Frontiers in Life Sciences and Related Technologies 4(3) (2023) 150-156

Contents lists available at Dergipark

Frontiers in Life Sciences and Related Technologies

Journal homepage: http://dergipark.org.tr/en/pub/flsrt

Research article

Antioxidant activities of plant species growing in different habitats (serpentine, gypsum and limestone)

Tugce Varol[1], Etem Osma[*2], Samed Simsek[3], Mujgan Elveren[4]

[1] *Erzincan Binali Yıldırım University, Institute of Natural and Applied Sciences, 24100, Erzincan, Türkiye*
[2] *Erzincan Binali Yıldırım University, Faculty of Sciences and Arts, Department of Biology, 24100, Erzincan, Türkiye*
[3] *Erzincan Binali Yıldırım University, Çayırlı Vocational School, Medical Services and Techniques Department, 24503, Erzincan, Türkiye*
[4] *Erzincan Binali Yıldırım University, Vocational School of Health Services, Medical Services and Techniques Department, 24036, Erzincan, Türkiye*

Abstract

In this study, plant species (gypsum, limestone, and serpentine) growing in different habitats in Erzincan province were investigated. Gypsum [*Verbascum alyssifolium* Boiss., *Tanacetum heterotomum* (Bornm.) Grierson, *Psephellus recepii* Wagenitz & Kandemir, *Gypsophila lepidioides* Boiss.], limestone [*Cyclotrichium niveum* (Boiss.) Manden. & Scheng, *Chrysophthalmum montanum* (DC.) Boiss, *Teucrium leucophyllum* Montbret & Aucher ex Bentham, *Phlomis oppositiflora* Boiss. & Hausskn] serpentine [*Fumana aciphylla* Boiss., *Convolvulus pseudoscammania* C. Koch., *Hypericum thymbrifolium* Boiss & Noé, *Salvia indica* L., *Gladiolus halophilus* Boiss. & Heldr.] were examined. The total phenolic contents (TPC), total flavonoid content (TFC), and the amount of antioxidant activity (DPPH, FRAP) were analyzed in different organs of the plants, including leaves, branches, and roots. According to the obtained data, when plant parts and habitats were taken into consideration, it was observed that the plant with the highest flavonoid content (29.71±0.57 mg QE g^{-1} extract) was *S. indica* growing in the serpentine area with its leaf parts. In terms of total phenolic content, it was determined that the root part of *S. indica* growing in the serpentine area had high values (91.53±2.48 mg GAE g^{-1} extract value). When evaluated in terms of the Iron (III) Ion Reducing Antioxidant Power (FRAP) method, it was observed that the highest value was the stem part of *F. aciphylla* growing in a serpentine area (100.35±1.60 mg TE g^{-1}). In terms of DPPH radical capacity, the highest value belonged to the leaf part of *Salvia indica* (15.75±1.74 µg mL^{-1}), which is also grown in the serpentine area. The results were evaluated utilizing the SPSS Statistical Program and differences were observed between habitats. A strong correlation was found between the phenolic and flavonoid contents of plants and their antioxidant activities. The findings showed that the phenolic, flavonoid content, and antioxidant activities of plants grown in different ecological conditions vary significantly.

Keywords: *DPPH; flavonoid; gypsum; limestone; phenolic; serpentine*

1. Introduction

Antioxidants are the first compounds to protect plants against free radicals. These compounds are not stable or active before free radicals attack cells (Percival, 1996; Saffaryazdi et al., 2020). Phenolic compounds are natural and complex containing antioxidants, flavonoids (anthocyanin, flavones, flavonols, and isoflavonoids), and commonly found tannins (Gentile et al., 2018; Williamson et al., 2018; Guven et al., 2019; Shen et al., 2022). Plants synthesize organic compounds such as

* Corresponding author.
E-mail address: eosma@erzincan.edu.tr (E. Osma).
https://doi.org/10.51753/flsrt.1357325 Author contributions
Received 08 September 2023; Accepted 22 November 2023
Available online 30 December 2023

tocopherol, flavonoid, phenolic compound, alkaloid, chlorophyll, polyfunctional organic acid, and carotene during their vital activities (Larson, 1988; Ergun, 2021). Phenolic compounds, defined as secondary metabolites, undertake the task of combating pests and shielding against external effects, as well as vital activities such as growth and reproduction in plants. The aroma and odor properties of plants are also due to phenolic compounds in the form of essential oil. In addition, these compounds are very important in determining the antioxidant capacity of the plant (Ergun, 2021; Ozyigit et al., 2023). In plants, these metabolites are affected by internal and environmental dynamics such as climate, soil, and genetics (Mikulajová et al., 2016; Tajik et al., 2019).

Türkiye is one of the richest countries in the temperate zone in terms of biodiversity, especially of floral diversity and endemism. Floristic diversity reflects the ecosystem and edaphic, climatic, topographic, and geological diversity. The contribution of edaphic diversity to biodiversity is considerable and important endemism in Türkiye is widely seen in serpentine, gypsum, or salty soils (Ozdeniz et al., 2017).

