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# The effect of the geological substrate on the morphology and chemical composition of plant organs of *Verbascum phoeniceum* L. (*Scrophulariaceae*)

**Abstract**

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*Verbascum phoeniceum* L. grows on various geological substrates, such as serpentine, andesite, dacite and limestone. The specificity of these substrates determines the formation of morphologic characteristics, mineral content of the plant organs and biomass production of the plants since they acumulate some metals from geological substrates and soil.

## Introduction

*Verbascum phoeniceum* L. (*Scrophulariaceae*) is a hemicriptophyte which belongs to the phytocoenoses of bright and dry habitats that exist on different geological substrataes (serpentine, andesite, limestone). Our research work over several years has shown striking morphological and ecophysiological adaptations of the plants of this species to the specific physicochemical properties of edaphic conditions within the habitat (Djelić 1994., Petković & al. 1997). Because of the strong dependence between plant growth, its disrtibution, the content of mineral matter on the one hand, and that of soil, on the other, we compared the chemical composition of the plant organs, to that of the soil on which the plants grew. We also examined primary production in the shoot and root mass and lastly morphological features of *V. phoeniceum* L. found on serpentine, andesite and limestone.

## Materials and methods

The concentrations of Ca, Mg, Fe, Mn, Zn, K, Cu, Co, Cr in soil have been determined, using soil samples from a depth of 10 cm. They were first air-dried, then ground into particles 1 mm in size and analysed for total and available concentrations of elements. For the total concentratiions of chemical elements, the plant material and soil were treated by

means of conc. nitric and perchloric acids, while the soil determining readily available elements has been treated with 0.1 N HCl.

The amounts of Ca, Mg, Fe, Mn, Zn, K, Cu, Co, Cr, contained in the plant organs (root, stem, rosette leaf, fruit) of *V. phoeniceum* have been determined using plant material, collected over the stage of rosette, flowering and fruiting. The material was taken from the thin serpentine (5 km from Ušće), andesite (at Golo Brdo) and limestone (5 km from Paraš in) (map. 1). These elements were quantified by atomic absorption spectrophotometry.

In order to analyse primary production of shoot and root biomass, we took 10 plants from a 10 $m^2$ area in each locality over the stage of rosette, flowering and fruiting. After the fresh shoot and root biomass had been measured, the samples were dried for 24 hours at 105 °C, after which the dry mass was measured with the accuracy of 0.1 g.

Morphological analysis as well as that of primary production were made to gain a clear picture of noticeable differences in the morphological features as related to the comparing chemical composition of the soil and that of plants growing on that soil.

