# MORPHOLOGICAL AND CHEMICAL PROPERTIES OF SELECTED SWEET VIOLET POPULATIONS

# MORFOLOŠKE I KEMIJSKE KARAKTERISTIKE ODABRANIH POPULACIJA MIRISNE LJUBIČICE

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## ABSTRACT

Sweet violet (Viola odorata L.) blooms in continental climate conditions in early spring (March-April) with delicate flowers of attractive scent because of which it is frequently gathered from its natural habitats. Differences among the populations were established according to their morphological properties of twelve populations from Križevci area.

Stated information indicates that the populations gathered from meadow – habitat are shorter and have a smaller diameter than the populations gathered from the habitat in forest, whereas the population from the orchards has the highest number of leaves and flowers. Correlation analysis shows strong ($P<0.01$) positive connection of the root mass, leaves mass, number of leaves with the total mass of the plants, as well as connection of the plant mass with the number of flowers.

Chemical analysis established agrochemical soil properties and nutrient concentrations in plants. Correlations between the examined properties of violets and soil properties indicate that the potassium concentration in the roots is in strong ($P <0.01$) correlation with potassium in the soil, whereas phosphorus concentration in flower is in a considerably strong ($P<0.05$) positive correlation with the phosphorus in the soil.

Key words: sweet violet (Viola odorata L.), morphology, soil, correlations

## SAŽETAK

Mirisna ljubičica (Viola odorata L.) cvate u uvjetima kontinentalne klime rano u proljeće (ožujak – travanj) nježnim cvjetovima privlačnog mirisa zbog kojih se često sakuplja s prirodnih staništa.

Na dvanaest populacija porijeklom s križevačkog područja utvrđene su razlike među populacijama s obzirom na njihova morfološka svojstva.

Navedeni podaci upućuju da su populacije sakupljene sa staništa livade niže i manjeg promjera od populacija sakupljenih sa staništa u šumi, dok najveći broj listova i cvjetova ima populacija iz voćnjaka. Korelacijska analiza pokazuje jaku ($P<0,01$) pozitivnu vezu između mase korijena, mase listova i broja listova s ukupnom masom biljaka, kao i između mase biljke i broja cvjetova.

Kemijskim analizama utvrđena su agrokemijska svojstva tla i koncentracije hraniva u biljkama. Korelacije između ispitivanih svojstava ljubičica i svojstava tla pokazuju da je koncentracija kalija u korijenu biljaka u jakoj ($P<0,01$) pozitivnoj korelacijskoj vezi s kalijem u tlu, dok je u značajnoj ($P<0,05$) pozitivnoj korelacijskoj vezi koncentracija fosfora u cvijetu s fosforom u tlu.

Ključne riječi: mirisna ljubičica (Viola odorata L.), morfologija, tlo, korelacije

## DETALJAN SAŽETAK

Mirisna je ljubičica zeljasta trajnica, srcolikih listova tamnozelene boje, blago pahuljastih na naličju, koji rastu iz puzajućih rizoma tvoreći rozetu. Rubovi mladih listova smotani su prema sredini lica lista tvoreći tako dva namotaja. Oblik listova se mijenja tijekom vegetacije: rani, projetni listovi su najčešće sjajni, bubrežastog ili srcolikog oblika, a širina i duljina su im podjednaki, ljetni listovi su dulji i često dlakavi.

Cvjetne stapke duge 3-7 cm izlaze iz pazušca listova i nose jedan cvijet. Cvjetovi promjera 1-2 cm najčešće su tamnoljubičasti te je po njihovoj boji vrsta i dobila ime, ali obična ljubičasta, blijedo ružičasta ili bijela boja, također su vrlo česte.

Osim kao rezani cvijet, u ukrasnoj se hortikulturi koristi za sadnju u privatne vrtove, a moguća je njena primjena i kao lončanice. Cijela biljka je jestiva i ljekovita tako da postoje brojne mogućnosti njezine primjene i u prehrambene, farmaceutske, kozmetičke i druge svrhe.

Njenoj općoj proširenosti van samog prirodnog areala znatno je doprinijela omiljenost same biljke kao rezanog cvijeta, vrtne biljke, ali i kao lončanice. Također, vrsta je jestiva i ljekovita, a njen ugodan miris koristi se u kozmetičkoj industriji za proizvodnju aroma, parfema, sapuna.

Osim što raste samonikla, mirisna ljubičica se i uzgaja. Zlatno doba njene proizvodnje bilo je u 18., a naročito u drugoj polovici 19. stoljeća kad je selekcioniran i velik broj kultivara koji su još i danas u proizvodnji.

Cilj ovog rada bio je istražiti kemijski sastav tla sa staništa mirisne ljubičice na lokacijama u okolici Križevaca te njegov utjecaj na rast (visinu i promjer biljke, broj listova, broj cvjetova u vrijeme pune cvatnje, masu lista, cvijeta i korijena) i kemijski sastav biljke.

Na dvanaest populacija porijeklom s križevačkog područja izmjerena su morfološka svojstva biljaka (visina, promjer, masa biljke i pojedinih biljnih dijelova, te broj listova i cvjetova), provedena je deskriptivna statistika i korelacijska povezanost. Utvrđene su razlike među populacijama s obzirom na njihova morfološka svojstva.

Navedeni podaci upućuju da su populacije sakupljene sa staništa livade niže i manjeg promjera od populacija sakupljenih sa staništa u šumi (Tablica 2), dok najveći broj listova i cvjetova ima populacija iz voćnjaka (Tablica 4). Korelacijska analiza pokazuje jaku ($P<0,01$) pozitivnu vezu između mase korijena, mase listova i broja listova s ukupnom masom biljaka, kao i između mase biljke i broja cvjetova (Tablica 6).