Rock and silicate minerals containing high amounts of Mg, Fe, and mafic minerals are olivine, pyroxene, and ultramafic rock (such as gabbro, basalt, and peridotite) while those containing <45% silica (SiO_2) are called ultrabasic rocks. The formation of serpentine by the reaction of olivine, the main mantle material, with water is called "serpentinization"/coiling. Soils containing serpentine are formed by the erosion of ultramafic rocks. At least 70% of these igneous or metamorphic rocks are composed of ferromagnesian or mafic (magnesium+ferric-mafic-) minerals (Kruckeberg, 2002; Ozdeniz et al., 2017).

Gypsum is in the form of calcium sulfate ($Ca_2SO_4.2H_2O$) containing water in crystalline form or anhydrite ($CaSO_4$) containing no water (Van Alphen et al., 1971; Herrero and Porta, 2000; Ozdeniz et al., 2016). When embedded at depths of several hundred meters, gypsum loses its water and turns into anhydrite. The solubility of gypsum is 2.6 gr/l at 25°C (Verheye and Boyadgiev, 1997; Ozdeniz et al., 2016).

While it can dissolve quickly in humid and rainy climates, in arid climates the rock may appear in the form of crystals with sand grains or the form of smaller and softer crystals (Ozdeniz et al., 2016). The efficiency of secondary metabolites is very important in the adaptation process of plants unique to these habitats since gypsum and serpentine soils have intemperate conditions (Politycka and Adamska, 2003). This study aimed to determine the effects of different habitats on antioxidant concentrations in plants.

2. Materials and methods

In this study, DPPH, total phenolic contents (TPC), flavonoids (TFC), and FRAP concentrations were determined in leaves, branches, and roots of plants grown in different habitats. The completely white and crystallized areas at the 3rd km to Kemah-İlic highway towards Yahşiler Village, the limestone rocks of Kocacimen Village (Kemaliye) and Eric Village (Kemah), and the serpentine regions around Yucebelen Village (Kemah) are the sampling areas (Fig. 1.).

In the present research, plant species specific to serpentine, gypsum, and limestone habitats were selected. Gypsum [*G. lepidioides* Boiss., *P. recepii* Wagenitz & Kandemir, *T. heterotomum* (Bornm.) Grierson, *V. alyssifolium* Boiss.], limestone [*C. montanum* (DC.) Boiss, *C. niveum* (Boiss.) Manden. & Scheng, *P. oppositiflora* Boiss. & Hausskn, *T. leucophyllum* Montbret & Aucher ex Bentham] serpentine [*C. pseudoscammania* C. Koch., *F. aciphylla* Boiss., *G. halophilus* Boiss. & Heldr., *H. thymbrifolium* Boiss & Noé, *S. indica* L.] native to their habitat were collected in an amount to represent the area where they bloom.

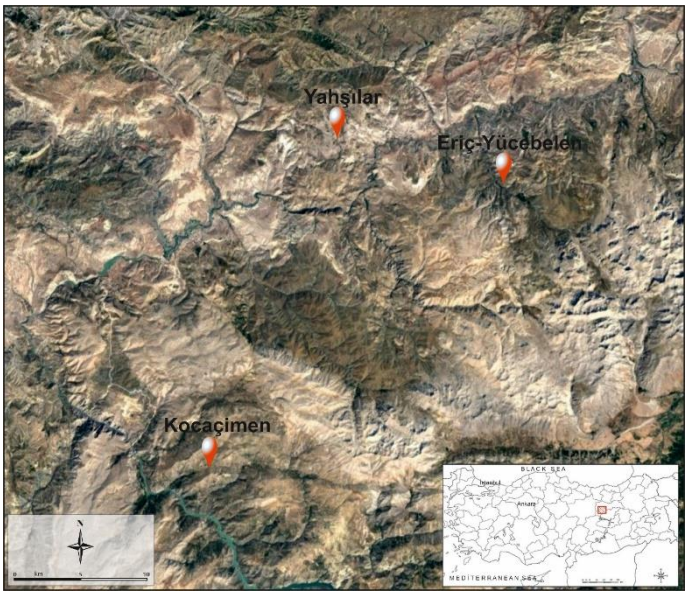

Fig. 1. Study areas.

2.1. DPPH free radical scavenging activity

The free radical scavenging activity of the extracts was determined using the method of Blois (1958), modified slightly. DPPH (2,2-diphenyl-1-picrylhydrazyl) solution was dissolved with methanol at a concentration of 0.26 mM. For the test, stock solutions (1 mg/ml) were prepared of the extracts and standards. Concentrations of 20, 40, 100, 200, 300, 400, 800, and 1000 µg/ml were prepared from the stock solutions, and the final volume was completed to 3 ml with methanol, followed by the addition of 1 ml of DPPH solution. The mixture was vortexed and incubated for 30 minutes in the dark at room temperature. At the end of this period, each mixture's absorbance was measured at 517 nm, and the results were converted to % activity. Each extract's IC_{50} (µg/ml) was determined, and the findings were compared to Trolox, the standard antioxidant.

2.2. Iron (III) ion reducing antioxidant power method (FRAP)

The reducing power activity assay of plant materials was carried out with some modifications using the method developed by Oyaizu (1986). For the test, stock solutions (1 mg/ml) were prepared of the extracts and standards. 100 µl of the prepared stock solutions were placed into test tubes, and the volume was diluted to 1.25 ml using phosphate buffer (0.2 M, pH 6.6). This mixture was incubated at 50°C for 20 minutes after 1.25 ml of potassium ferric cyanide [$K_3Fe(CN)_6$] (1%) was added. Then, the absorbance of the final mixture was measured at 700 nm following the addition of 1.25 ml of 10% trichloroacetic acid (TCA) and 0.25 ml of 0.1% $FeCl_3$ solutions to the reaction medium. The results were given as mg TE/g extract using the calibration curve created from varied concentrations of Trolox used as a standard (Murathan and Ozdinc, 2018).