## Results

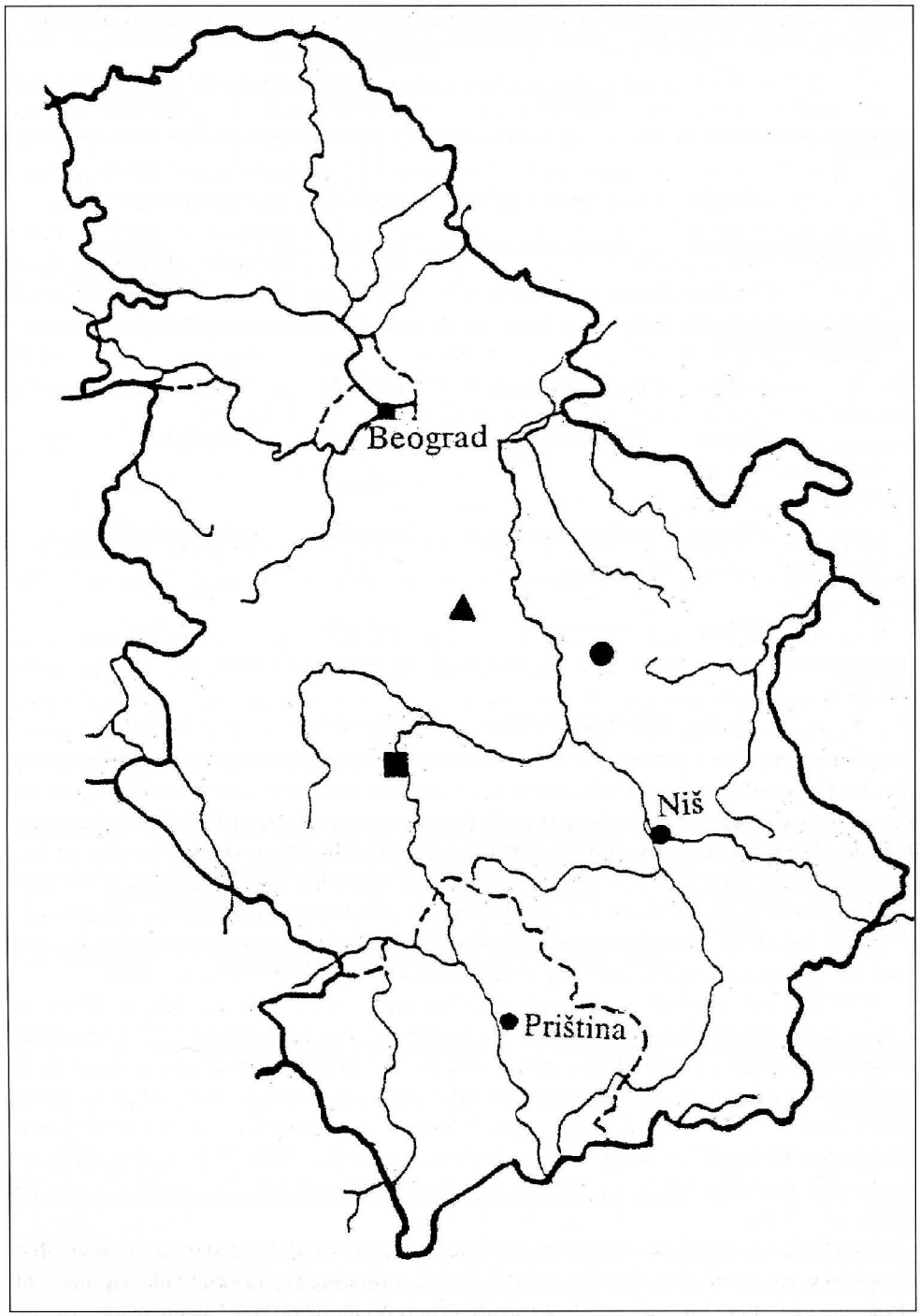
As can be seen from Table 1, the plants of *V. phoeniceum* growing on serpentine, andesite and limestone have been found to greatly differ in the morphology of all the organs studied.

Both root and shoot biomass resulted highly dependent upon the edaphic conditions (Borisavljević 1979). The analysis of primary plant production has shown that at the rosette stage (Table 2) plants on limestone have twice as high dry and 2.6 times higher fresh shoot matter than those from serpentine substrate. As is shown in Table 3 the plants from limestone at the flowering stage, had twice as much fresh and 2.4 times higher dry shoot matter, compared with those from the serpentine substrate. The plants that grew on limestone had better root and shoot biomass production compared with the plants from serpentine (Table 4.). In their biomass production, the plants from andesite substrate had intermediate values compared with the above ones. Such a low plant growth on the serpentine substrate can be accounted for by a strong effect of a series of factors, particularly that of the physicochemical properties of this type of rock for its adverse thermic and aqueous regime and high availability of Mg, Co, Cr, Ni (Tatić & Veljović 1992).

The comparative chemical analysis made of the soils taken from various substrates (Table 5) has shown that serpentine has a 18.5 times lower total and by 13.3 times lower plant-available Ca than has limestone. It also has a 2.08 times lower total and nearly as much plant-available K, such as limestone with higher availability of the other elements than found in limestone. Compared with limestone, serpentine soils contained different total and plant-available fractions in several other elements. These were (plant-available fractions in parentheses): Fe - x20.6 (x23.2), Mn - x2.71 (x4.46), Zn - x4.84, Cu - x1.25 (x10), Cr - x3.9.

The lack of proportionality in the plant vs. soil elemental concentrations suggests that plants take up metals from the substrates, further distributing and accumulating them in plant organs throughout individual phenophases (Tatić & Veljović 1982).

The comparative chemical analysis on the *V. phoeniceum* L. plants has shown that at the




Map.1. Republic of Serbia ▲ Andesite (Golo Brdo) ■ Serpentine (Ušće) ● Limestone (Parašin).

