to succulence, its level was generally considerably lower in roots than in aboveground organs. The mineral content differed significantly among plant organs. For all the parameters analyzed, the most considerable seasonal differences were found in leaves. The Spearman correlations were calculated for the relations between plant traits. Mineral deposition in tissues is the most sensitive parameter, regardless of the organ. The data were subjected to Spearman correlation and linear regression analysis for each physiological parameter and some meteorological factors. The strongest association was generally found with the wind. Variations in the investigated parameters in roots and scapes are more associated with meteorological factors. *Taraxacum officinale* plants are able to tolerate urban conditions in proximity to a road. Plastic responses to environmental cues make the plant useful in biomonitoring the quality of the urban habitat.

Keywords

phenotypic plasticity; *Taraxacum officinale*; seasonal fluctuations; physiological traits, mineral deposition in tissues

Introduction

The advantages of street vegetation for the quality of the urban environment include the mitigation of the heat island effect, climate regulation [1–3], air pollution removal via absorption of gaseous pollutants [4–6], storm water management [7], indirect impact on human health [8], beauty and aesthetic value [9]. Vegetation cover can also serve as an indicator of the degree of surface shading [10,11]. The biomass of aboveground vegetation can serve as an indicator of the conversion of solar energy into plants [12]. Street vegetation is subjected to high stress from environmental influences due to its location and poor maintenance. Anthropogenic stressors (such as the number of houses on a street or the level of traffic passing through a neighborhood) reduce the lifespan of many plants in the urban environment [13–15]. The strength, duration, and rate of progression of stress also have an impact on the physiological responses of a plant, as well as on its developmental stage and sensitivity to different environmental components [16–18].

The phenology of the species is dependent on weather patterns that differ in particular climate zones across geographical areas [19]. Changes in climatic conditions have the strongest impact upon the annual seasonal dynamics of perennial plants [20,21]. It was stated that *Taraxacum officinale* F. H. Wigg. (common dandelion) may be used as a phenological indicator [19,22]. It can grow in a wide range of soil types, wide range of soil pH, it resists drought, and adapts to a wide range of light and shade intensity [23]. *Taraxacum officinale* has been used in a number of regional-scale studies as a biomonitor of environmental pollution in Bulgaria [24], Poland [25], Hungary [26], Italy [27], the Czech Republic [28], and Switzerland [29].

It is known that phenotypic plasticity in *T. officinale* increases its ability to colonize a wide range of habitats. On the other hand, the vitality of plants is a complex phenomenon resulting from different factors and physiological parameters assessed through various diagnostic methods [30].The gravimetric method, which has been described as optimal with respect to reliability and simplicity, remains widely used [31–36]. In this study, we used such a method to investigate the hypothesis that some physiological traits of *T. officinale* differ in their flowering phenophase and express phenotypic plasticity.

Seasonal fluctuations are known for more compounds in *T. officinale*, but seasonal variations in physiological traits in the conditions of urban stress are not known. Those traits are easily and rapidly screened, and the screening procedures are relatively inexpensive. Such physiological parameters can be used to characterize the habitat. The objective of this study was to investigate variations in physiological traits in plants with increased vitality when *T. officinale* are grown under inconstant environmental conditions in the urban habitat of the city of Timisoara (Romania).

Material and methods

Study location

The study was performed in 2013 in the city of Timisoara, western Romania. The characteristic vegetation of Timisoara is anthropogenic forest steppe which is typical of the Banat Plain [37]. The climate is moderate temperate-continental [38]. The main pollutants tend to be airborne particles, sulfur dioxide, nitrogen dioxide, carbon monoxide, ozone, and volatile organic compounds. The principal sources of pollution are industry, transportation, and households. The public transportation system consisting of bus, trolleybus, and tramlines and the complex system of regional transportation, providing road, air, and rail connections to major cities in the country and Europe are the principal sources of pollution in Timisoara [39,40].

February was the driest and cloudiest month of 2013 (with 54% of days being more cloudy than clear). The longest warm spell was from April 11 to May 12, constituting 32 consecutive days with warmer than average temperatures. July had the highest average cloud ceiling, with an average cloud ceiling of 1508 m. The longest dry spell was from July 16 to July 30, constituting 15 consecutive days with no precipitation. September had the largest fraction of cooler than average days, with 70% days with lower than average temperatures. November was characterized with 77% of days with higher than average temperatures.

Plant material and sampling

Taraxacum officinale (Asteraceae) appear to be a good material, simple to identify, easy and inexpensive to collect. To reach full maturity, they require 85 to 95 days. The stems are acaulescent with very short internodes at or below the soil surface [41].

It forms a leaf rosette close to the ground and a taproot. The runcinate-pinnatifid leaves have glabrous to sparsely pubescent lower surfaces. The basal rosette gives rise to numerous glabrous and cylindrical scapes. Each scape bears a single terminal inflorescence of 2–5 cm diameter, composed of up to 250 ligulate yellow florets [23]. The development of the inflorescence is quick. Dandelions flower throughout the entire vegetative season, with the peak in spring (April) and fall (September). The taproot can be up to 2–3 cm in diameter and grow up to 1–2 m in length. The lateral roots are distributed relatively regularly along its length. The roots are highly regenerative, capable of producing shoots and roots from very small fragments. The plant may regrow from cut roots due to the presence of callus buds [42]. In winter, the root is shorter and comes down into the soil, where it is better protected from unfavorable conditions. The roots remain viable during the winter and are a source of nutrients which facilitate the resumption of growth in early spring.

Plants were collected during the flowering stage. The samples were taken from plants in full light. The soil had low aeration, porosity, and drainage due to compaction [43]. It was contaminated with pollutants associated with demolition of buildings and vehicle emissions [44]. As consistently as possible, plants were of the same size and had leaves of the same form. All plant material was collected during winter (late February), spring (late April), summer (mid-July), and fall (mid-September and early November). We collected the samples during the late morning. Immediately after cutting, plants were sealed within plastic bags and quickly transferred to the laboratory. The plants were dug from the earth as a whole, so as not to damage the root system. We did not wash the leaves before the analysis. We selected juvenile leaves as well as fully expanded and hardened leaves from adult plants. Leaf age classes were defined based on preliminary field observations:

- young (juvenile) – usually from 0–2 weeks old, before attaining full expansion;
- mature – from 2–4 weeks old; a fully grown and structurally developed leaf;
- senescent – a leaf in the process of dying and just prior to abscission; characterized by a basal position, the loss of chlorophyll, or the onset of decomposition.

Physiological measurements

All mass measurements were made using an analytical balance, with precision of 0.0001 g. For each organ, the fresh weight was quickly measured (FW). Turgid weight (TW) was obtained after soaking leaves in distilled water in Petri dishes for 2 hours at room temperature and under the low light conditions of the laboratory. After soaking, leaves were quickly and carefully blotted dry with tissue paper for analysis. Finally, all the leaves (and all the organs) were dried in an oven at 80°C for 24 hours and weighed (DW). Dried samples were burned in ash in a furnace at 500°C for 2 h. After cooling, the mass of ash content (AC) was determined. Ash content is the inorganic residue left after burning and it is the reflection of the mineral content of biomass. Organic matter was calculated by subtracting crude ash weight from dry matter weight.

Several physiological parameters were calculated: mineral deposition in tissues ($TDM = AC/DW \times 1000$ – in g/kg dry weight), tissue density ($TD = DW/FW \times 1000$ – in g/kg). Mineral content (MC; on the basis of the fresh weight) and organic content (OC; on the basis of the fresh weight) are expressed as mass percentage of fresh biomass and organic content / mineral content ratio. Succulence (S) was defined as total water mass divided by the dry mass of organic material (total dry mass minus ash content) [45]. Leaf relative water content (LRWC) was calculated according to the following equation: $LRWC\% = (FW - DW) / (\mathrm{TW} - \mathrm{DW}) \times 100$. LRWC is the ratio of the amount of water in leaf tissue at sampling to that present when fully turgid (TW). Because excess water may be absorbed and held in the apoplast, it is likely that the RWC of an artificially hydrated organ is outside of the natural range for plants in natural conditions. This is an argument for simply measuring initial water content as plants are collected, without further rehydration (for scapes and roots) [46]. Initial water content (IWC) is expressed as the mass percentage of fresh biomass. This parameter can be compared across all plant organs.

Specific leaf area (SLA) is defined as the amount of leaf area per unit leaf weight. Fifteen randomly selected leaf discs (with calculated areas) were sampled and dried in an oven at 80°C for 24 hours. Dry weight (DW) of the samples was measured and used for the calculation of a specific leaf area, where *S* is the area of leaf discs: SLA (cm^{-2}/g^{-1}) = S (cm^2) / DW (g) [47,48].