2.3. Determination of total phenolic content

The Folin-Ciocalteu method was used to determine total phenolic content (Singleton et al., 1999). For this purpose, 100 µl Folin-Ciocalteu, 4.5 mL of distilled water, and 300 µl (2%) Na_2CO_3 were added to 100 µl of the sample stock solutions at 1 mg/ml concentrations. After 2 hours of incubation at room temperature, the total phenolics content was measured in a spectrophotometer at 760 nm (Unico, S1205). The total phenolic content of the samples was measured as mg gallic acid equivalent to phenolic substance/g extract (Murathan and Ozdinc, 2018).

2.4. Determination of total flavonoid content

The total flavonoid content was determined using the method developed by Chang et al. (2002). 4.7 mL of methanol was added to test tubes containing 100 µL of the sample stock solutions prepared with methanol at 1 mg/ml concentrations. Following, 100 µL of 1 M NH_4CH_3COO solution and 100 µL of 10% $AlCl_3$ solution were added to the mixture, which was vortexed and incubated for 45 minutes at room temperature. After incubation, the total flavonoid content of the mixture was measured in a spectrophotometer at 415 nm. The total flavonoid content of the extracts was determined as mg quercetin equivalent/g extract by creating a calibration curve from different concentrations of quercetin used as standard (Murathan and Ozdinc, 2018). The data obtained in the study were statistically evaluated. In statistical calculations and comparisons, $p \leq 0.05$ was accepted as significant. The data were analyzed with SPSS 22 Package Statistical Program, ANOVA test at 95% confidence interval, and differences between habitats in multiple comparisons were determined by S-N-K and Tukey's B. The relationship between antioxidant activities and phenolic compounds was performed using the Pearson correlation coefficient (r). Differences at $p<0.05$ were considered significant by using the software (Chang et al., 2020).

3. Results and discussion

In this study, the antioxidant activities of root, branch, and leaf parts of 13 plants growing in different habitats were determined, leading to significant conclusions. In the study, when the data related to DPPH free radical scavenging activity were examined, the best activation in the leaves was 17.90±1.74 and 17.52±0.16 in the branch with *S. indica* in the serpentine region, and 33.19±1.54 in the root with *G. lepidioides* plant species growing in the gypsum region. When the data obtained for total phenolic content were evaluated, the highest amount was 55.97±0.51 in the leaves with *V. alyssifolium* in the gypsum region, 60.19±0.84 in the branch with *F. aciphylla* in the serpentine region, and 33.19±1.54 in the roots with 91.53±2.48 *S. indica* L. plant species grown in the gypsum region. When the data obtained regarding the total flavonoid content were examined, the highest amount was 29.71±0.57 in the leaves of the plant with *V. alyssifolium, S. indica* in the serpentine region, 26.86±0.86 in the branch, and 18.19±0.72 in the root with *H. thymbrifolium* in the serpentine region. Among the FRAP activity data, the highest amount was 76.51±3.83 in leaves of *H. thymbrifolium* 100.35±1.60 in branches, and 93.55±1.67 in roots of *F. aciphylla* in the serpentine region (Tables 1, 2 and 3).

When the data were analyzed statistically, significant differences were observed between habitats. Based on statistical evaluations, it was obvious that plants grown in the serpentine area were different in terms of antioxidant compounds compared to plants grown in other habitats (Table 4). It was determined that there were differences only in the correlation relationship within the habitat and in the correlation between all plants. According to the correlation made in the roots, branches, and leaves of all plants collected from different regions, a strong correlation was found between antioxidant compounds. A negative correlation was seen between antioxidant activity and phenolic, flavonoid content FRAP. The correlation between phenolic content and DPPH was strongly negative in leaves (r = -0.74), branches (r = -0.62), and roots (r= 0.62). The correlation has been reported in previous studies (Rumbaoa et al., 2009; Ghafar et al., 2010; Singanusong et al., 2015; Indradi et al., 2017; Fitriansyah et al., 2018; El Atki et al., 2019; Chang et al., 2020; Alizadeh and Fattahi, 2021) (Tables 5, 6, 7 and 8.) The data obtained in this study were compared with those in previous studies.

Their data on total phenolic, flavonoid contents, DPPH and

Table 1
Total phenolic, flavonoid contents and antioxidant activity in plant leaves.