Table 1. Morphological characters *Verbascum phoeniceum* L. from different geological substrata.

| | Geological substrate | | |
|---|---|---|---|
| | Serpentine | Andesite | Limestone |
| STEM: | | | |
| Lenght | Average 44 cm | Average 59,2 | Average 70,1 |
| Pilosity I internodium | Conspicious | Moderate | Weak |
| Color | Intense violet reddish | Violet -green | Green-reddish |
| ROSETTE LEAVES: | | | |
| Basa | Ear-shaped to ovate | Cuneate | Cuneate seldom oval |
| Margine | Weacly crenate | Mildly rough to crenate | Wearly mildly rouch to crenate |
| Sharpe | Broad egg-shaped to cordate | Long ovate | Rhomboid to long ovate |
| Pilosity | Conspicious | Moderate | Weak |
| FRUIT: | | | |
| Sharpe | Ball-shaped to eliptic | Elongated to ovate | Long ovate |

Table 2. Comparative analysis of the production of shoot and root organs of *Verbascum phoeniceum* L. in the stage of rosette's growing from different geological substrates.

| geological substrate | number of plants | shoot biomass (g) | | root biomass (g) | |
|---|---|---|---|---|---|
| | | fresh mass | dry mass ( 105 °C ) | fresh mass | dry mass ( 105 °C ) |
| serpentine | 10 | 19 | 3 | 16 | 4 |
| andesite | 10 | 47 | 6 | 20 | 7 |
| limestone | 10 | 48 | 6 | 35 | 10 |

rosette (Table 6), flowering (Table 7) and fruiting stage (Table 8), the phase of ontogenesis, plant organ as well as the type of substrate are responsible for the concentrations of chemical elements, contained in the plants. The comparisons have been made for the phenophases with the highest concentrations of metals in the plants. Compared with plants

Table 3. Comparative analysis of the production of shoot and root organs of *Verbascum phoeniceum* L. in the stage of flowering from different geological substrates.

| geological substrate | number of plants | shoot biomass (g) | | root biomass (g) | |
|---|---|---|---|---|---|
| | | fresh mass | dry mass ( 105 °C ) | fresh mass | dry mass ( 105 °C ) |
| serpentine | 10 | 46 | 9 | 19 | 3 |
| andesite | 10 | 66 | 13 | 18 | 5 |
| imestone | 10 | 94 | 21 | 32 | 8 |

Table 4. Comparative analysis of the production of shoot and root organs of *Verbascum phoeniceum* in the stage of fruiting from different geological substrata.

| geological substrate | number of plants | shoot biomass (g) | | root biomass (g) | |
|---|---|---|---|---|---|
| | | fresh mass | dry mass ( 105 °C ) | fresh mass | dry mass ( 105 °C ) |
| serpentine | 10 | 65 | 13 | 23 | 4 |
| andesite | 10 | 91 | 21 | 34 | 8 |
| imestone | 10 | 94 | 28 | 47 | 11 |

on serpentine, plants on limestone contained higher concentration of Ca in different plant organs: in root – x6.6 at the fruiting stage, in leaves – x5.4 at the rosette stage, in stem at the fruiting stage, in fruit –x5.4.

Compared with plants on serpentine, plants on limestone also had higher concentrations of other chemical elements in different plant organs:

- root: Zn – 1.3 at the rosette stage, Co – x2.8 at the flowering stage, Mg – x1.4 at the fruiting stage.
- leaves : Mg – x1.6 at the flowering stage, Mn – x3.3 at the fruiting stage.
- stem: Mn – x2 at the fruiting stage, Mg – 1.2 at the fruiting stage, Zn – 5.7at the flowering stage
- fruit: Mg – x1.2, Zn – 2.7, Cu – x5.1, Cr – x1.3.

According to their chemical composition, plants on andesite are somewhere inbetween these two groups, approximating plants on serpentine with regard to their Ca concentration and plants on limestone with regard to their Mg, Fe and Zn concentrations.

## Conclusion

The investigations, conducted with *V. phoeniceum* L. growing on the various types of

Table 5. Comparative chemical analysis ( concentrations in mg/kg ) of the soil from different geological substrates, t.q. - total, r.a.f. - readily available.