Kemijskim analizama utvrđena su agrokemijska svojstva tla (Tablica 5) i koncentracije hraniva u biljkama (Grafikoni 2, 3, 4). Korelacije između ispitivanih svojstava ljubičica i svojstava tla pokazuju da je koncentracija kalija u korijenu biljaka u jakoj ($P<0,01$) pozitivnoj korelacijskoj vezi s kalijem u tlu, dok je u značajnoj ($P<0,05$) pozitivnoj korelacijskoj vezi koncentracija fosfora u cvijetu s fosforom u tlu (Tablica 6).

## INTRODUCTION

Due to its specific position on the border of different climatic impacts Croatia is one of the most interesting European countries when it comes to its flora [21]. According to the information of State Directorate for Environmental Protection [14], Croatia is the seventh country in broad European area by its large number of plant species. Objective indicators, taking into account the surface area, place Croatia with its vegetal abundance of 0.075 plant species per square kilometre in the third place in Europe [9]. Numerous wild growing species in wilderness are endangered, in a large part due to uncontrolled exploitation by humans. Commercial cultivation of wild growing horticultural plants represents one of the forms of „ex situ" protection of plant species [11].

Sweet violet (Viola odorata L.) grows wild in nature, in places exposed to sun, alongside hedges, river banks, on the edges of deciduous forests and in forest glades [23, 4]. It is wide-spread all across Croatia, along with the mentioned species, [5] lists further 19 species of the same genus. The Mediterranean is considered to be the sweet violet's original habitat [13], and nowadays it ranges from the North of Europe to South Africa, Tierra del Fuego and Australia.

Early studies [3] indicate that the soil for growing violets needs to be fresh, fertile, well cultivated and deeply treated during autumn or winter and fertilized with a sufficient amount of combusted manure. According to more recent data, the violet grows mostly on alkaline soils [1], but it can also be found on acidic soils with low calcium concentration (pH 4.1 – 7.8). Soils from natural habitats contain a significant amount of organic matter (5.8-10.86 %). Organic matter has a positive effect on plant growth because it contributes to the improvement of the physical, chemical and biological soil properties, mineralization of nutrients and therefore, on the plant growth itself [15]. Peat and compost based substrates gave the best results (the greatest height of plants, the greatest mass and leaf surface, the longest root) in cultivation of numerous plant species (lettuce, cucumbers, peppers, strawberries, forest plants), whereas substrates based on soil gave the weakest results [6, 22]. Violets are usually found on soils with less phosphorus and larger potassium content [15, 1].

Table 1. Locations of the gathered sweet violets in Križevci area
Tablica 1. Lokacije sakupljenih populacija mirisne ljubičice na području Križevaca

| No. | Location | Geographical characteristic | Elevation (m) | Habitat | Habitat vegetation |
|---|---|---|---|---|---|
| 1 | Križevci I | N 46º 01' 33.3" and E 16º 33' 4.8" | 145 | KCA garden | *Forsythia* |
| 2 | Križevci I | N 46º 01' 33.3" and E 16º 33' 4.8" | 145 | KCA garden | American Arbor Vitae (*Thuja occidentalis)* |
| 3 | Vratno I | N 46º 07' 47.9" and E 16º 30' 35.6" | 213 | meadow | meadow vegetation |
| 4 | Vratno II | N 46º 07' 47,9" and E 16º 30' 35,6" | 213 | forest | Norway spruce (*Picea abies)* |
| 5 | Žabno I | N 45º 58' 48.4" and E 16º 34' 57.27" | 184 | edge of forest | English oak (*Quercus robur)* |
| 6 | Žabno II | N 45º 58' 48.4" and E 16º 34' 57.27" | 184 | forest | English oak (*Quercus robur)* |
| 7 | Potočec I | N 46º 02' 45.6" and E 16º 34' 20.2" | 181 | orchard | apple (*Malus domestica)* |
| 8 | Potočec II | N 46º 02' 45.6" and E 16º 34' 20.2" | 181 | orchard | Sweet cherry (*Prunus avium*) |
| 9 | Kalnik I | N 46º 07' 56.9" and E 16º 27' 50" | 446 | meadow | Elder (*Sambucus* ssp.) Dog rose (*Rosa canina*) |
| 10 | Kalnik II | N 46º 07' 56.9" and E 16º 27' 50" | 446 | meadow | Blackthorn (*Prunus spinosa*) |
| 11 | Sokolovac I | N 46º05'39.8" and E 16º39'16.7" | 195 | edge of forest | Sessile oak (*Quercus petraea*) hornbeam (*Carpinus betulus*) |
| 12 | Sokolovac II | N 46º05'39.8" and E 16º39'16.7" | 195 | forest | Sessile oak (*Quercus petraea*) Hornbeam (*Carpinus betulus*) |

Elemental analysis of the sweet violet plant material showed the presence of carbon, oxygen, sodium, magnesium, aluminum, silicon, chlorine, potassium, calcium and iron in different plant parts in varying concentrations [18]. [19] according to [18], established high concentration of nitrogen and potassium in vegetative plant parts, whereas calcium accumulates in roots and phosphorus and sulphur in the flower. Potassium, magnesium and sulphur level are the highest at the end of the flowering season. Sweet violet contains odorous principle, blue colouring matter and sugar (glycoside). Viola-quercetine is found throughout the plant. Salicylic acid was also obtained from the plant [10] according to [18]. An alkaloid violine is found in roots, leaves, flowers and seeds. Essential oil contains ionone, saponins, glycoside, methyl salicylate, mucilage, A and C vitamins and alkaloids [12] according to [18].