List of non-standard abbreviations of gravimetric parameters: AC (g) – ash content; DW (g) – dry weight; FW (g) – fresh weight; TW (g) – turgid weight; WC (g) – water content.

List of non-standard abbreviations of physiological parameters calculated: LIWC (%) – leaf initial water content; LMC (%) – leaf mineral content; LOC (%) – leaf organic content; LOC/LMC ratio – leaf organic content / leaf mineral content ratio; LRWC (%) – leaf relative water content; LS – leaf succulence; LTD (g/kg) – leaf tissues density; LTDM (g/kg dry weight) – leaf tissues mineral deposition; RIWC (%) – root initial water content; RMC (%) – root mineral content; ROC (%) – root organic content; ROC/RMC ratio – root organic content / root mineral content ratio; RS – root succulence; RTD (g/kg) – root tissues density; RTDM (g/kg dry weight) – root tissues mineral deposition; SIWC (%) – scape initial water content; SLA (cm^2/g) – specific leaf area; SMC (%) – scape mineral content; SOC (%) – scape organic content; SOC/SMC ratio – scape organic content / scape mineral content ratio; SS – scape succulence; STD (g/kg) – scape tissues density; STDM (g/kg dry weight) – scape tissues mineral deposition.

Statistical analysis

Statistical differences between measurements were analyzed following the analysis of variance (ANOVA), using SPSS software (IBM SPSS Statistics for Windows, version 22.0. Armonk, NY: IBM Corp.). A value of $p < 0.05$ was considered significant. The Spearman correlations were calculated for the relations between plant traits. A linear regression analysis was performed between physiological parameters and seasonal sampling. A *t*-test analysis was carried out on mature and juvenile leaves. A linear regression analysis was performed in order to determine how much of total variance in physiological parameters can be explained by meteorological variables.

Results

The descriptive statistics of gravimetric and physiological parameters calculated for each organ are shown in Tab. 1, Tab. 2, and Fig. 1–Fig. 3.

Leaf-level traits

Mature leaves were found to weigh above 0.2000 g. The leaves of plants blooming in February were the lowest in fresh weight. These organs showed significant differences from one season to another for all the parameters analyzed. LIWC was higher in February. In November, they had the lowest values of LOC and LOC/LMC ratio, but the highest values of LMC and LTMD. The leaves in November had the highest average of succulence and the highest average of LRWC. Simple regression analysis showed that there was a linear relationship between seasonal samplings and average values of LAC ($y = 0.0009x + 0.0036$; $R^2 = 0.4092$), LMC ($y = 0.2228x + 1.5131$; $R^2 = 0.8889$), LTDM ($y = 17.352x + 110.8$; $R^2 = 0.6447$). LOC/LMC ratio showed a negative trend during 2013 ($y = -0.5889x + 7.3737$; $R^2 = 0.6186$). The values of fresh weight, turgid weight, dry weight, ash content and water content were significantly different between mature leaves and juvenile leaves, for all seasons (Tab. 2). LRWC indicated a greater ability to allow mature leaf tissue to soak water in winter and spring. In winter, significant differences to the following parameters were found: leaf organic content, LOC/LMC ratio, and mineral deposition in tissues. The values of LRWC, LOC, and LTMD were higher in mature leaves than in young leaves. For other parameters, no significant differences were observed.

Tab. 1 Descriptive statistics and results of one-way ANOVA for gravimetric and physiological parameters in 2013 (with significant *p*-values indicated in bold).

Organs	Parameters	Minimum	Maximum	Mean	*SD*	One-way ANOVA	
						F	*p* (same)
Roots	FW (g)	0.72	9.94	2.2295	1.70966	2.028	0.1199
	DW (g)	0.15	2.79	0.6078	0.49543	2.269	0.08895
	AC (g)	0.01	0.31	0.0428	0.05339	1.112	0.3722
	WC (g)	0.55	7.16	1.6217	1.22297	1.905	0.1396
	RIWC (%)	62.7	79.33	73.2862	4.0734	0.9953	0.4277
	RMC (%)	0.82	3.15	1.7428	0.5073	3.128	0.03162
	ROC (%)	18.53	35.85	24.971	4.19544	1.176	0.3443
	ROC/RMC ratio	7.44	34.85	15.9018	6.61195	4.596	**0.006106**
	RTD (g/kg)	206.71	372.95	267.1382	40.73398	0.9953	0.4277
	RTDM (g/kg)	27.89	118.46	67.1375	23.06986	2.751	**0.04948**
	RS	1.75	4.26	3.0367	0.64082	1.754	0.1685
Scapes	FW (g)	0.21	1.58	0.7981	0.38553	2.234	0.08587
	DW (g)	0.02	0.25	0.104	0.05333	1.175	0.339
	AC (g)	0.0036	0.03	0.0114	0.0067	1.187	0.3343
	WC (g)	0.18	1.37	0.6941	0.33466	2.156	0.09519
	SIWC (%)	83.67	90.69	86.9755	1.58708	2.289	0.08059
	SMC (%)	0.65	2.72	1.4667	0.46103	3.064	**0.02984**
	SOC (%)	7.95	14.34	11.5578	1.54059	3.152	**0.02668**
	SOC/SMC ratio	3.4	17.35	8.7308	3.09142	3.364	**0.02046**
	STD (g/kg)	93.06	163.28	130.245	15.87077	2.289	0.08059
	STDM (g/kg)	54.49	227.46	113.2685	37.46364	4.281	**0.006712**
	SS	5.84	11.4	7.6826	1.23146	3.352	**0.02078**
Leaves	FW (g)	0.04	1.01	0.3265	0.23454	4.724	**0.001289**
	DW (g)	0.0048	0.18	0.0466	0.03585	5.531	**0.000354**
	AC (g)	0.0006	0.03	0.0072	0.00563	4.765	**0.001208**
	WC (g)	0.03	0.86	0.2798	0.20011	4.563	**0.001672**
	LIWC (%)	77.75	91.84	85.9915	2.03079	12.77	**5.90E-09**
	LMC (%)	0.96	4.69	2.1758	0.55808	11.25	**5.40E-08**
	LOC (%)	6.54	18.69	11.8327	1.98851	17.93	**5.01E-12**
	LOC/LMC ratio	2.14	12.41	5.8004	1.79978	14.23	**7.48E-10**
	LTD (g/kg)	81.56	222.52	140.0849	20.30784	12.77	**5.90E-09**
	LTDM (g/kg)	74.59	318.01	157.4594	43.28093	22.74	**1.17E-14**
	LS	4.16	14.04	7.5051	1.47561	20.73	**1.39E-13**
	SLA (cm^2/g)	108.05	942.00	454.8213	154.49336	2.428	0.07601

Tab. 1 Continued

Organs	Parameters	Minimum	Maximum	Mean	*SD*	One-way ANOVA	
						F	*p* (same)
	LRWC (%)	66.19	98.19	85.4911	5.24757	1.214	0.3071

Tab. 2 Analysis of differences (with significant *p*-values indicated in bold; ns – not significant) between mature leaves (ML) and juvenile leaves (JL).

		LIWC (%)	LRWC (%)	LMC (% FW)	LOC (% FW)	LOC/LMC	TD (g/kg FW)	TMD (g/kg DW)	S
Late February	ML	88.7636	89.4930	1.8112	9.4252	5.2487	112.3639	162.7673	9.6921
	JL	87.2695	85.0351	1.6944	11.0362	6.8368	127.3052	133.1927	7.9849
	p	ns	**0.0161725**	ns	**0.045008**	**0.03961**	ns	**0.037701**	ns
Late April	ML	84.6350	86.6970	1.9933	13.3717	6.9694	153.6501	129.8938	6.3967
	JL	84.9271	80.4019	1.9540	13.1189	6.9907	150.7289	129.0133	6.5254
	p	ns	**0.0159199**	ns	ns	ns	ns	ns	ns
Mid-July	ML	85.9364	84.4452	2.2056	11.8580	5.4088	140.6357	158.2342	7.4954
	JL	87.2558	86.2231	2.3242	10.4200	4.6070	127.4417	183.2563	8.4534
	p	ns	ns	ns	ns	ns	ns	ns	ns
Mid-September	ML	85.7406	85.8365	2.2348	12.0247	5.5577	142.5944	157.4609	7.2956
	JL	85.4730	83.6466	2.1023	12.4248	6.5235	145.2703	146.2452	7.0247
	p	ns	ns	ns	ns	ns	ns	ns	ns
Early November	ML	87.4044	90.8283	2.6503	9.9453	3.9108	125.9557	212.2992	9.0575
	JL	87.3851	88.6502	2.8854	9.7295	3.7994	126.1492	228.4078	9.1500
	p	ns	ns	ns	ns	ns	ns	ns	ns

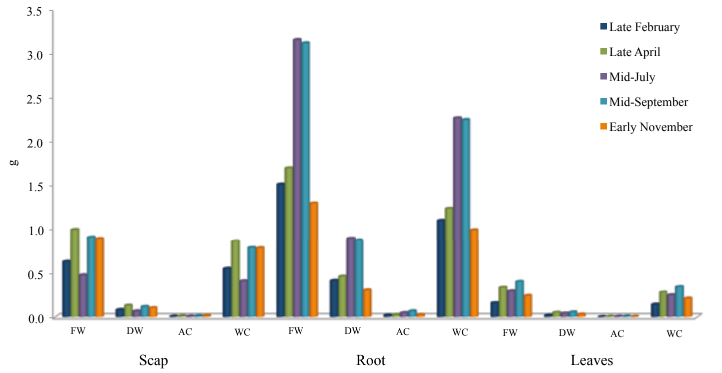

Fig. 1 The mean values of gravimetric parameters for all organs.