Habitat	Plant Species and Families	DPPH IC_{50} (µg mL^{-1})	Total phenolics mg GAE g^{-1} Extract	Total flavonoids mg QE g^{-1} Extract	Reducing power mg TE g^{-1} Extract
Gypsum	*G. lepidioides* Boiss (Caryophyllaceae)	118.36±2.40	17.97±0.90	4.95±0.33	41.32±0.63
	P. recepii Wagenitz & Kandemir (Asteraceae)	59.07±3.01	29.08±0.71	15.14±0.57	52.79±2.88
	T. heterotomum (Bornm.) Grierson (Asteraceae)	>250	8.27±0.89	1.90±0.44	4.59±0.20
	V. alyssifolium Boiss (Scrophulariaceae)	27.57±1.47	55.97±0.51	13.14±1.03	72.98±2.44
Limestone	*C. montanum* (DC.) Boiss (Asteraceae)	>250	13.75±1.70	3.33±0.44	32.28±2.46
	C. niveum (Boiss.) Manden. & Scheng (Lamiaceae)	134.98±2.01	26.64±0.13	12.95±0.72	39.24±2.69
	P. oppositiflora Boiss. & Hausskn. (Lamiaceae)	149.98±0.69	19.01±0.84	3.52±0.82	49.08±1.90
	T. leucophyllum Montbret & Aucher ex Bentham (Lamiaceae)	110.14±1.24	22.41±1.80	3.43±1.03	51.37±1.42
Serpentine	*C. pseudoscammania* C. Koch (Convolvulaceae)	>250	17.90±0.68	7.14±3.97	22.04±0.29
	F. aciphylla Boiss (Cistaceae)	142.90±3.22	34.27±0.67	26.48±0.66	63.91±2.13
	G. halophilus Boiss. & Heldr (Iridaceae)	161.17±3.18	33.75±1.22	29.14±1.25	63.05±1.93
	H. thymbrifolium Boiss. & Noë (Hypericaceae)	61.19±2.59	42.93±1.11	29.62±0.82	76.51±3.83
	S. indica L. (Lamiaceae)	15.75±1.74	36.12±2.56	29.71±0.57	69.05±2.65
	Trolox	11.95±0.15			

Table 2
Total phenolic, flavonoid contents and antioxidant activity in plant branch.

Habitat	Plant Species and Families	DPPH IC_{50} (µg mL^{-1})	Total phenolics mg GAE g^{-1} Extract	Total flavonoids mg QE g^{-1} Extract	Reducing power mg TE g^{-1} Extract
Gypsum	*G. lepidioides* Boiss (Caryophyllaceae)	116.08±0.86	18.19±2.98	2.00±0.29	35.79±2.27
	P. recepii Wagenitz & Kandemir (Asteraceae)	56.30±1.20	13.16±1.56	9.90±0.16	41.66±1.90
	T. heterotomum (Bornm.) Grierson (Asteraceae)	>250	8.41±0.68	0.76±0.44	11.35±0.12
	V. alyssifolium Boiss (Scrophulariaceae)	54.63±0.69	27.30±3.22	5.43±0.29	70.93±3.81
Limestone	*C. montanum* (DC.) Boiss (Asteraceae)	>250	11.53±0.26	1.81±1.90	26.23±1.11
	C. niveum (Boiss.) Manden. & Scheng (Lamiaceae)	>250	16.19±1.78	1.90±0.44	19.86±1.47
	P. oppositiflora Boiss. & Hausskn. (Lamiaceae)	>250	9.45±1.05	0.38±0.44	27.94±0.32
	T. leucophyllum Montbret & Aucher ex Bentham (Lamiaceae)	>250	18.19±2.58	0.95±0.16	38.13±0.73
Serpentine	*C. pseudoscammania* C. Koch (Convolvulaceae)	248.56±60.03	15.08±1.85	4.86±0.57	31.14±0.41
	F. aciphylla Boiss (Cistaceae)	30.06±1.13	60.19±0.84	16.00±1.31	100.35±1.60
	G. halophilus Boiss. & Heldr (Iridaceae)	231.01±1.67	19.82±1.54	6.67±0.66	42.43±1.41
	H. thymbrifolium Boiss. & Noë (Hypericaceae)	44.64±1.83	37.45±2.28	26.86±0.86	72.38±1.56
	S. indica L. (Lamiaceae)	24.44±0.16	31.16±1.92	10.48±1.00	59.29±3.25
	Trolox	11.95±0.15			

Table 3
Total phenolic, flavonoid contents and antioxidant activity in plant roots.

Habitat	Plant Species and Families	DPPH IC_{50} (µg mL^{-1})	Total phenolics mg GAE g^{-1} Extract	Total flavonoids mg QE g^{-1} Extract	Reducing power mg TE g^{-1} Extract
Gypsum	*G. lepidioides* Boiss (Caryophyllaceae)	22.06±1.54	18.34±1.80	1.52±0.92	43.65±0.15
	P. recepii Wagenitz & Kandemir (Asteraceae)	147.10±0.74	14.64±3.30	3.71±0.76	41.89±0.92
	T. heterotomum (Bornm.) Grierson (Asteraceae)	>250	13.53±0.34	0.19±0.16	24.75±0.32
	V. alyssifolium Boiss (Scrophulariaceae)	30.31±1.31	33.82±2.52	8.86±0.29	37.05±3.08
Limestone	*C. montanum* (DC.) Boiss (Asteraceae)	>250	14.04±0.97	1.43±2.23	29.73±0.57
	C. niveum (Boiss.) Manden. & Scheng (Lamiaceae)	189.69±0.95	17.23±1.36	2.95±0.66	36.80±3.43
	P. oppositiflora Boiss. & Hausskn. (Lamiaceae)	>250	14.64±0.13	3.24±0.44	42.51±0.72
	T. leucophyllum Montbret & Aucher ex Bentham (Lamiaceae)	243.42±3.41	16.56±1.58	1.90±0.44	35.84±0.49
Serpentine	*C. pseudoscammania* C. Koch (Convolvulaceae)	205.16±20.55	17.97±0.68	1.62±0.16	44.53±0.47
	F. aciphylla Boiss (Cistaceae)	33.67±1.21	74.56±2.78	8.38±0.72	93.55±1.67
	G. halophilus Boiss. & Heldr (Iridaceae)	175.04±0.45	15.75±1.78	2.29±3.22	34.75±1.05
	H. thymbrifolium Boiss. & Noë (Hypericaceae)	92.85±2.64	27.60±0.44	18.19±0.72	57.29±1.84
	S. indica L. (Lamiaceae)	29.71±1.17	91.53±2.48	7.90±0.59	65.19±0.92
	Trolox	11.95±0.15			