The aim of this work is to study chemical composition of the soil in the sweet violet habitats on locations around Križevci and its impact on growth (height and diameter of the plant, number of leaves, and number of flowers during an intensive flowering period, mass of leaves, flowers and roots) as well as the chemical composition of the plant.

## MATERIAL AND METHODS

In the spring of 2009 (from 2nd to 5th April), during the intensive flowering period of sweet violet, field studies and gathering of domestic populations were carried out. Twelve populations were gathered from habitats around Križevci (west part of continental Croatia) in order to determine their phenotypic diversity:

Each location had two populations, and each population contained 10 individual plants on which the following properties were measured: height of the plant (mm),

diameter of the plant (mm), number of leaves (n), number of flowers (n), mass of the whole plant (g), mass of leaves (g), mass of flowers (g) and root mass (g). The results are shown in Tables 2, 3 and 4. For wild growing populations, the obtained results were taken from the samples of 10 gathered individual plants. Descriptive statistics was carried out in order to obtain morphological characteristics. The following parameters were determined for each variable: arithmetic mean, minimum and maximum, and variation width.

Soil and plant material analyses were carried out in the agrochemical laboratory of the Križevci College of agriculture (KCA). For the purpose of soil analyses samples from violet habitats were taken at depth of 20 cm, and the used methods are standard in analytical practice of Croatian agrochemical laboratories: pH soil reaction in water and 1M KCl solution, bichromate method for humus content analysis and Egner-Riehm-Domingo method for establishing available phosphorus and potassium. A sample of the plant material was made up from the total mass of the above-ground plant and after measurements, dry matter was determined at 105 °C until constant weight, as well as phosphorus and potassium concentrations. Phosphorus was determined spectrophotometrically using a molybdate, whereas potassium was determined by flame photometry directly from the filtrates.

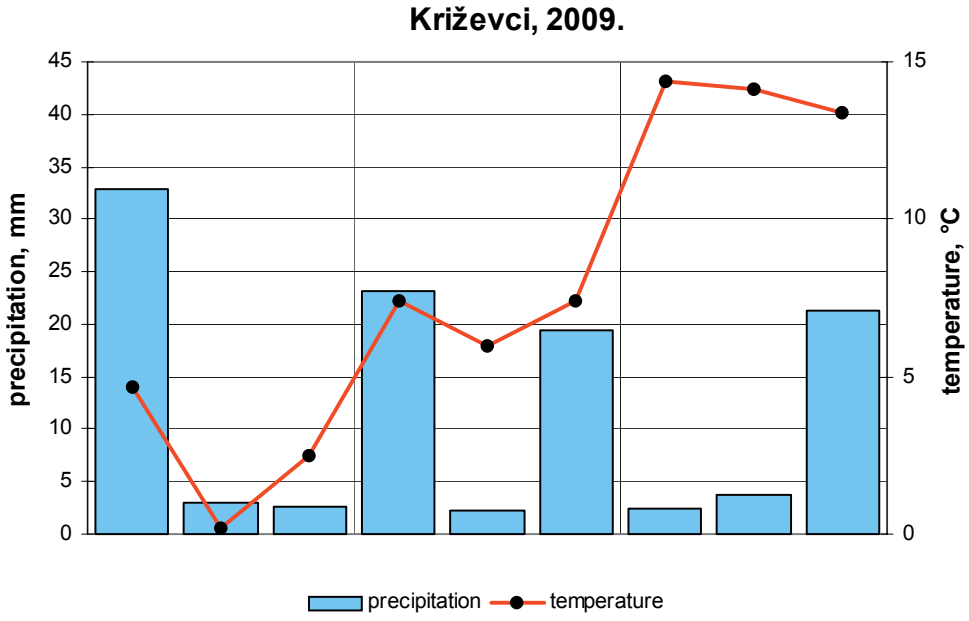
Based on the data about morphological and chemical characteristics of sweet violet, as well as the chemical characteristics of the soil habitats, their correlation was determined by a Pearson's correlation coefficient [20].

Data obtained from the State hydrometeorological department, Agrometeorological station in Križevci were used in order to show the most significant meteorological indicators during intensive vegetation of sweet violet.

Data about the amount of precipitations and average air temperatures during intensive vegetation of sweet violet in the period from February to April 2009 are shown in decades (Graph 1).

## RESULTS AND DISCUSSION

Results of descriptive statistical analysis of sweet violet populations are shown in Tables 2,3 and 4 . The shortest average plants were those of Vratno I and Kalnik I populations (7.30 cm), both gathered on a meadow (Table 2). The tallest average plants were on Žabno II (12.60 cm) and Sokolovac I sites (11.00 cm) both gathered in the forest. Plants of the Križevci I population from a meadow (7.20 cm) and those of Sokolovac II population from the edge of forest (9.20 cm) had the lowest average diameter, whereas plants of Vratno II forest population (15.40 cm)




Graph 1. Air temperatures (°C) per decade and precipitation amounts (mm) during intensive vegetation of sweet violet in 2009

Grafikon 1. Dekadne temperature zraka (°C) i količina oborina (mm) za vrijeme intenzivne vegetacije mirisave ljubičice 2009. godine

Table 2. Descriptive statistical parameters of height and diameter at the plant (mm) on the studied populations of *Viola odorata* L.
Tablica 2. Deskriptivni statistički pokazatelji visine i promjera biljke (mm) istraživanih populacija *Viola odorata* L.