| Chemical elements (mg/kg) | | Serpentine | Andesite | Limestone |
|---|---|---|---|---|
| Ca | t.q. | 40 | 39 | 745 |
| | r.a.f. | 8 | 11 | 106 |
| Mg | t.q. | 330 | 45 | 197 |
| | r.a.f. | 21 | 5 | 3 |
| Fe | t.q. | 66240 | 15415 | 3205 |
| | r.a.f. | 279 | 32 | 1 |
| Mn | t.q. | 675 | 595 | 395 |
| | r.a.f. | 115 | 77 | 25 |
| Zn | t.q. | 94 | 68 | 90 |
| | r.a.f. | 14 | 10 | 3 |
| K | t.q. | 21 | 33 | 44 |
| | r.a.f. | 0.3 | 0.2 | 0.3 |
| Cu | t.q. | 27 | 10 | 22 |
| | r.a.f. | 3 | 2 | 0.3 |
| Co | t.q. | 13 | 7 | 7 |
| | r.a.f. | 1 | 0.4 | 0.9 |
| Cr | t.q. | 66 | 29 | 17 |
| | r.a.f. | 1 | 0.002 | 0.00018 |

substrate (serpentine, andesite, limestone) clearly show the nature of the substrate does have a significant effect on the concentrations of the chemical elements, contained in plant organs, as well as on the morphological characters of the plants themselves.

The plants growing on serpentine have shown the poorest growth with all organs con-

Table 6. Comparative chemical analysis of plant organs of *Verbascum phoeniceum* L. at rosette stage growing from different geological substrates.

| Plant organs | Geological substrate | Ca mg/kg | Mg mg/kg | Fe mg/kg | Mn mg/kg | Zn mg/kg | K mg/kg | Cu mg/kg | Co mg/kg | Cr mg/kg |
|---|---|---|---|---|---|---|---|---|---|---|
| Root | Serpentine | 15.0 | 31.2 | 272..6 | 58.7 | 399.6 | 69.5 | 53.0 | 2.6 | 30.7 |
| | Andesite | 86.7 | 25.0 | 309.9 | 39.3 | 290.4 | 48.1 | 33.0 | 0.8 | 2.8 |
| | Limestone | 32.5 | 9.5 | 833.4 | 22.0 | 311.5 | 99.8 | 48.5 | 0.9 | 0.5 |
| Rosette leaves | Serpentine | 28.7 | 78.7 | 4358.4 | 92.4 | 86.1 | 117.1 | 15.0 | 6.0 | 53.6 |
| | Andesite | 22.2 | . 7.2 | 846.8 | 87.7 | 99.6 | 111.1 | 10.7 | 1.8 | 2.2 |
| | Limestone | 190.2 | 42.0 | 2230.2 | 98.7 | 170.0 | 122.5 | 16.0 | 2.1 | 3.4 |

Table 7. Comparative chemical analysis of the plant organs of *Verbascum phoeniceum* L. at the flowering stage from different geological substrates.

| Plant organs | Geological substrate | Ca mg/kg | Mg mg/kg | Fe mg/kg | Mn mg/kg | Zn mg/kg | K mg/kg | Cu mg/kg | Co mg/kg | Cr mg/kg |
|---|---|---|---|---|---|---|---|---|---|---|
| Root | Serpentine | 16.2 | 32.5 | 6536.4 | 97.2 | 341.1 | 86.4 | 50.0 | 4.0 | 3.1 |
| | Andesite | 25.5 | 16.2 | 1355.8 | 82.2 | 290.5 | 54.5 | 20.5 | 1.2 | 2.7 |
| | Limestone | 54.0 | 17.5 | 847.2 | 48.1 | 205.1 | 33.3 | 29.8 | 1.4 | 1.2 |
| Rosette leaves | Serpentine | 32.5 | 80.5 | 2872.4 | 115.5 | 77.6 | 104.7 | 18.0 | 7.1 | 44.0 |
| | Andesite | 113.7 | 27.5 | 1279.3 | 110.2 | 111.6 | 203.2 | 9.95 | 2.2 | 3.2 |
| | Limestone | 175.0 | 49.5 | 1472.4 | 82.9 | 117.2 | 131.6 | 15.2 | 1.0 | 2.6 |
| Stem up to the inflorence | Serpentine | 13.0 | 30.0 | 684.7 | 21.1 | 457.2 | 136.6 | 12.9 | 0.9 | 3.7 |
| | Andesite | 20.0 | 7.5 | 928.8 | 25.1 | 116.2 | 185.5 | 10.3 | 0.4 | 3.5 |
| | Limestone | 47.5 | 37.5 | 456.5 | 20.6 | 80.1 | 84.1 | 10.6 | - | 0.7 |

Table 8. Comparative chemical analysis of the plant organs of *Verbascum phoeniceum* L. at fruiting stage from different geological substrates.