Table 4
Statistical differences between habitats.

Antioxidant	Leaf			Branch			Root		
Compounds	Gypsum	Limestone	Serpentine	Gypsum	Limestone	Serpentine	Gypsum	Limestone	Serpentine
TFC	ab	a	b	a	a	b	a	a	b
TFP	a	b	c	a	a	b	a	a	b
FRAP	a	a	b	a	a	b	a	a	b
DPPH	a	b	ab	a	b	a	a	b	c

Letters indicate significant differences among the different habitats at $p \leq 0.05$.

FRAP in the leaves of *Achillea aleppica* D.C. subsp. *aleppica* were generally lower than the data obtained in this study, especially DPPH activity was lower (Colak et al., 2020). The total phenolic data of the leaves and stem parts of *V. major* subsp. *hirsute* was similar to the data obtained in this study, while FRAP and DPPH data were found lower (Saral et al., 2015). The data obtained from five *Isatis* species regarding total phenolic, flavonoid contents, DPPH, and FRAP in roots and stems are considerably lower than the data obtained in this study (Comlekcioglu, 2020). The antioxidant activity data obtained from *U. filipendula and V. album* plants are lower than the data obtained in this study (Yildiz et al., 2019).

Arituluk et al. (2016) determined the antioxidant activity and total phenolic and flavonoid contents of some *Tanacetum* L.

taxa growing in Türkiye. In their study, it was found that the data obtained in the aboveground parts of the plants were similar to the data obtained in some plants in this study. Antioxidant activity and phenolic compounds were examined in 10 selected plants from Serbia and it was reported that all plant species examined were rich in phenolic compounds and the data measured by two different methods used showed satisfactory antioxidant activity. A high correlation was found between antioxidant properties and phenolic compounds by Zugic et al. (2014). In their study, DPPH, FRAP, total phenolic (TP), and total flavonoid (TF) contents were analyzed to determine the antioxidant capacity of the methanol extract of *S. verticillata* subsp. *amasiaca*. As a result of the antioxidant tests, DPPH lC_{50}, FRAP, total phenolic and total flavonoid contents were determined as 11.47 ± 0.30, 22.22 ± 0.36 mmol TE/g extract, 140.18 ± 8.73 mg GAE/g extract and 51.56 ± 1.18 mg QE/g extract, respectively (Bayan and Genc, 2016).

Table 5
Correlation among total phenolic content (TPC), total flavonoid content (TFC), DPPH and FRAP of plants grown in serpentine habitat.

Correlation		Leaf	Branch	Root
DPPH	TPC	-0,92*	-0,69	-0,93*
TPC	TFC	0,93*	0,60	0,18
TPC	FRAP	0,99**	0,99**	0,77
TFC	FRAP	0,98**	0,67	0,38
DPPH	TFC	-0,94*	-0,63	-0,50
DPPH	FRAP	-0,95*	-0,73	-0,81

**Correlation is significant at $p \leq 0.01$; * correlation is significant at $p \leq 0.05$.

Table 6
Correlation among total phenolic content (TPC), total flavonoid content (TFC), DPPH and FRAP of plants grown in limestone habitat.

Correlation		Leaf	Branch	Root
DPPH	TPC	-0,83	-0,96**	-0,98*
TPC	TFC	0,76	0,31	0,29
TPC	FRAP	0,39	0,32	0,20
TFC	FRAP	-0,27	-0,56	0,90
DPPH	TFC	-0,34	-0,26	-0,23
DPPH	FRAP	-0,81	-0,51	-0,06

**Correlation is significant at $p \leq 0.01$; * correlation is significant at $p \leq 0.05$.

Table 7
Correlation among total phenolic content (TPC), total flavonoid content (TFC), DPPH and FRAP of plants grown in gypsum habitat.

Correlation		Leaf	Branch	Root
DPPH	TPC	-0,79	-0,71	-0,65
TPC	TFC	0,77	0,18	0,91
TPC	FRAP	0,92	0,93	0,18
TFC	FRAP	0,85	0,52	0,29
DPPH	TFC	-0,80	-0,66	-0,59
DPPH	FRAP	-0,97*	-0,82	-0,82

**Correlation is significant at $p \leq 0.01$; * correlation is significant at $p \leq 0.05$.

Table 8
Correlation among total phenolic content (TPC), total flavonoid content (TFC), DPPH and FRAP of plants grown plants.