| *Morphological characteristic* | *Descriptive parameters* | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Plant's height* (cm) | Average | 8.30 | 9.20 | **7.30** | 10.00 | 10.00 | **12.60** | 8.80 | 8.10 | **7.30** | 7.40 | **11.00** | 8.40 |
| | Std.dev | 1.50 | 1.14 | 1.82 | 2.48 | 1.67 | 1.68 | 1.80 | 1.59 | 1.56 | 1.71 | 2.68 | 1.58 |
| | Min | 6.00 | 7.30 | 5.50 | 6.00 | 7.80 | 11.00 | 6.50 | 5.00 | 5.50 | 5.00 | 6.00 | 6.00 |
| | Max | 11.00 | 10.70 | 11.50 | 15.50 | 12.00 | 16.50 | 12.50 | 11.00 | 10.30 | 11.00 | 14.00 | 11.00 |
| | CV (%) | 18.08 | 12.46 | 24.96 | 24.61 | 16.75 | 13.20 | 18.21 | 19.74 | 21.41 | 23.14 | 24.34 | 18.95 |
| *Plant's diameter* (cm) | Average | **7.20** | 11.30 | 10.10 | **15.40** | 10.80 | 12.20 | 12.20 | **13.90** | 10.40 | 11.20 | 11.40 | **9.20** |
| | Std.dev | 2.09 | 2.22 | 2.81 | 4.79 | 3.53 | 3.73 | 2.59 | 3.37 | 3.93 | 2.75 | 2.88 | 2.38 |
| | Min | 4.00 | 8.70 | 5.50 | 8.00 | 5.50 | 4.50 | 8.50 | 8.00 | 5.00 | 7.50 | 7.00 | 6.00 |
| | Max | 11.00 | 16.30 | 14.00 | 21.50 | 18.00 | 17.00 | 15.50 | 19.50 | 18.00 | 15.50 | 17.00 | 15.00 |
| | CV (%) | 28.98 | 19.72 | 27.99 | 31.02 | 32.83 | 30.68 | 21.34 | 24.27 | 37.77 | 24.56 | 25.31 | 25.90 |

Table 3. Descriptive statistical parameters of mass of the whole plant, leaf, flower and root (g) at the studied populations of *Viola odorata* L.
Tablica 3. Deskriptivni statistički pokazatelji mase cijele biljke, lista, cvijeta i korijena (g) istraživanih populacija *Viola odorata* L.

| *Morphological characteristic* | *Descriptive parameters* | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mass of the whole plant (g) | Average | **1.33** | 2.56 | 2.32 | 3.42 | 3.75 | 5.21 | **6.30** | **8.11** | **1.89** | 2.91 | 3.60 | 2.10 |
| | Std.dev | 0.52 | 1.10 | 0.70 | 1.21 | 3.39 | 3.68 | 3.58 | 5.35 | 0.90 | 1.44 | 3.73 | 0.68 |
| | Min | 0.60 | 1.20 | 1.30 | 1.50 | 1.00 | 1.50 | 1.50 | 1.90 | 0.70 | 1.00 | 1.30 | 1.40 |
| | Max | 2.20 | 4.76 | 3.76 | 5.83 | 12.98 | 13.34 | 12.14 | 21.76 | 3.29 | 5.30 | 13.00 | 3.40 |
| | CV (%) | 38.97 | 42.95 | 30.16 | 35.51 | 90.40 | 70.66 | 56.89 | 65.93 | 47.74 | 49.30 | 103.63 | 32.49 |
| *Mass of the leaves* (g) | Average | **0.77** | 1.73 | 1.25 | 1.85 | 2.02 | 3.22 | **4.41** | **5.64** | 0.60 | 1.28 | 1.50 | 0.80 |
| | Std.dev | 0.36 | 0.84 | 0.39 | 0.83 | 2.02 | 2.36 | 2.57 | 4.07 | 0.45 | 0.61 | 2.32 | 0.44 |
| | Min | 0.30 | 0.90 | 0.70 | 0.60 | 0.50 | 0.70 | 1.30 | 0.80 | 0.30 | 0.40 | 0.70 | 0.50 |
| | Max | 1.50 | 3.88 | 1.72 | 2.95 | 7.53 | 7.49 | 9.33 | 15.96 | 1.72 | 2.34 | 3.73 | 1.97 |
| | CV (%) | 47.38 | 48.30 | 30.85 | 45.12 | 99.94 | 73.28 | 58.19 | 72.12 | 46.99 | 47.48 | 70.70 | 55.54 |
| *Mass of the flowers* (g) | Aveage | 0.29 | 0.35 | 0.34 | **0.14** | **0.68** | **0.67** | 0.45 | 0.57 | 0.29 | 0.32 | 0.38 | 0.20 |
| | Std.dev | 0.12 | 0.23 | 0.17 | 0.07 | 0.49 | 0.45 | 0.43 | 0.32 | 0.21 | 0.12 | 0.42 | 0.12 |
| | Min | 0.10 | 0 | 0.10 | 0 | 0.30 | 0.20 | 0 | 0.20 | 0 | 0.10 | 0 | 0.10 |
| | Max | 0.48 | 0.64 | 0.69 | 0.26 | 1.95 | 1.60 | 1.54 | 1.23 | 0.73 | 0.48 | 1.28 | 0.44 |
| | CV (%) | 41.75 | 63.85 | 51.34 | 46.55 | 71.25 | 67.34 | 94.97 | 56.36 | 72.87 | 37.77 | 110.84 | 59.44 |
| *Mass of the root* (g) | Average | **0.28** | 0.47 | 0.71 | 1.45 | 0.96 | 1.21 | 1.19 | **1.78** | 0.60 | 1.30 | 1.70 | 1.06 |
| | Std.dev | 0.15 | 0.37 | 0.30 | 0.78 | 0.97 | 1.00 | 1.20 | 0.99 | 0.32 | 0.65 | 2.32 | 0.48 |
| | Min | 0.10 | 0.10 | 0.50 | 0.70 | 0.10 | 0.40 | 0.20 | 0.70 | 0.20 | 0.40 | 0.50 | 0.60 |
| | Max | 0.48 | 1.37 | 1.47 | 2.98 | 3.14 | 3.93 | 4.19 | 4.03 | 1.03 | 2.54 | 7.97 | 2.01 |
| | CV (%) | 55.10 | 79.35 | 42.41 | 54.07 | 101.32 | 82.87 | 100.46 | 55.38 | 53.53 | 49.90 | 137.15 | 44.71 |

and Potočec II orchard population (13.90 cm) had the highest average diameter.