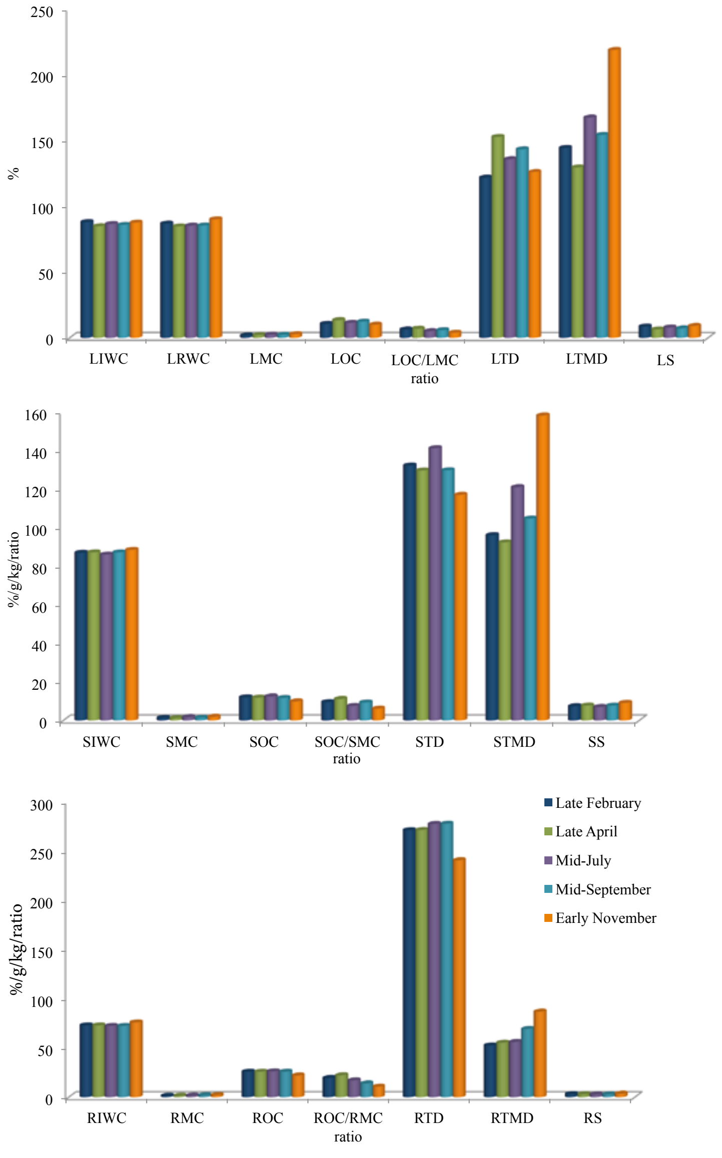

Fig. 2 **a–c** The mean values of physiological parameters calculated for leaves (**a**), scapes (**b**), and roots (**c**).

In our study, SLA of old leaves was significantly lower than SLA of young leaves (p = 0.035533). The average value of SLA was 454.8213 cm^{-2}/g^{-1}. SLA was higher in spring (April) and lower in July (summer). In our study, seasonal changes of SLA in leaves did not show a linear decrease or increase over the growing season.

Scape with inflorescence-level traits

Scapes showed significant differences for a few parameters: SMC, SOC, SOC/SMC ratio, STDM, and SS. In July, the mean of SS and SIWC were the lowest, but the average values of SOC and STD were higher than in other seasons. Fresh weights were lower in July. In the fifth sampling, scapes showed a significant increase in SAC ($y = 0.0018x + 0.0058$; $R^2 = 0.6783$), SMC ($0.1336x + y = 1.0698$; $R^2 = 0.5491$), STMD ($13.66x + y = 73.341$; $R^2 = 0.6498$), and SS ($y = 0.3489x + 6.6753$; $R^2 = 0.4742$). Two parameters had decreasing values: SOC ($-0.4359x + y = 12.818$; $R^2 = 0.4957$) and SOC/SMC ratio ($y = -0.8643x + 11.253$; $R^2 = 0.4864$).

Root system-level traits

Roots showed significant differences for the following parameters: RMC, ROC/RMC ratio, and RTDM. The average values of RIWC and RS were relatively constant. In July, roots had the highest values of ROC. Fresh weights of roots were lowest in November. Blooming plants had the strongest roots in July. Two physiological parameters have increasing average values: RMC ($0.1977x + y = 1.0617$; $R^2 = 0.9391$) and RTDM ($8.2382x + y = 39.248$; $R^2 = 0.8293$). RTDM and RMC values increased gradually. Two parameters indicated that average values were decreasing during the investigated seasons: ROC/RMC ratio ($y = -2.5645x + 24.346$; $R^2 = 0.8169$) and ROC ($-0.747x + y = 27.344$; $R^2 = 0.4554$).

Correlations between physiological parameters

The Spearman's rho coefficient indicated the same correlations (positive or negative) between physiological parameters in all organs studied. Organic and mineral content was negatively correlated to the amount of moisture in samples. A correlation coefficient of -1 indicated a perfect linear relationship. Therefore, the density of tissues was perfectly inversely correlated with the initial water content, while tissues mineral deposition was perfectly inversely correlated with the organic content / mineral content ratio.

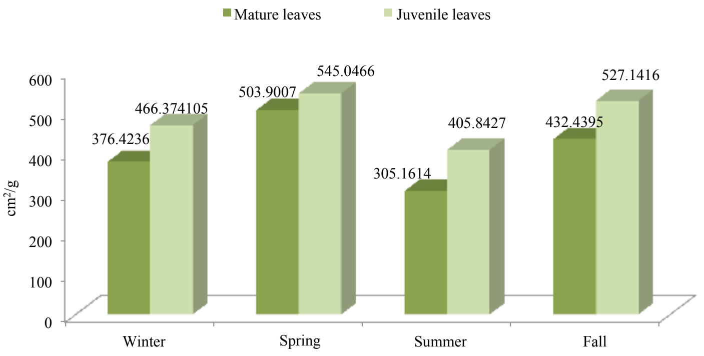

Fig. 3 The mean values of specific leaf area (SLA).

The most sensitive parameter for all organs analyzed was mineral deposition in tissues (LTDM, STDM, RTDM).

Correlations and regression analysis between physiological parameters and meteorological factors (Tab. 3–Tab. 5)

Increasing average wind speeds correlated significantly with RS and RIWC. This increase is correlated with decreased RTD and ROC. The average wind speed showed no significant correlations with leaf and scape parameters. In terms of maximum wind speed, we identified several physiological parameters that have no correlation with it: LTMD, LOC/LMC ratio, STMD, SOC/SMC ratio, SMC. On the other hand, this parameter correlated significantly and positively with succulence of organs (roots and scapes), but significantly negatively with STD. Temperature showed no significant correlation with physiological parameters analyzed, with one exception: an increase in average and minimum temperature was correlated significantly with a decrease in succulence in roots. Average humidity demonstrated significant positive correlations with LRWC and RS. Atmospheric pressure had no significant correlations with any of the calculated parameters.