Correlation		Leaf	Branch	Root
DPPH	TPC	-0,74*	-0,65*	-0,62*
TPC	TFC	0,69**	0,73**	0,46
TPC	FRAP	0,88**	0,94**	0,81**
TFC	FRAP	0,74**	0,75**	0,55*
DPPH	TFC	-0,54	-0,65*	-0,53
DPPH	FRAP	-0,82**	-0,75**	-0,59*

**Correlation is significant at $p \leq 0.01$; * correlation is significant at $p \leq 0.05$.

Calluna vulgaris (L.) Hull investigated the changes in the content of some phenolic groups and their biological activities in various parts of the plant during different growth periods. The data obtained in different parts of the plant are generally similar to the data obtained in this study (Chepel et al., 2020). They determined the phenolic content and antioxidant activity of purslane (*Portulaca oleracea* L.) during growth stages. They determined that FRAP, DPPH, phenol, and total flavonoid contents were higher in the generative period than in the vegetative period. As a result, they revealed that the growth stages of plants significantly affect antioxidant activity (Saffaryazdi et al., 2020). In this study, they determined the total phenolic content, flavonoid content, and antioxidant activities of hot water extracts of mint (*Mentha piperita*), lemon balm (*Mellissa officinalis*), marshmallow (*Althea officinalis*), chamomile (*Matricaria chamomilla*), green tea (*Camellia sinensis*) and sage (*Salvia officinalis*). The data obtained generally show similarity to those in this study (Karatas et al., 2019).

In their comparative study on phenolic, flavonoids, and *in vitro* antioxidant activities of wild edible plants obtained from the Wetland Ecosystem of Loktak Lake in the Himalayan Region of North East India, Singh et al. (2021) determined 3 plants with potential bioactivity among 28 plants species. They investigated the possibility of potential medicinal plants by determining the antioxidant activity and flavonoid content in relation to total phenolic compounds in plants collected in the Central Balkans. In their study, Stankovic et al. (2015) determined that *Statice gmelinii* and *Artemisia santonicum* species had high antioxidant activity among 16 halophyte plants collected from different families. The correlation between phenolic content and DPHH was found to be parallel with the correlation in this study.

They obtained different data on the phenolic contents and biological activities of two endemic plant species growing in Türkiye, *Corydalis oppositifolia* and *Senecio cilicius*, as well as ethanol, methanol, and ethyl acetate extracted from the subsoil parts of the plants. They determined that the antioxidant activities of the two plants were high (Acet et al., 2021).

They determined that the number of phenolic compounds varied significantly in different growth stages of *Rumex crispus* L. and *Rumex obtusifolius* L. species and that there were differences in antioxidant activity in different plant organs. They found that there was a high correlation between the fractions of phenolic compounds and antioxidant activity (Feduraev et al., 2019).

4. Conclusion

The biochemical and physiological structures of plants vary according to the ecological factors in the environment where they grow. In this study, the amount of some bioactive components and antioxidant capacities of the plants studied were compared. It was observed that the total phenolic, total flavonoid, DPPH, and FRAP activity values of the samples collected from various habitats were different from each other. In addition, the data obtained from leaves, branches, and roots of the same plant species differed. The correlation analysis showed a wide variation in the correlation coefficient between the studied parameters. The results show that there are significant differences in the parameters studied in the plants. In addition to the different morphological characteristics of the plants, it is evident that the antioxidant activities and phenolic

contents of the examined plants vary according to the geographical regions where they grow. Since Türkiye has a great diversity of endemic plants, it is very important to carry out research for more effective and efficient use of natural compounds obtained from plants.

Acknowledgements: We would like to express our gratitude to Prof. Dr. Ali Kandemir for his assistance with plant diagnosis and providing pictures.

Conflict of interest: The authors declare that they have no conflict of interests.

Informed consent: The authors declare that this manuscript did not involve human or animal participants and informed consent was not collected.

References

Acet, T., Corbaci, C., & Ozcan, K. (2021). Phenolic contents and biological activities of two endemic plants in Turkey. *South African Journal of Botany*, *143*, 457-461.

Van Alphen, J. G., & de los Ríos Romero, F. (1971). *Gypsiferous soils: notes on their characteristics and management*. (pp. 1-44). International Institute for Land Reclamation and Improvement, Wageningen, The Netherlands.

Alizadeh, Z., & Fattahi, M. (2021). Essential oil, total phenolic, flavonoids, anthocyanins, carotenoids and antioxidant activity of cultivated Damask Rose (*Rosa damascena*) from Iran: With chemotyping approach concerning morphology and composition. *Scientia Horticulturae*, *288*, 110341.

Arituluk, Z. C., Cankaya, I. I. T., & Ozkan, A. M. G. (2016). Antioxidant activity, total phenolic and flavonoid contents of some *Tanacetum* L. (Asteraceae) taxa growing in Turkey. *FABAD Journal of Pharmaceutical Sciences*, *41*(1), 17-25.

Bayan, Y., & Genc, N. (2016). Determination of antioxidant capacity and total phenolic matter of *Salvia verticillata* subsp. *amasiaca*. *Nevşehir Bilim ve Teknoloji Dergisi*, *5*(2), 158-166.

Blois, M. S. (1958). Antioxidant determinations by the use of a stable free radical. *Nature*, *181*(4617), 1199-1200.