| Plant organs | Geological substrate | Ca mg/kg | Mg mg/kg | Fe mg/kg | Mn mg/kg | Zn mg/kg | K mg/kg | Cu mg/kg | Co mg/kg | Cr mg/kg |
|---|---|---|---|---|---|---|---|---|---|---|
| Root | Serpentine | 15.7 | 31.2 | 3820 | 80.9 | 229.0 | 69.6 | 27.8 | 3.1 | 27.5 |
| | Andesite | 28.7 | 10.5 | 1403.6 | 72.1 | 336.0 | 57.3 | 49.7 | 0.9 | 3.25 |
| | Limestone | 103.2 | 23.0 | 932.4 | 52.4 | 239.5 | 30.0 | 34.4 | 0.4 | 1.8 |
| Rosette leaves | Serpentine | 38.7 | 120.0 | 9084.8 | 272.7 | 107.7 | 107.2 | 7.2 | 13.2 | 45.1 |
| | Andesite | 78.8 | 22.2 | 1162.6 | 138.0 | 109.4 | 219.7 | 7.9 | 3.8 | 2.6 |
| | Limestone | 177.2 | 42.5 | 1626.2 | 82.4 | 267.8 | 194.8 | 22.9 | 1.2 | 2.8 |
| Stem up to the inflorence | Serpentine | 12.7 | 41.2 | 3320.0 | 53.4 | 281.2 | 127.2 | 8.6 | 1.0 | 14.7 |
| | Andesite | 24.5 | 10.7 | 292.9 | 17.1 | 176.1 | 127.7 | 18.6 | 0.3 | 2.0 |
| | Limestone | 73.0 | 20.2 | 885.8 | 44.2 | 68.4 | 37.7 | 8.4 | - | 3.2 |
| Fruit | Serpentine | 11.9 | 12.1 | 774.0 | 15.4 | 204.3 | 85.0 | 25.3 | - | 9.0 |
| | Andesite | 16.2 | 8.4 | 290.2 | 12.5 | 88.6 | 106.3 | 8.0 | - | 4.0 |
| | Limestone | 67.5 | 10.0 | 1142.3 | 26.6 | 76.2 | 109.6 | 4.9 | - | 7.0 |

taining the highest concentrations of Mg, Fe, Co and Cr; Mn in leaves and stems and Zn in stem and fruit have the highest concentrations in comparison with plants from the two remaining substrates.

The plants on limestone have shown the best growth, Ca being abundant in all organs studied, whereas Zn and Cu have shown the highest concentrations in the rosette leaves, in comparision with the plants from two other substrates.

With respect to all the characters studied, the plants from andesite have indicated to be intermediate between those from serpentine and those from limestone.

The specificity of ecological conditions prevalent in the serpentine habitat (dry and warm and having rather poor soil that has higher Ca/Mg quotients and being loaded with heavy metals of the high toxicity) has led to a series of both morphological and chemical characteristics, which differentiate the serpentine plants from those growing on the substrates other than serpentine.

**References**

Borisavljević, Lj. 1979: Odnos produkcije nadzemnog i podzemnog dela biomase zeljastih biljaka u zajednici *Festuco-Quercetum petraea* Jank. - II Kongres ekologa Yugoslavia, knj. II: 272-279.

Djelić, G. 1994: Morfoloske odlike vrste *Verbascum phoeniceum* L. (fam. *Scrophulariaceae*) na serpentinskoj, krecnjackoj i andezitnoj podlozi.- magistarski rad, Beograd, 1-66.

Petković, B., Djelić, G. & Tatić, B. 1997: Variation in *Verbascum phoeniceum* L. (fam. *Scrophulariaceae)* in Serbia as affected by geological substratum. - Bocconea 5: 647-654.

Tatić, B. & Veljović, V. 1982: Uticaj silikatne i krecnjacke geoloske podloge na morfoloska svojstva i hemijski sastav pepela biljnih organa *Seseli rigidum* W. et K. - Glasnik Instituta za botaniku i Botanicke baste Univerziteta u Beogradu, Tom (XIII) XV, 1-3: 63-68.

— & — 1992: Distribution of serpentinized massivess on the Balkan peninsula and their ecology.- The ecology of areas with serpentinized rocks. A world wiew (Roberts, B. A. & Proctor, J. ed.). Kluwer Academic Pubeishers, Netherlands, 199-215.

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