Based on the descriptive statistical parameters we can see that the measured morphological characteristics in the sweet violet populations are very different (Table 3). The most variable properties were recorded in Skolovac I population: mass of the whole plant (CV=103.63 %), mass of the flowers (CV=103.63 %), mass of the roots (CV=137.15 %), and the number of flowers (CV=110.31 %) table 4. It is presumed that variability of some analysed properties is the consequence of the environmental influence on the plant. It is also possible that the characteristics which show the greatest variability are the result of both habitat influence and genetic differences among populations. The data show that populations gathered from meadow habitats were shorter and had a lower diameter than the ones gathered from forest habitats. [7] describe the morphological variations between species Viola elatior, Viola pumila and Viola stagnina. The Viola elatior species (from 13 to 51 cm high) prevails in forest habitat, whereas Viola pumila (3.5 to 33 cm) and Viola stagnina (7 to 27 cm) prevail in meadow habitat. [16] state that Viola elatior is found in meadows overgrown by bushes and in forests. The main reason of its poor presence in open spaces is its sensitivity to light. This shows that Viola species growing in forest habitat, due to poor light conditions are taller and have a higher diameter than the species growing in meadows. The results of our research are in line with these researchers.

Table 3. shows that plants with the highest mass were gathered on the Potočec II (8.11 g) and Potočec I (6.30 g)

Table 4. Descriptive statistical parameters of number of the leaves and flowers at the studied populations of *Viola odorata* L.
Tablica 4. Deskriptivni statistički pokazatelji broja listova i cvjetova istraživanih populacija *Viola odorata* L.

| *Morphological characteristic* | *Descriptive parameters* | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Number of leaves* | Average | **6** | 13 | 9 | 14 | 15 | **24** | 18 | **23** | 10 | 12 | 12 | 6 |
| | Std.dev | 2.76 | 6.30 | 3.03 | 6.10 | 14.75 | 17.39 | 10.27 | 16.33 | 4.38 | 4.27 | 9.33 | 3.27 |
| | Min | 2 | 6 | 5 | 5 | 4 | 5 | 5 | 3 | 3 | 3 | 5 | 4 |
| | Max | 11 | 29 | 13 | 22 | 55 | 55 | 5 | 64 | 17 | 17 | 33 | 15 |
| | CV (%) | 49.23 | 48.82 | 32.19 | 44.82 | 98.96 | 73.38 | 58.05 | 72.26 | 44.27 | 34.47 | 79.08 | 51.14 |
| *Number of flowers* | Average | **2** | 3 | 11 | 5 | 15 | **22** | 15 | **19** | 7 | 11 | 9 | 5 |
| | Std.dev | 1.05 | 2.11 | 6.29 | 2.32 | 12.62 | 15.03 | 14.19 | 10.62 | 4.90 | 4.09 | 10.04 | 2.72 |
| | Min | 1 | 0 | 2 | 0 | 10 | 6 | 0 | 5 | 0 | 3 | 0 | 2 |
| | Max | 4 | 6 | 23 | 9 | 51 | 53 | 0 | 41 | 16 | 16 | 31 | 11 |
| | CV (%) | 52.70 | 63.96 | 59.94 | 50.41 | 81.98 | 67.42 | 95.25 | 56.50 | 69.99 | 38.57 | 110.31 | 60.41 |

locations, also having the highest mass of leaves (Potočec II 5.64 g and Potočec I 4.41 g) and roots as well (Potočec II 1.78 g). Populations with the lowest plant mass were gathered in the meadow habitat of Križevci I (1.33 g) and Kalnik I (1.89 g). Plants from Križevci I location also had the lowest leaf mass (0.77 g) and root mass (0.28 g), whereas Vratno II population had the lowest flower mass. Žabno I (0.68 g) and Žabno II (0.67 g) populations gathered from forest habitat had the heaviest average flowers.

Properties related to the number of leaves and flowers (table 4) indicate that there is a possibility to use sweet violet as certain paddy perennial for garden planting or its use as pot flower. It is desirable that these species grow in dense turfs, filled with leaves [25]. In this sense, Žabno II population from the forest habitat (24 leaves and 22 flowers) and Potočec II population from the orchard habitat (23 leaves and 19 flowers) would be the most desirable, since they had the largest number of leaves and flowers. Kalnik I population (meadow) and Križevci I population (park) had the smallest number of leaves (4) and flowers (2). According to the research of [25], Vratno population (near forester's station) in the open had the largest average number of flowers (2.75), whereas the Kalnik population in the greenhouse (28.80) and in the open (27.90) had the highest average number of leaves, almost identical.

After measurements, samples of plant material and soil were taken from the plants' habitats for chemical analyses. As shown the nitrogen (Graph 2), phosphorus (Graph 3) and potassium (Graph 4) concentrations vary in populations and in plant parts. [8] implies that depending on the population, plant parts and the time of sampling there is a difference in the presence of phosphorus and potassium. They also state that the root of sweet violet is less supplied with phosphorus and potassium than the leaf. Our results are in accordance with the results of these researchers.