Chang, C. C., Yang, M. H., Wen, H. M., & Chern, J. C. (2002). Estimation of total flavonoid content in propolis by two complementary colometric methods. *Journal of Food and Drug Analysis*, *10*(3), 3.

Chang, M. Y., Lin, Y. Y., Chang, Y. C., Huang, W. Y., Lin, W. S., Chen, C. Y., ... & Lin, Y. S. (2020). Effects of infusion and storage on antioxidant activity and total phenolic content of black tea. *Applied Sciences*, *10*(8), 2685.

Chepel, V., Lisun, V., & Skrypnik, L. (2020). Changes in the content of some groups of phenolic compounds and biological activity of extracts of various parts of heather (*Calluna vulgaris* (L.) Hull) at different growth stages. *Plants*, *9*(8), 926.

Colak, S., Dağlı, F., Comlekcioglu, N., Kocabas, Y. Z., & Aygan, A. (2020). Antimicrobial activity and some phytochemical properties of extracts from *Achillea aleppica* subsp. *aleppica*. *GIDA-Journal of Food*, *45*(5), 929-941.

Comlekcioglu, N. (2020). Bazı endemik ve doğal *Isatis* L. türlerine ait kök ve gövde ekstraktlarının biyoaktivitesi ile tohum yağlarının analizi. *Kahramanmaraş Sütçü İmam Üniversitesi Tarım ve Doğa Dergisi*, *23*(4), 860-869.

El Atki, Y., Aouam, I., Taroq, A., Lyoussi, B., Taleb, M., & Abdellaoui, A. (2019). Total phenolic and flavonoid contents and antioxidant activities of extracts from Teucrium polium growing wild in Morocco. *Materials Today: Proceedings*, *13*, 777-783.

Ergun, F. (2021). Erzurum Olur yöresinden toplanan Berberis vulgaris L. meyvelerinin antioksidan aktivitelerinin belirlenmesi. *Türk Tarım ve Doğa Bilimleri Dergisi*, *8*(4), 1028-1034.

Feduraev, P., Chupakhina, G., Maslennikov, P., Tacenko, N., & Skrypnik, L. (2019). Variation in phenolic compounds content and antioxidant activity of different plant organs from *Rumex crispus* L. and *Rumex obtusifolius* L. at different growth stages. *Antioxidants*, *8*(7), 237.

Fitriansyah, S. N., Aulifa, D. L., Febriani, Y., & Sapitri, E. (2018). Correlation of total phenolic, flavonoid and carotenoid content of Phyllanthus emblica extract from Bandung with DPPH scavenging activities. *Pharmacognosy Journal*, *10*(3), 447-452.

Gentile, D., Fornai, M., Pellegrini, C., Colucci, R., Blandizzi, C., & Antonioli, L. (2018). Dietary flavonoids as a potential intervention to improve redox balance in obesity and related co-morbidities: a review. *Nutrition Research Reviews*, *31*(2), 239-247.

Ghafar, M. F., Prasad, K. N., Weng, K. K., & Ismail, A. (2010). Flavonoid, hesperidine, total phenolic contents and antioxidant activities from *Citrus* species. *African Journal of Biotechnology*, *9*(3), 326-330.

Guven, H., Arici, A., & Simsek, O. (2019). Flavonoids in our foods: a short review. *Journal of Basic and Clinical Health Sciences*, *3*(2), 96-106.

Herrero, J., & Porta, J. (2000). The terminology and the concepts of gypsum-rich soils. *Geoderma*, *96*(1-2), 47-61.

Indradi, R. B., Fidrianny, I., & Wirasutisna, K. R. (2017). DPPH scavenging activities and phytochemical content of four Asteraceae plants. *International Journal of Pharmacognosy and Phytochemical Research*, *9*(6), 755-759.

Karatas, I., Karatas, R., & Elmastas, M. (2019). Yaygın olarak kullanılan bazı tıbbi ve aromatik bitkilerin sıcak su infüzyonlarının sekonder metabolit içeriği ve antioksidan aktivitelerinin belirlenmesi. *Gaziosmanpaşa Bilimsel Araştırma Dergisi*, *8*(2), 49-57.

Kruckeberg, A. R. (2002). The influences of lithology on plant life. *Geology and plant life: the effects of landforms and rock type on plants*, 160-81.

Larson, R. A. (1988). The antioxidants of higher plants. *Phytochemistry*, 27, 969-978.

Mikulajová, A., Sedivá, D., Hybenová, E., & Mosovská, S. (2016). Buckwheat cultivars--phenolic compounds profiles and antioxidant properties. *Acta Chimica Slovaca*, *9*(2), 124-129.

Murathan, Z. T., & Ozdinc, M. (2018). Ardahan ve Elazığ illerinde yetişen *Anchusa azurea* Miller var. *Azurea* bitkisinin biyoaktif bileşenleri ve antioksidan kapasitesi üzerine bir araştırma. *Kahramanmaraş Sütçü İmam Üniversitesi Tarım ve Doğa Dergisi*, *21*(4), 529-534.

Oyaizu, M. (1986). Studies on products of browning reaction antioxidative activities of products of browning reaction prepared from glucosamine. *The Japanese Journal of Nutrition and Dietetics*, *44*(6), 307-315.