The regression analysis between temperature and initial water content showed relatively high values of coefficients between these variables (for scapes and roots). Minimum temperature explained variance of roots (38.44%) and scapes (49.49%). Leaf variance was explained in the proportion of 29.26% by the maximum temperature. Initial water content for roots and scapes was more associated with wind and humidity. The variations in the initial water content in leaves were better explained by humidity and atmospheric pressure. However, in the case of LRWC, the importance of minimum temperature (39.62%), average wind speed (66.68%), and average humidity (60.34%) increased. The most important meteorological factor which explained changes in mineral content in all plant organs, but especially in leaves, was air pressure (38.02%). Variations in the organic content in roots and scapes were explained by the minimum temperature in proportion of 29.52% and 32.76%, respectively. In roots and scapes, the following factors had the biggest influence on the organic content: average wind speed, maximum wind speed, and average humidity. Linear regression revealed that organic content variations in leaves were mostly explained by average humidity. The organic/mineral ratio and mineral deposition in tissues are not significantly influenced by meteorological factors. The same factors explained variance in tissue density of roots and scapes: minimum temperature, average wind speed, maximum wind speed, and average humidity. Temperature, humidity, and atmospheric pressure affected the density of leaf tissue.

Discussion

Plants from a heterogeneous environment exhibit a greater plasticity in terms of photosynthetic performance and flowering time in response to water shortage than plants from a less variable environment [49]. *Taraxacum officinale* has wide ecological valence in relation to anthropogenic influences [50]. In proximity to a high-traffic road, this species is an indicator of heavy metal and nutrient concentrations resulting from atmospheric deposition. It is hypothesized that significant differences in seed reproduction indices of *Taraxacum* were caused by changes in weather conditions, but not by traffic intensity [51]. For example, achenes from urban plants showed higher germination and flowering success, producing a significantly higher number of flowers [52]. Other studies have shown that these plants exhibit a variability of leaf blade shapes depending on the habitat conditions [53].

Tab. 3 Correlations and regression analysis between physiological parameters of scapes and meteorological factors.

Scapes	Statistical coefficients	Average tempera-ture (°C)	Minimal tempera-ture	Maximum tempera-ture	Average wind speed (km/h)	Maximum wind speed (km/h)	Average humidity (%)	Average air pressure (hPa)
SIWC	Spearman's rho	−0.4000	−0.4000	−0.2050	0.7380	0.900*	0.6000	−0.2240
	Multiple *R*	0.5687	0.7036	0.4095	0.8296	0.7234	0.7886	0.0862
	R-square	0.3234	0.4950	0.1677	0.6883	0.5233	0.6219	0.0074
SMC	Spearman's rho	0.2000	0.2000	0.1030	0.1050	0.0000	0.3000	0.4470
	Multiple *R*	0.2785	0.1660	0.3558	0.2585	0.1114	0.0578	0.4768
	R-square	0.0776	0.0275	0.1266	0.0668	0.0124	0.0033	0.2273
SOC	Spearman's rho	0.3000	0.3000	0.3590	−0.5270	−0.7000	−0.7000	0.2240
	Multiple *R*	0.4206	0.5724	0.2577	0.8073	0.6057	0.7126	0.0628
	R-square	0.1769	0.3276	0.0664	0.6517	0.3669	0.5078	0.0039
SOC/ SMC	Spearman's rho	−0.2000	−0.2000	−0.1030	−0.1050	0.0000	−0.3000	−0.4470
	Multiple *R*	0.1273	0.0500	0.1762	0.3025	0.0627	0.2065	0.3062
	R-square	0.0162	0.0025	0.0311	0.0915	0.0039	0.0426	0.0938
STD	Spearman's rho	0.4000	0.4000	0.2050	−0.7380	−0.900*	−0.6000	0.2240
	Multiple *R*	0.5687	0.7036	0.4095	0.8296	0.7234	0.7886	0.0862
	R-square	0.3234	0.4950	0.1677	0.6883	0.5233	0.6219	0.0074
STMD	Spearman's rho	0.2000	0.2000	0.1030	0.1050	0.0000	0.3000	0.4470
	Multiple *R*	0.0418	0.1080	0.1759	0.5226	0.1733	0.3113	0.3798
	R-square	0.0017	0.0117	0.0310	0.2731	0.0300	0.0969	0.1442
SS	Spearman's rho	−0.4000	−0.4000	−0.2050	0.7380	0.900*	0.6000	−0.2240
	Multiple *R*	0.3995	0.5704	0.2121	0.8226	0.6379	0.6747	0.1024
	R-square	0.1596	0.3253	0.0450	0.6767	0.4070	0.4552	0.0105

* Correlation is significant at the 0.05 level.

In this study, the highest content of dry matter was found in roots and decreased in the following order: root > scape > leaf. Fresh or dry biomass is a common measure of growth for herbaceous plants [54]. Dry matter content has been proposed as an indicator of plant resource use [55]. This trait is related to leaf lifespan and it is involved in the fundamental trade-off between rapid production of biomass and efficient conservation of nutrients [56,57]. Herbaceous perennials maintain the capacity to develop new leaves and continue to grow throughout their life. The carbohydrates stored in vegetative organs are important in terms of balancing the source–sink relationship in perennial plants. Great amounts of carbohydrate reserves stored in roots support the emergence of shoots when temperature and soil moisture are favorable [58]. Dandelions are able to delay the onset of water stress by both controlling transpiration and by increasing the water uptake through having a large and deep root volume

Tab. 4 Correlations and regression analysis between physiological parameters of roots and meteorological factors.

Roots	Statistical coefficients	Average temperature (°C)	Minimal temperature	Maximum temperature	Average wind speed (km/h)	Maximum wind speed (km/h)	Average humidity (%)	Average air pressure (hPa)
RIWC	Spearman's rho	−0.8000	−0.8000	−0.4100	0.949*	0.8000	0.7000	−0.4470
	Multiple *R*	0.4432	0.6200	0.2080	0.9057	0.6932	0.6747	0.0094
	R-square	0.1964	0.3845	0.0433	0.8203	0.4805	0.4552	0.0001
RMC	Spearman's rho	0.3000	0.3000	0.1540	0.1050	0.2000	0.3000	0.4470
	Multiple *R*	0.0883	0.0147	0.0531	0.2369	0.0436	0.3359	0.4298
	R-square	0.0078	0.0002	0.0028	0.0561	0.0019	0.1128	0.1848
ROC	Spearman's rho	0.7000	0.7000	0.3590	−0.949*	−0.959**	−0.7000	0.4470
	Multiple *R*	0.3740	0.5434	0.1734	0.8413	0.6025	0.6561	0.0875
	R-square	0.1399	0.2952	0.0301	0.7077	0.3630	0.4305	0.0077
ROC/ RMC	Spearman's rho	−0.1000	−0.1000	0.1540	−0.1050	−0.1000	−0.5000	−0.2240
	Multiple *R*	0.0333	0.0037	0.0233	0.2367	0.0874	0.3884	0.2972
	R-square	0.0011	0.0000	0.0005	0.0560	0.0076	0.1509	0.0884
RTD	Spearman's rho	0.8000	0.8000	0.4100	−0.949*	−0.8000	−0.7000	0.4470
	Multiple *R*	0.4432	0.6200	0.2080	0.9057	0.6932	0.6747	0.0094
	R-square	0.1964	0.3845	0.0433	0.8203	0.4805	0.4552	0.0001
RTMD	Spearman's rho	0.3000	0.3000	0.1540	0.1050	0.2000	0.3000	0.4470
	Multiple *R*	0.1306	0.2541	0.0620	0.5357	0.2638	0.5208	0.3022
	R-square	0.0171	0.0646	0.0038	0.2870	0.0696	0.2713	0.0913
RS	Spearman's rho	−0.900*	−0.900*	−0.6670	0.949*	0.900*	0.900*	−0.6710
	Multiple *R*	0.6220	0.7723	0.3890	0.9614	0.8069	0.7901	0.1962
	R-square	0.3868	0.5965	0.1513	0.9242	0.6510	0.6242	0.0385

Correlation is significant at the 0.05 (*) or 0.01 (**) level.

[59]. Plants of *T. officinale* lose a part or all of their aboveground tissues before the onset of the unfavorable season, which suggests that they invest resources to protect the regenerating tissues located below the ground and/or to accumulate reserves in belowground tissues instead of cold hardening the aboveground organs [60]. *Taraxacum officinale* has a medium drought tolerance, but generally grows with a minimum rooting depth of 15 cm and most root activity at a depth of 10–15 cm [61]. Roots, on average, contained approximately 12% less water than floriferous scapes and leaves. Therefore, roots had the highest density of tissues among the analyzed organs. The levels of density of tissues showed considerable variations in samples throughout the study period. The organic content in the collected roots (24.97%) was higher than in scapes and leaves. The differences between these organs were significant. The organic content / mineral content ratio in roots was generally higher than that in leaves and

Tab. 5 Correlations and regression analysis between physiological parameters of leaves and meteorological factors.