In the research, the highest concentration of nitrogen in root (2.04 %), leaf (4.19 %) and flower (3.06 %) was measured at Potočec I population from the orchard, which was also morphologically characterized of having a higher average plant mass. Population with the lowest concentration of nitrogen in root (0.91 %) is Potočec II from the orchard as well, whereas the lowest nitrogen concentration in leaf (1.83 %) and flower (1.90 %) was measured at Sokolovac II population from the edge of forest (Graph 2).

The highest phosphorus concentration in root (Graph 3) was measured at Potočec I population (0.37 %), whereas the highest concentration in leaf was established at Kalnik II population (1.03 %) from meadow, in flower at Žabno II (0.70 %) from forest. Žabno I and Sokolovac II (the edge of forest) populations had the lowest concentration of phosphorus in root (0.17 %), whereas Vratno I population (meadow) had the lowest phosphorus concentration in leaf (0.40 %), and Vratno II (forest) in flower (0.05 %).

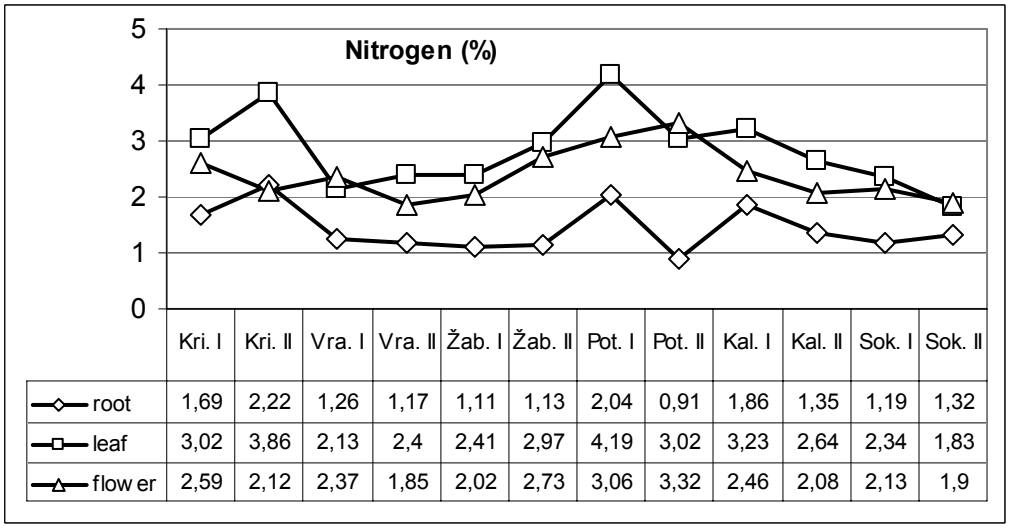
The highest concentration of potassium in root (0.96%) and leaf (1.86 %) was established in Potočec I population, and in flower (1.99 %) in Vratno II population. According to the data by [18], the potassium level in all plant parts is the highest at the end of the flowering period (Graph 4).

These figures are partly comparable to the results by [15] who analyzed chemical composition of the wild growing plants (Viola ssp., Hedera helix, Rubus ssp., Galium odoratum, Ruscus ssp., Salvia forskahler, Trachystemon orientalis) in forest. Nitrogen concentration in wild growing plants (2.00 – 2.03 %) is similar to nitrogen concentration in violets (1.44 – 2.84 %), while the phosphorus concentration is several times lower, and potassium level is higher. The wild growing plants contain 0.11 % of phosphorus and 6.05 % of potassium, and violets 0.45 % of phosphorus and 1.26 % of potassium.

Results of soil analyses showed (Table 4) that the soil in Žabno was acidic (pH 4.66) and the one in Sokolovac

was neutral (pH 5.20), whereas on other locations it was neutral to mild alkaline (pH 6.53 – 6.92). The highest pH variation coefficient (0.05 – 0.15) was determined by [2], who arranged herbal plants (Mercurialis perennis, Arum maculatum, Lamiastrum galeobdolon, Galium odoratum, Viola reichenbachiana, Oxalis acetosella, Luzula luzuloides) according to decreasing pH values and concentration of exchangeable calcium. This is in line with our research results which indicate that the smallest plants were measured on soils with the lowest pH value (6.45 to 6.61). Potočec populations had the most abundant growth.

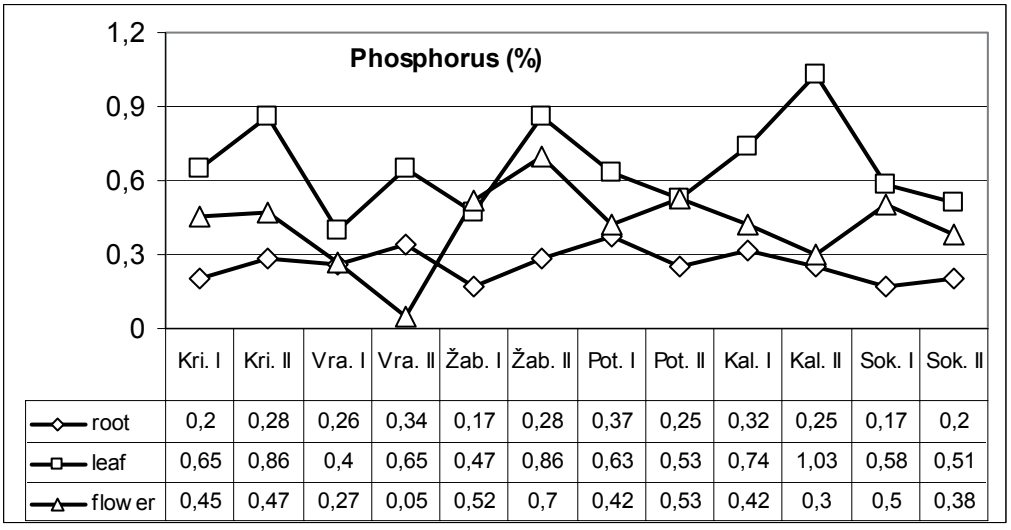
Humosity of all soils is good (4.00 – 7.49 %). [15] show high content of organic matter (4.22 – 13.24 %) in the top layer of the forest soil in violet habitat. [17] point out that the presence of organic matter is in positive correlation with enzymatic activity which favours the plant growth, whereas our research does not show any correlation between these two properties. [6, 24] point out that the restricting growth factor on soils with little