Ozdeniz, E., Ozbey, B. G., Kurt, L., & Bolukbasi, A. (2017). Serpentine ecology and contributions to the serpentine flora of Turkey. *Toprak Bilimi ve Bitki Besleme Dergisi*, *5*(1), 22-33.

Ozdeniz, E., Bolukbasi, A., Kurt, L., & Ozbey, B. G. (2016). Ecology of gypsophile plants. *Toprak Bilimi ve Bitki Besleme Dergisi*, *4*(2), 57-62.

Ozyigit, I. I., Dogan, I., Hocaoglu-Ozyigit, A., Yalcin, B., Erdogan, A., Yalcin, I. E., ... & Kaya, Y. (2023). Production of secondary metabolites using tissue culture-based biotechnological applications. *Frontiers in Plant Science*, *14*, 1132555.

Percival, M. (1996). Antioxidants. *Clinical Nutrition Insights*, NUT031 1/96 Rev.10/98.

Politycka, B., & Adamska, D. (2003). Release of phenolic compounds from apple residues decomposing in soil and the influence of temperature on their degradation. *Polish Journal of Environmental Studies*, *12*(1), 95-98.

Rumbaoa, R. G. O., Cornago, D. F., & Geronimo, I. M. (2009). Phenolic content and antioxidant capacity of Philippine potato (*Solanum tuberosum*) tubers. *Journal of Food Composition and Analysis*, *22*(6), 546-550.

Saffaryazdi, A., Ganjeali, A., Farhoosh, R., & Cheniany, M. (2020). Variation in phenolic compounds, a-linolenic acid and linoleic acid contents and antioxidant activity of purslane (*Portulaca oleracea* L.) during phenological growth stages. *Physiology and Molecular Biology of Plants*, *26*(7), 1519-1529.

Saral, O., Sahin, H., & Karakose, M. (2015). *Vinca major* subsp. *hirsuta*'nın antioksidan aktivitesinin ve RP-HPLC-UV ile fenolik bileşenlerinin belirlenmesi. *Artvin Çoruh Üniversitesi Orman Fakültesi Dergisi*, *16*(2), 124-131.

Shen, N., Wang, T., Gan, Q., Liu, S., Wang, L., & Jin, B. (2022). Plant flavonoids: Classification, distribution, biosynthesis, and antioxidant activity. *Food Chemistry*, *383*, 132531.

Singh, T. S., Roy, S. S., Kshetri, P., Ansari, M. A., Sharma, S. K., Verma, M. R., ... & Kandpal, B. (2021). Comparative study on phenolic, flavonoids and in vitro antioxidant activity of wild edible plants from Loktak Lake wetland ecosystem under North East Indian Himalayan Region. *Natural Product Research*, *35*(24), 6045-6048.

Singanusong, R., Nipornram, S., Tochampa, W., & Rattanatraiwong, P. (2015). Low power ultrasound-assisted extraction of phenolic compounds from mandarin (*Citrus reticulata* Blanco cv. *Sainampueng*) and lime (*Citrus aurantifolia*) peels and the antioxidant. *Food Analytical Methods*, *8*, 1112-1123.

Singleton, V. L., Orthofer, R., & Lamuela-Raventós, R. M. (1999). [14] Analysis of total phenols and other oxidation substrates and antioxidants by means of folin-ciocalteu reagent. In *Methods in enzymology* (Vol. 299, pp. 152-178). Academic press.

Stankovic, M. S., Petrovic, M., Godjevac, D., & Stevanovic, Z. D. (2015). Screening inland halophytes from the central Balkan for their antioxidant activity in relation to total phenolic compounds and flavonoids: Are there any prospective medicinal plants?. *Journal of Arid Environments*, *120*, 26-32.

Tajik, S., Zarinkamar, F., Soltani, B. M., & Nazari, M. (2019). Induction of phenolic and flavonoid compounds in leaves of saffron (*Crocus sativus* L.) by salicylic acid. *Scientia Horticulturae*, *257*, 108751.

Verheye, W. H., & Boyadgiev, T. G. (1997). Evaluating the land use potential of gypsiferous soils from field pedogenic characteristics. *Soil Use and Management*, *13*(2), 97-103.

Yildiz, S., Gurgen, A., Kilic, C., Tabbouche, S., Kilic, A. O., & Can, Z. (2019). Antioxidant, antimicrobial and anti-quorum sensing activities of *Usnea filipendula* and *Viscum album*. *Journal of Anatolian Environmental and Animal Sciences*, *4*(4), 613-620.

Zugic, A., Dorđevic, S., Arsic, I., Markovic, G., Zivkovic, J., Jovanovic, S., & Tadic, V. (2014). Antioxidant activity and phenolic compounds in 10 selected herbs from Vrujci Spa, Serbia. *Industrial Crops and Products*, *52*, 519-527.

Williamson, G., Kay, C. D., & Crozier, A. (2018). The bioavailability, transport, and bioactivity of dietary flavonoids: A review from a historical perspective. *Comprehensive Reviews in Food Science and Food Safety*, *17*(5), 1054-1112.

Cite as: Varol, T., Osma, E., Simsek, S., & Elveren, M. (2023). Antioxidant activities of plant species growing in different habitats (serpentine, gypsum and limestone). *Front Life Sci RT*, *4*(3), 150-156.