Leaves	Statistical coefficients	Average tempera-ture (°C)	Minimal tempera-ture	Maximum tempera-ture	Average wind speed (km/h)	Maximum wind speed (km/h)	Average humidity (%)	Average air pressure (hPa)
LIWC	Spearman's rho	−0.6000	−0.6000	−0.6160	0.3690	0.1000	0.6000	−0.4470
	Multiple *R*	0.5333	0.4635	0.5410	0.4076	0.2474	0.6128	0.5554
	R-square	0.2845	0.2148	0.2926	0.1661	0.0612	0.3755	0.3085
LMC	Spearman's rho	0.4000	0.4000	0.4100	0.1050	0.1000	0.1000	0.6710
	Multiple *R*	0.2364	0.0657	0.3479	0.3841	0.0514	0.1543	0.6167
	R-square	0.0559	0.0043	0.1210	0.1476	0.0026	0.0238	0.3803
LOC	Spearman's rho	0.5000	0.5000	0.4620	−0.5270	−0.3000	−0.7000	0.2240
	Multiple *R*	0.4288	0.4109	0.4052	0.4825	0.2430	0.6095	0.3449
	R-square	0.1838	0.1689	0.1642	0.2328	0.0591	0.3714	0.1189
LOC/ LMC	Spearman's rho	−0.2000	−0.2000	−0.1030	−0.1050	0.0000	−0.3000	−0.4470
	Multiple *R*	0.0855	0.0100	0.1457	0.3731	0.0073	0.2793	0.3337
	R-square	0.0073	0.0001	0.0212	0.1392	0.0001	0.0780	0.1113
LTD	Spearman's rho	0.6000	0.6000	0.6160	−0.3690	−0.1000	−0.6000	0.4470
	Multiple *R*	0.5333	0.4635	0.5410	0.4076	0.2474	0.6128	0.5554
	R-square	0.2845	0.2148	0.2926	0.1661	0.0612	0.3755	0.3085
LTMD	Spearman's rho	0.2000	0.2000	0.1030	0.1050	0.0000	0.3000	0.4470
	Multiple *R*	0.0351	0.1585	0.0685	0.5242	0.1763	0.3973	0.2910
	R-square	0.0012	0.0251	0.0047	0.2748	0.0311	0.1579	0.0847
LS	Spearman's rho	−0.5000	−0.5000	−0.4620	0.5270	0.3000	0.7000	−0.2240
	Multiple *R*	0.4618	0.4524	0.4223	0.5257	0.2928	0.6349	0.3616
	R-square	0.2133	0.2046	0.1784	0.2763	0.0857	0.4030	0.1308
LRWC	Spearman's rho	−0.6000	−0.6000	−0.7180	0.5270	0.4000	0.900*	−0.4470
	Multiple *R*	0.5316	0.6295	0.3855	0.8166	0.5807	0.7768	0.1808
	R-square	0.2826	0.3962	0.1486	0.6668	0.3372	0.6034	0.0327

* Correlation is significant at the 0.05 level.

scapes. As far as mineral deposition in tissues is concerned, leaves showed the highest value (157.4590 g/kg dry weight), followed by scapes (113.2690 g/kg dry weight), and roots (67.1375 g/kg dry weight). The analysis of variance showed significant differences for this parameter.

In the present study, ash values give an idea of the amount of mineral content in plants. Leaves usually had a higher mineral content (2.17%). We observed an increase in ash content related to leaf maturity. Mineral nutrients can be measured in organs to assess vitality [62]. Ash refers to the sum of all other oxidized elements in addition to carbon, hydrogen, oxygen, and nitrogen. Most of them are calcium, phosphorus, and potassium oxides, which reflects the total amount of minerals [63]. These minerals increase the abrasiveness of leaf material, and reduce herbivore growth rates and digestion efficiency [64]. Our results indicate that the variation of minerals at the growing stage is more complex than the variation of organic matter [65]. The analysis of the accumulation of minerals in plants has been proposed as an inexpensive and simple way to predict yield and genotypic adaptation to drought in some C_3 cereals [66].

Plant water status can be indicated by the features of such tissues as root, scape, and leaf. Leaf initial water content (LIWC), scape initial water content (SIWC), and root initial water content (RIWC) give an overall estimate of the amount of water in these organs of a plant at the time of sampling. The highest initial water content was found in scapes and decreased in the following order: scape > leaf > root. Slow water uptake has been shown to be associated with growth, and is greater in young tissue than in mature tissue. Water storage in stems can serve as a buffer against transitional insufficient supply of water from soil [67]. In another study, leaf structures were shown to reflect the effects of water stress more clearly than stem and/or root structures [59].

LRWC is considered as an alternative measure of plant water status, reflecting the metabolic activity in plant tissues [68]. In our study, we observed only in July that young leaves had higher values of LRWC, but there were no significant differences in comparison to mature leaves. The rate of transpiration is the fastest when air temperature is between 20°C to 30°C. High temperatures in April may explain the decrease in value to 80.4% for LRWC in juvenile leaves. LRWC correlates closely with a plant's physiological activities and soil water status, and is a reliable trait, e.g., for screening for drought tolerance of different genotypes [69]. It is a sensitive variable, which quickly responds to environmental conditions such as temperature, light, humidity, and water supply. Some researchers believe that LRWC is higher in the initial stages of leaf development and declines as dry matter accumulates and the leaf matures [70].

In the present study, the highest succulence was found in scapes and decreased in the following order: scape > leaf > root. This parameter is interpreted as providing a measure of water stored per gram carbon expenditure on the part of the plant [46]. In larger-scale comparative studies, succulence is treated as a discrete characteristic. However, it has clear ecophysiological implications [71,72].

In this study, SLA of old leaves is generally lower than SLA of young leaves. Lower SLA contributes to long leaf survival, nutrient retention, and protection from desiccation. In fall, lower SLA is associated with higher leaf dry-matter content. Lower SLA is a consequence of an increase in the density of foliar tissue [73]. In spring, higher SLA is associated with lower concentrations of phenolic compounds, including lignin [74]. The decrease is at least partly caused by the accumulation of secondary compounds like lignin or other phenolics. A decrease in SLA may also occur in response to drought in herbaceous leaves as a result of an increased investment in structural tissues, allowing increased resistance to adverse environmental conditions [75]. SLA declines along the gradients of decreasing moisture and/or nutrient availability [76]. Water status during leaf development has been identified as an important factor influencing SLA of mature leaves [77]. SLA is frequently used in growth analysis as it is often positively related to the relative growth rate [78]. SLA is a measure of density and, therefore, the health of individual leaves is often used for assessing growth [79,80]. *Taraxacum officinale* plants have a greater aboveground surface area coupled with a greater capacity to extract water from the soil [81].

Leaf is considered the most sensitive organ and can easily change its morphology and anatomy to adapt to the existing conditions. Nevertheless, in our study, variations in the investigated parameters of roots and scapes are more associated with meteorological factors. Plants react simultaneously to a combination of climate factors. The same meteorological factor may have different influences depending on the season. In our analysis, the values of minimum temperature were generally more significant than values of maximum and mean temperature. The strongest association was generally found with the wind. It seems that in natural conditions, profiles of temperature and humidity are much less important for photosynthesis and transpiration than profiles of wind [82]. It is possible that other meteorological factors which were not measured in the present study may have some influence on physiological parameters. Likewise, non-climatic parameters such as soil type or nutrient supply can also affect phenological appearance in the urban habitat [83]. Moreover, a plant's phenology is affected by its genotype and age, as well as by the presence of other plant species [84]. On the other hand, it has been suggested that plants in closely mowed areas devote a lot of their energy to seed production (r-strategist), and those located in less frequently mowed areas devote more energy to vegetative reproduction (k-strategist) [85]. These plants allocate 24% of their net production to seed production and only 13% percent to vegetative reproduction. Furthermore, in the urban environment, establishment and performance of herbaceous vegetation depend on the cutting height and frequency [86].

Several studies on *T. officinale* have examined the general rhythm of flowering, seasonal variation in flowering, environmental factors which control the opening and closing of the inflorescence and seed reproduction [87]. It is known that inflorescences of *T. officinale* demonstrate thermonasty and photonasty [35]. A decrease in temperature is usually connected with rainfall and can even stop blooming. The capitulum of *T. officinale* is reopened up to four times. Generally, an increase in relative humidity and decrease in temperature result in inflorescence and/or flower closing [88]. Long-term studies have proven that it is mostly temperature that influences the process of flower opening. However, nutrients can also modulate flowering time [89]. During anthesis, the production of flowers is a likely major metabolic sink for photosynthates. Expressions of plant traits are constrained by other traits, according to the patterns of resource allocation among the organs of an individual plant. Flowering time in natural populations might primarily be determined by environmentally induced phenotypic plasticity.