| | Kri. I | Kri. II | Vra. I | Vra. II | Žab. I | Žab. II | Pot. I | Pot. II | Kal. I | Kal. II | Sok. I | Sok. II |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| root | 1,69 | 2,22 | 1,26 | 1,17 | 1,11 | 1,13 | 2,04 | 0,91 | 1,86 | 1,35 | 1,19 | 1,32 |
| leaf | 3,02 | 3,86 | 2,13 | 2,4 | 2,41 | 2,97 | 4,19 | 3,02 | 3,23 | 2,64 | 2,34 | 1,83 |
| flower | 2,59 | 2,12 | 2,37 | 1,85 | 2,02 | 2,73 | 3,06 | 3,32 | 2,46 | 2,08 | 2,13 | 1,9 |

Graph 2. Concentration of nitrogen in the root, leaf and flower at the studied *Viola odorata* L. populations

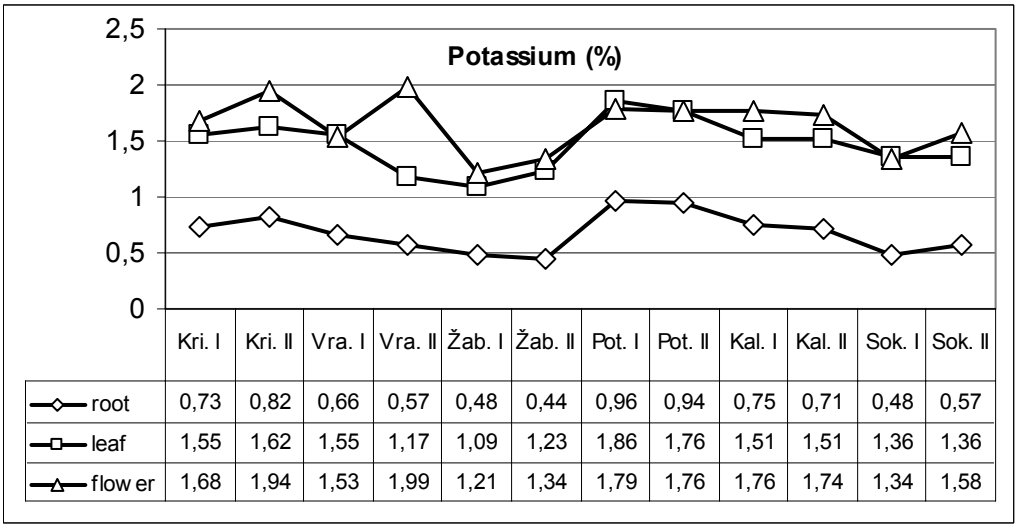
Grafikon 2. Koncentracija dušika u korijenu, listu i cvijetu istraživanih populacija *Viola odorata* L.




| | Kri. I | Kri. II | Vra. I | Vra. II | Žab. I | Žab. II | Pot. I | Pot. II | Kal. I | Kal. II | Sok. I | Sok. II |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| root | 0,2 | 0,28 | 0,26 | 0,34 | 0,17 | 0,28 | 0,37 | 0,25 | 0,32 | 0,25 | 0,17 | 0,2 |
| leaf | 0,65 | 0,86 | 0,4 | 0,65 | 0,47 | 0,86 | 0,63 | 0,53 | 0,74 | 1,03 | 0,58 | 0,51 |
| flower | 0,45 | 0,47 | 0,27 | 0,05 | 0,52 | 0,7 | 0,42 | 0,53 | 0,42 | 0,3 | 0,5 | 0,38 |

Graph 3. Concentration of phosphorus in the root, leaf and flower at the studied Viola odorata L. populations

Grafikon 3. Koncentracija fosfora u korijenu, listu i cvijetu istraživanih populacija Viola odorata L.




| | Kri. I | Kri. II | Vra. I | Vra. II | Žab. I | Žab. II | Pot. I | Pot. II | Kal. I | Kal. II | Sok. I | Sok. II |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| root | 0,73 | 0,82 | 0,66 | 0,57 | 0,48 | 0,44 | 0,96 | 0,94 | 0,75 | 0,71 | 0,48 | 0,57 |
| leaf | 1,55 | 1,62 | 1,55 | 1,17 | 1,09 | 1,23 | 1,86 | 1,76 | 1,51 | 1,51 | 1,36 | 1,36 |
| flow er | 1,68 | 1,94 | 1,53 | 1,99 | 1,21 | 1,34 | 1,79 | 1,76 | 1,76 | 1,74 | 1,34 | 1,58 |

Graph 4. Concentration of potassium in the root, leaf and flower at the studied Viola odorata L. populations
Grafikon 4. Koncentracija kalija u korijenu, listu i cvijetu istraživanih populacija Viola odorata L.