Our results show that *T. officinale* plants bloom throughout the year in different seasonal conditions. Plants tolerate a wide range of temperatures. In urban areas in proximity to a high-traffic road, the plants are resistant and show phenotypic plasticity. Short sampling durations provide only a snapshot of physiological parameters. Obviously, it is necessary to investigate multiannual dynamic, which can conclusively illustrate correlations with environmental factors. All in all, the present study reveals important differences in *T. officinale* properties throughout the various seasons in the urban habitat. These plants can serve as indicator of how well the urban environment is doing.

Conclusions

Taraxacum officinale is a highly successful weed which grows profusely in urban landscapes and colonizes diverse urban habitats. These plants exhibit exhibits seasonal variations in physiological traits. Several of these differences (the highest initial water content was found in scapes; leaves had a higher mineral content, and tissues – a higher mineral deposition; roots had the highest density of tissues) result from adaptive responses to seasonal changes. In our study, variations in the investigated parameters of roots and scapes are more associated with meteorological factors. It could be speculated that a particular pattern of variation in meteorological factors in the urban habitat, with decreasing and increasing trends during the seasons, determines phenotypic responses to physiological traits. *Taraxacum officinale* can serve as an important indicator of the quality of the urban habitat.

References

1. Akbari H, Pomerantz M, Taha H. Cool surfaces and shade trees to reduce energy use and improve air quality in urban areas. Sol Energy. 2001;70:295–310. http://dx.doi.org/10.1016/S0038-092X(00)00089-X
2. Mayer H, Kuppe S, Holst J, Imbery F, Matzarakis A. Human thermal comfort below the canopy of street trees on a typical Central European summer day. Berichte des Meteorologischen Instituts der Albert-Ludwigs-Universität Freiburg. 2009;18:211–219.
3. Shashua-Bar L, Potcher O, Bitan A, Boltansky D, Yaakov Y. Microclimate modelling of street tree species effects within the varied urban morphology in the Mediterranean city of Tel Aviv, Israel. Int J Climatol. 2010;30(1):44–57.
4. Nowak DJ, Crane DE. Carbon storage and sequestration by urban trees in the USA. Environ Pollut. 2002;116:381–389. http://dx.doi.org/10.1016/S0269-7491(01)00214-7
5. Chen WY, Jim CY. Assessing the ecosystem service of air pollutant removal by urban trees in Guangzhou (China). J Environ Manage. 2008;88(4):665–676. http://dx.doi.org/10.1016/j.jenvman.2007.03.035
6. Buccolieri R, Gromke C, Silvana S, Ruck B. Aerodynamic effects of trees on pollutant concentration in street canyons. Sci Total Environ. 2009;407(19):5247–5256. http://dx.doi.org/10.1016/j.scitotenv.2009.06.016
7. Clayden A, Jorgesen A, Stovin R. Street trees and stormwater management. The International Journal of Forestry. 2008;30(4):297–310.
8. Lovasi GS, Quinn JW, Neckerman KM, Perzanowski MS, Rundle A. Children living in areas with more street trees have lower prevalence of asthma. J Epidemiol Community Health. 2008;62:647–649. http://dx.doi.org/10.1136/jech.2007.071894
9. Price C. Quantifying the aesthetic benefits of urban forestry. Urban Forestry and Urban Greening. 2003;1(3):123–133. http://dx.doi.org/10.1078/1618-8667-00013
10. Tsiros IX. Assessment and energy implications of street air temperature cooling by shadetress in Athens (Greece) under extremely hot weather conditions. Renewable Engery. 2010;35(8): 1866–1869. http://dx.doi.org/10.1016/j.renene.2009.12.021
11. Robinson SL, Lundholm JT. Ecosystem services provided by urban spontaneous vegetation. Urban Ecosyst. 2012;15:545–557. http://dx.doi.org/10.1007/s11252-012-0225-8
12. de Groot RS, Wilson MA, Boumans RMJ. A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecol Econ. 2002;41:393–408. http://dx.doi.org/10.1016/S0921-8009(02)00089-7
13. Nowak DJ, Kuroda M, Crane DE. Tree mortality rates and tree population projections in Baltimore, Maryland, USA. Urban Forestry and Urban Greening. 2004;2(3):139–147. http://dx.doi.org/10.1078/1618-8667-00030
14. Zhu W, Hope D, Gries C, Grimm NB. Soil characteristics and the accumulation of inorganic nitrogen in an arid urban ecosystem. Ecosystems. 2006;9:711–724. http://dx.doi.org/10.1007/s10021-006-0078-1
15. Park S, Cheng Z, Yang H, Morris EE, Sutherland M, McSpadden Gardener BB, et al. Soil chemical properties vary with distance to roads and age of urban development. Urban Ecosystems. 2010;13:483–497. http://dx.doi.org/10.1007/s11252-010-0130-y
16. Shannon MC. Adaptation of plants to salinity. Advances in Agronomy. 1997;60:75–120. http://dx.doi.org/10.1016/S0065-2113(08)60601-X
17. Ianovici N, Novac ID, Vlădoiu D, Bijan A, Ionaşcu A, Sălăşan B, Rămuş I. Biomonitoring of urban habitat quality by anatomical leaf parameters in Timişoara. Annals of West University of Timişoara, series of Biology. 2009;12:73–86.
18. Pinheiro C, Chaves MM. Photosynthesis and drought: can we make metabolic connections from available data? J Exp Bot. 2011;62:869–882. http://dx.doi.org/10.1093/jxb/erq340
19. Črepinšek Z, Kajfež-Bogataj L, Bergant K. Modelling of weather variability effect on fitophenology. Ecol Modell. 2006;194:256–265. http://dx.doi.org/10.1016/j.ecolmodel.2005.10.020
20. Menzel A. Trends in phenological phases in Europe between 1951 and 1996. Int J Biometeorol. 2000;44(2):76–81. http://dx.doi.org/10.1007/s004840000054
21. Wiegolaski FE. Starting dates and basic temperatures in phenological observations of plants. Int J Biometeorol. 1999;42(3):158–168. http://dx.doi.org/10.1007/s004840050100
22. Boddy L, Buntgen U, Egli S, Gange AC, Heegaard E, Kirk PM, et al. Climate

variation effects on fungal fruiting. Fungal Ecol. 2014;10:20–33. http://dx.doi.org/10.1016/j.funeco.2013.10.006

23. Stewart-Wade SM, Neumann S, Collins LL, Boland GJ. The biology of Canadian weeds. 117. *Taraxacum officinale* G. H. Weber ex Wiggers. Can J Plant Sci. 2002;82:825–853. http://dx.doi.org/10.4141/P01-010
24. Petrova S, Yurukova L, Velcheva I. *Taraxacum officinale* as a biomonitor of metals and toxic elements (Plovdiv, Bulgaria). Bulgarian Journal of Agricultural Science. 2013;19(2):241–247.
25. Ligocki M, Tarasewicz Z, Zygmunt A, Mieczysław A. The common dandelion (*Taraxacum officinale*) as an indicator of anthropogenic toxic metal pollution of environment. Acta Scientiarum Polonorum Zootechnica. 2011;10(4):73–82.
26. Kovac P, Turcsanyi G, Penksza K, Kaszab L, Szöke P. Heavy metal accumulation by ruderal and cultivated plants in a heavily polluted district of Budapest. In: Markert B, editor. Plants as biomonitors – indicators for heavy metal in terrestrial environment. Weinheim: VCH; 1993.
27. Bini C, Wahsha M, Fontana S, Maleci L. Effects of heavy metals on morphological characteristics of *Taraxacum officinale* Web growing on mine soils in NE Italy. J Geochem Explor. 2012;123:101–108. http://dx.doi.org/10.1016/j.gexplo.2012.07.009
28. Kleckerová A, Dočekalová H. Dandelion plants as a biomonitor of urban area contamination by heavy metals. Int J Environ Res. 2014;8(1):157–164.
29. Rosselli W, Rossi M, Sasu I. Cd, Cu and Zn contents in the leaves of *Taraxacum officinale*. Forest Snow and Landscape Research. 2006;80(3):361–366.
30. Breuste LH. Investigations of the urban street tree forest of Mendoza, Argentina. Urban Ecosyst. 2013;16:801–818. http://dx.doi.org/10.1007/s11252-012-0255-2
31. Ianovici N. Histoanatomical and ecophysiological studies on some halophytes from Romania – *Plantago maritima*. Annals of West University of Timişoara, series of Biology. 2011;14:1–14.
32. Fernández-García N, Olmos E, Bardisi E, García de la Garma J, López-Berenguer C, Rubio-Asensio JS. Intrinsic water use efficiency controls the adaptation to high salinity in a semi-arid adapted plant, henna (*Lawsonia inermis* L.). J Plant Physiol. 2014;(5):64–75. http://dx.doi.org/10.1016/j.jplph.2013.11.004
33. Liu P, Yin L, Deng X, Wang S, Tanaka K, Zhang S. Aquaporin-mediated increase in root hydraulic conductance is involved in silicon-induced improved root water uptake under osmotic stress in *Sorghum bicolor* L. J Exp Bot. 2014;65(17):4747–4756. http://dx.doi.org/10.1093/jxb/eru220
34. Thameur A, Ferchichi A, López-Carbonell M. Involvement of abscisic acid metabolites and the oxidative status of barley genotypes in response to drought. Can J Plant Sci. 2014;94(8):1481–1490. http://dx.doi.org/10.4141/cjps-2014-069
35. Grudnicki M, Ianovici N. Noțiuni teoretice și practice de Fiziologie vegetală. Timişoara: Mirton; 2014.
36. Ianovici N, Vereș M, Catrina RG, Pîrvulescu AM, Tănase RM, Datcu DA. Methods of biomonitoring in urban environment: leaf area and fractal dimension. Annals of West University of Timişoara, series of Biology. 2015;18(2):169–178.
37. Ianovici N, Birsan MV, Tudorică D, Balița A. Fagales pollen in the atmosphere of Timisoara, Romania (2000–2007). Annals of West University of Timişoara, series of Biology. 2013;16(2):115–134.
38. Ianovici N, Maria C, Răduțoiu MN, Haniş A, Tudorică D. Variation in airborne fungal spore concentrations in four different microclimate regions in Romania. Not Bot Horti Agrobot Cluj Napoca. 2013;41(2):450–457.
39. Vetres I, Calinoiu DG, Ionel I, Brochet F. Modelling as instrument for air quality assesment. Timisoara case study. Termotehnica. 2014;1:59–63.
40. Ianovici N, Panaitescu Bunu C, Brudiu I. Analysis of airborne allergenic pollen spectrum for 2009 in Timişoara, Romania. Aerobiologia. 2013;29(1):95–111. http://dx.doi.org/10.1007/s10453-012-9266-y
41. Gier LJ, Burress RM. Anatomy of *Taraxacum officinale* 'Weber'. Trans Kans Acad Sci. 1942;45:94–97. http://dx.doi.org/10.2307/3624987
42. Degórska A. An assessment of urban habitat contamination with selected heavy metals within the city of Katowice using the common dandelion (*Taraxacum officinale* Web.) as a

bioindicator. Environmental and Socio-economic Studies. 2013;1(4):29–40. http://dx.doi.org/10.1515/environ-2015-0021

43. Cogger CG. Potential compost benefits for restoration of soils disturbed by urban development. Compost Sci Util. 2005;13:243–251. http://dx.doi.org/10.1080/1065657X.2005.10702248
44. Petersen EJ, Jennings AA, Ma J. Screening level risk assessment of heavy metal contamination in Cleveland area commons. J Environ Eng (New York). 2006;132:392. http://dx.doi.org/10.1061/(ASCE)0733-9372(2006)132:3(392)
45. Ianovici N, Ciocan GV, Matica A, Scurtu M, Şesan TE. Study on the infestation by *Cameraria ohridella* on *Aesculus hippocastanum* foliage from Timisoara, Romania. Annals of West University of Timişoara, series of Biology. 2012;15(1):67–80.
46. von Willert DJ, Eller BM, Werger MJA, Brinckmann E. Desert succulents and their life strategies. Vegetatio. 1990;90:133–143. http://dx.doi.org/10.1007/BF00033023
47. Cornelissen JHC, Lavorel S, Garnier E, Díaz SM, Buchmann N, Gurvich DE, et al. A handbook of protocols for standardised and easy measurement of plant functional traits worldwide. Aust J Bot. 2003;51(4):335–380. http://dx.doi.org/10.1071/BT02124
48. Ianovici N. Approaches on the invasive alien taxa in Romania – *Ambrosia artemisiifolia* (ragweed) II. Annals of West University of Timişoara, series of Biology. 2011;14:93–112.
49. Molina-Montenegro MA, Atala C, Gianoli E. Phenotypic plasticity and performance of *Taraxacum officinale* (dandelion) in habitats of contrasting environmental heterogeneity. Biol Invasions. 2010;12:2277–2284. http://dx.doi.org/10.1007/s10530-009-9638-6
50. Pavlović-Muratspahić D, Stanković M, Branković S. Taxonomical analysis of ruderal flora (sensu stricto) in area of the city of Kragujevac. Kragujevac Journal of Science. 2010;32:101–108.
51. Erofeeva EA. Dependence of dandelion (*Taraxacum officinale* Wigg.) seed reproduction indices on intensity of motor traffic pollution. Dose Response. 2014;12(4):540–550. http://dx.doi.org/10.2203/dose-response.14-009.Erofeeva
52. Arathi HS. A Comparison of dispersal traits in dandelions growing in urban landscape and open meadows. J Plant Stud. 2012;1(2):40–46. http://dx.doi.org/10.5539/jps.v1n2p40
53. Balasooriya BIWK, Samson R, Mbikwa F, Vitharana UWA, Boeckx P, van Meirvenne M. Biomonitoring of urban habitat by anatomical and chemical leaf characteristics. Environ Exp Bot. 2009;65(2–3):386–394. http://dx.doi.org/10.1016/j.envexpbot.2008.11.009
54. Roberts MJ, Long SP, Tieszen LL, Beadle CL. Measurement of plant biomass and net primary production of herbaceous vegetation. In: Hall DO, Scurlock HR, Bolhar-Nordenkampf HR, Leegood RC, Long SP, editors. Photosythesis and production in a changing environment. London: Chapman & Hall; 1993. p. 1–20.
55. Garnier E, Shipley B, Roumet C, Laurent G. A standardized protocol for the determination of specific leaf area and leaf dry matter content. Funct Ecol. 2001;15:688–695. http://dx.doi.org/10.1046/j.0269-8463.2001.00563.x
56. Grime JP, Thompson K, Hunt R, Hodgson JG, Cornelissen JH, Rorison IH, et al. Integrated screening validates primary axes of specialization in plants. Oikos. 1997;79:259–281. http://dx.doi.org/10.2307/3546011
57. Ryser P, Urbas P. Ecological significance of leaf life span among Central European grass species. Oikos. 2000;91:41–50. http://dx.doi.org/10.1034/j.1600-0706.2000.910104.x
58. Rohde A, Bhalerao RP. Plant dormancy in the perennial context. Trends Plant Sci. 2007;12:217–223. http://dx.doi.org/10.1016/j.tplants.2007.03.012
59. Ennajeh M, Vadel AM, Cochard HH, Khemira H. Structural adaptations to drought in olive leaves. J Hortic Sci Biotechnol. 2010;85(4):289–294. http://dx.doi.org/10.1080/14620316.2010.11512670
60. Sierra-Almeida A, Cavieres LA, Bravo LA. Freezing resistance varies within the growing season and with elevation in high-Andean species of central Chile. New Phytol. 2009;182:461–469. http://dx.doi.org/10.1111/j.1469-8137.2008.02756.x
61. Tsialtas JT, Handley LL, Kassioumi MT, Veresoglou DS, Gagianas AA. Interspecific variation in potential water-use efficiency and its relation to plant species abundance in a water-limited grassland. Funct Ecol. 2001;15:605–614. http://dx.doi.org/10.1046/j.0269-8463.2001.00555.x
62. Johnstone D, Moore G, Tausz M, Nicolas M. The measurement of plant vitality in landscape trees. Arboricultural Journal. 2013;35(1):18–27. http://dx.doi.org/10.1080/03071375.2013.783746

63. Dong QM, Zhao XQ, Ma YS. Effects of *Bos gunnens* grazing in warm season on forage digestibility. Chinese Joumal of Ecology. 2007;26(11):1171–1776.