Table 5. Results of analyses of agrochemical soil properties
Tablica 5. Rezultati analiza agrokemijskih svojstava tala istraživanih populacija

| Sampled population | $pH_{HOH}$ | $pH_{KCl}$ | Humus (%) | AL- method | |
|---|---|---|---|---|---|
| | | | | $P_2O_5$ mg $100g^{-1}$ | $K_2O$ mg $100g^{-1}$ |
| Križevci l | 6.97 | 6.50 | 4.26 | 27.06 | 25.09 |
| Križevci II | 7.21 | 6.80 | 3.74 | 34.85 | 54.39 |
| Vratno I | 7.33 | 7.03 | 4.93 | 3.82 | 15.54 |
| Vratno II | 7.07 | 6.81 | 10.03 | 5.46 | 37.23 |
| Žabno I | 5.82 | 4.98 | 6.02 | 3.61 | 14.62 |
| Žabno II | 5.48 | 4.34 | 3.91 | 1.17 | 14.31 |
| Potočec I | 7.07 | 6.61 | 4.57 | 34.96 | 129.82 |
| Potočec II | 6.99 | 6.45 | 3.53 | 34.78 | 68.95 |
| Kalnik I | 7.16 | 6.76 | 7.03 | 9.67 | 29.12 |
| Kalnik II | 7.29 | 6.89 | 6.98 | 38.13 | 62.81 |
| Sokolovac I | 5.48 | 4.38 | 3.52 | 8.84 | 27.54 |
| Sokolovac II | 6.47 | 6.01 | 10.86 | 16.04 | 43.16 |
| Average | 6.70 | 6.13 | 5.78 | 18.20 | 43.55 |

organic matter is a low level of available water and poor physical soil properties.

Supply levels of physically active phosphorus in soil were very heterogeneous, ranging from extremely low in Žabno and Vratno (2.39 and 4.64 mg $P_2O_5$/100 g of soil) to moderate levels in Sokolovac (12.44 mg $P_2O_5$/100 g of soil), and to extremely high levels in Kalnik, Križevci and Potočec (28, 74; 30, 96 and 34, 87 mg $P_2O_5$/100 g of soil) Table 5. Supply levels of physically active potassium were moderate only at Žabno location (14, 47 mg $K_2O$/100 g of soil), while at other locations the levels were extremely high (26, 39 – 99, 39 mg $K_2O$/100 g of soil). By researching the chemical composition of forest soil as the habitat of wild growing plants, [15] also point out low supply levels of phosphorus in soil (0.00 – 0.15 ppm at a depth of 5 – 10 cm and 1.88 – 5.17 ppm at 0 – 5

Table 6. Phenotypical correlation coefficients of analyzed properties
Tablica 6. Fenotipski koeficijenti korelacije između analiziranih svojstava istraživanih populacija

| Property | Height of plant (mm) | Diameter of plant (mm) | Mass of plant (g) | Mass of root (g) | Mass of flower (g) | Mass of leaves (g) | Number of leaves | Number of flowers |
|---|---|---|---|---|---|---|---|---|
| Diameter of plant (mm) | 0,32 | 1 | | | | | | |
| Mass of plant (g) | 0,27 | 0,65* | 1 | | | | | |
| Mass of root (g) | 0,34 | 0,71** | 0,69* | 1 | | | | |
| Mass of flower (g) | 0,45 | 0,14 | 0,62* | 0,21 | 1 | | | |
| Mass of leaf (g) | 0,19 | 0,60* | 0,98** | 0,55 | 0,60* | 1 | | |
| Number of leaves | 0,50 | 0,70 | 0,89** | 0,57 | 0,74** | 0,87** | 1 | |
| Number of flowers | 0,36 | 0,40 | 0,80** | 0,53 | 0,84** | 0,75** | 0,75** | 1 |

*,** F test significant in level $p<0.05$, $p<0.01$
*,** F test značajan na razini $p<0.05$, $p<0.01$

cm) and much higher potassium supply levels (128.93 – 130.77 ppm at a depth of 5 – 10 cm and 146.83 – 165.45 ppm at 0-5 cm)

[1, 17] while researching the soil properties in natural violet habitats came to similar results: acidic soils (pH 4.1-5.6) and alkaline soils (pH 7.8), significant amount of organic matter (5.8 %), phosphorus insufficiency and higher level of potassium.

Based on determined correlation coefficients the strength and direction of correlation between the most significant morphological properties of plants were established. Using simple correlation coefficients a significant correlation was established.

Table 6. shows that the mass of root, diameter of plant, mass of leaves and number of leaves are in positive correlation with the mass of the whole plant. A strong correlation was established between the mass of root and diameter of plant, as well as between the mass of plant and mass of flowers. There was a very strong correlation between the number of leaves, mass of plant and number of flowers, as well as the number of flowers and number of leaves, whereas a complete correlation was established between the mass of leaf and the mass of the whole plant.

Correlations between examined properties of violets and soil properties indicate that potassium concentration in plant root was in a strong positive correlation (0.76**) with potassium in the soil, whereas phosphorus concentration in the flower ($P<0.05$) was in significant positive correlation with phosphorus in the soil.

## CONCLUSIONS

Soil analysis on all locations indicates that the soils are extremely heterogeneous in their reactions (pH 4.34 – 7.03), well supplied with humus (3.52 – 10. 86 %) and therefore suitable for cultivation of the sweet violet. Potočec locations show extremely high supply levels of physically active phosphorus and potassium in the soil, which also affected phosphorus and potassium concentrations in all plant parts of the populations. The lowest supply of the stated nutrients, both in plants and in the soil, is established at Žabno locations. Based on determined correlation coefficients, correlations between the examined properties of violets and soil properties are established, which indicates that the presence of each element in the soil affects the mineral composition of the plant. Moreover, a strong positive correlation (0.62 - 0.98) is determined between the individual plant parts and the mass of the whole plant.

Chemical analysis of the soil composition and its impact on the growth of violets could help in the selection of soil and substrates for cultivation of the sweet violet as horticultural, medicinal or edible plant. Cultivation of this species on family farms would reduce devastation of self-growing populations in their natural habitats, and at the same time the production of the plant as edible and

medicinal one could be improved.

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