64. Korth KL, Doege SJ, Park SH, Goggin FL, Wang Q, Gomez SK, et al. *Medicago truncatula* mutants demonstrate the role of plant calcium oxalate crystals as an effective defense against chewing insects. Plant Physiol. 2006;141:188–195. http://dx.doi.org/10.1104/pp.106.076737

65. Zheng H, Li X, Wang Y, Yin X, Yan Q, Chen Y. Nutrient status and dynamics of *Trifolium* spp. at different growing stages. Journal of Northeast Agricultural University. 2013;20(3):6–11. http://dx.doi.org/10.1016/S1006-8104(14)60002-7

66. Monneveux P, Reynolds MP, Trethowan R, Peña J, Zapata F. Carbon isotope discrimination, leaf ash content and grain yield in bread and durum wheat grown under full-irrigated conditions. Journal of Agronomy and Crop Science. 2004;190:389–394. http://dx.doi.org/10.1111/j.1439-037X.2004.00115.x

67. Stratton L, Goldstein G, Meinzer FC. Stem water storage capacity and efficiency of water transport: their functional significance in a Hawaiian dry forest. Plant Cell Environ. 2000;23:99–106. http://dx.doi.org/10.1046/j.1365-3040.2000.00533.x

68. Hossain AA, Halim MA, Hossain F, Maher Niger MA. Effect of NaCl salinity on some physiological characters of wheat (*Triticum aestivum* L.). Bangladesh Journal of Botany. 2006;35(1):9–15.

69. Ozkur O, Ozdemir F, Bor M, Turkan I. Physiochemical and antioxidant responses of the perennial xerophyte *Capparis ovate* Desf. to drought. Environ Exp Bot. 2009;66(3):487–492. http://dx.doi.org/10.1016/j.envexpbot.2009.04.003

70. Anjum S, Xie X, Wang L, Saleem N, Man C, Lei W. Morphological, physiological and biochemical responses of plants to drought stress. Afr J Agric Res. 2011;6(9):2026–2032.

71. Mantovani AA. Method to improve leaf succulence quantification. Brazilian Archives of Biology and Technology. 1999;41(1):9–14. http://dx.doi.org/10.1590/s1516-89131999000100002

72. Ogburn RM, Edwards EJ. Anatomical variation in Cactaceae and relatives: trait lability and evolutionary innovation. Am J Bot. 2009;96:391–408. http://dx.doi.org/10.3732/ajb.0800142

73. Centritto M. Interactive effects of elevated (CO_2) and drought on peach seedlings. Plant Biosyst. 2002;5:177–188. http://dx.doi.org/10.1080/11263500212331351079

74. Lambers H, Poorter H. Inherent variation in growth rate between higher plants: a search for physiological causes and ecological consequences. Adv Ecol Res. 1992;23:187–261. http://dx.doi.org/10.1016/S0065-2504(08)60148-8

75. Maroco JP, Pereira JS, Chaves MM. Growth, photosynthesis and water-use efficiency of two C_4 Sahelian grasses subjected to water deficits. J Arid Environ. 2000;45:119–137. http://dx.doi.org/10.1006/jare.2000.0638

76. Ackerly DD, Knight CA, Weiss SB, Barton K, Starmer KP. Leaf size, specific leaf area and microhabitat distribution of chaparral woody plants: contrasting patterns in species level and community level analyses. Oecologia. 2002;130(3):449–457. http://dx.doi.org/10.1007/s004420100805

77. Niinemets U. Photosynthesis and resource distribution through plant canopies. Plant Cell Environ. 2007;30:1051–1071. http://dx.doi.org/10.1111/j.1365-3040.2007.01683.x

78. Laclau JP, Almeida JCR, Gonc Alves JLM, Saint-Andre L, Ventura M, Ranger J, et al. Influence of nitrogen and potassium fertilization on leaf lifespan and allocation of above-ground growth in Eucalyptus plantations. Tree Physiol. 2009;29:111–124. http://dx.doi.org/10.1093/treephys/tpn010

79. Calvo-Alvarado J, McDowell N, Waring R. Allometric relationships predicting foliar biomass and leaf area: sapwood area ratio from tree height in five Costa Rican rain forest species. Tree Physiol. 2008;28(11):1601–1608. http://dx.doi.org/10.1093/treephys/28.11.1601

80. Gotsch SG, Geiger EL, Franco AC, Goldstein G, Meinzer FC, Hoffmann WA. Allocation to leaf area and sapwood area affects water relations of co-occurring savanna and forest trees. Oecologia. 2010;163(2):291–301. http://dx.doi.org/10.1007/s00442-009-1543-2

81. Brock MT, Weinig C, Galen C. A comparison of phenotypic plasticity in the native dandelion, *Taraxacum ceratophorum* and its invasive congener, *T. officinale*. New Phytol. 2005;166:173–183. http://dx.doi.org/10.1111/j.1469-8137.2004.01300.x

82. Goudriaan J, van Kraalingen DWG, Ephrath JE. Microweather simulation and its simplification for including transpiration in a crop growth model. In: Kabat P, Marshall B, van den

Broek BJ, Vos J, van Keulen H, editors. Modelling and parameterization of the soil-plant-atmosphere system: a comparison of potato growth models. Wageningen: Wageningen Pers; 1995. p. 39–55.

83. Wielgolaski FE. Phenological modifications in plants by various edaphic factors. Int J Biometeorol. 2001;45:196–202. http://dx.doi.org/10.1007/s004840100100
84. Chmielewski FM, Rotzer T. Response of tree phenology to climate change across Europe. Agric For Meteorol. 2001;108:101–112. http://dx.doi.org/10.1016/S0168-1923(01)00233-7
85. Bostock S, Benton R. The reproduction strategies of five perennial Compositae. J Ecol. 1979;67:91–107. http://dx.doi.org/10.2307/2259339
86. Mølgaard P. Competitive effect of grass on establishment and performance of *Taraxacum officinale*. Oikos. 1977;29(2):376–382. http://dx.doi.org/10.2307/3543629
87. Collier MH, Rogstad SH. Clonal variation in floral stage timing in the common dandelion *Taraxacum officinale* (Asteraceae). Am J Bot. 2004;91(11):1828–1833. http://dx.doi.org/10.3732/ajb.91.11.1828
88. Denisow B. Factors determining the diurnal dynamics of blooming of chosen plant species. Acta Agrobot. 2009;62(1):83–89. http://dx.doi.org/10.5586/aa.2009.010
89. Ausin I, Alonso-Blanco C, Zapater M. Environmental regulation of flowering. Int J Dev Biol. 2005;49:689–705. http://dx.doi.org/10.1387/ijdb.052022ia

Taraxacum officinale (Asteraceae) w środowisku miejskim: sezonowe fluktuacje cech roślin oraz ich związek z czynnikami meteorologicznymi

Streszczenie

Rośliny mogą być wykorzystane jako użyteczne bioindykatory jakości środowiska miejskiego. W przedstawionej pracy badano cechy fizjologiczne roślin *Taraxacum officinale* rosnących na terenie nieużytków miejskich, w pobliżu drogi, bez osłon, w różnych porach roku (zima, wiosna, lato, jesień). Cały materiał zbierano z roślin bujnych, dobrze wyrośniętych. Wszystkie pomiary wykonano w fazie rozwoju generatywnego. Oznaczono niektóre parametry wagowe (świeża masa, masa w stanie turgoru, sucha masa, zawartość wody, zawartość popiołu) i fizjologiczne (zawartość wody początkowa, zawartość związków mineralnych, zawartość związków organicznych, stosunek zawartości związków organicznych do mineralnych, soczystość, odkładanie związków mineralnych w tkankach, gęstość tkanek, względna zawartość wody w liściach, powierzchnia właściwa liścia). Do porównania cech liści, kwiatostanów i korzeni wykorzystano jednoczynnikową analizę wariancji (ANOVA). Zawartość wody początkowa i względna zawartość wody były dobrymi wskaźnikami stanu uwodnienia u *T. officinale*. Poziom uwodnienia był ogólnie wyraźnie niższy w korzeniach niż w organach nadziemnych. Organy istotnie różniły się pod względem zawartości związków mineralnych. Dla wszystkich analizowanych parametrów największe różnice pomiędzy porami roku stwierdzono w liściach. Obliczono korelacje Spearmana dla zależności pomiędzy cechami. Najbardziej wrażliwą cechą, niezależnie od organu, okazało się odkładanie związków mineralnych w tkankach. Poddano analizie metodą korelacji Spearmana i regresji liniowej zależności pomiędzy wszystkimi parametrami fizjologicznymi i czynnikami meteorologicznymi. Ogólnie, stwierdzono najsilniejszą zależność badanych cech roślin od siły wiatru. Różnice w badanych parametrach korzeni i kwiatostanów są bardziej związane z czynnikami meteorologicznymi. Rośliny *T. officinale* są w stanie tolerować warunki miejskie w sąsiedztwie dróg. Plastyczne odpowiedzi na bodźce środowiskowe sprawiają, że gatunek ten jest przydatny w biomonitoringu jakości siedliska miejskiego.