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# Properties of cambisol in beech-fir forests of Velebit and Gorski Kotar

**DARKO BAKŠIĆ**
**NIKOLA PERNAR**
**JOSO VUKELIĆ**
**DARIO BARIČEVIĆ**

Faculty of Forestry
University of Zagreb
Svetošimunska 25
p. p. 422, 10002 Zagreb, Croatia

**Correspondence:**
Darko Bakšić
Faculty of Forestry
University of Zagreb
Svetošimunska 25
p. p. 422, 10002 Zagreb, Croatia
E-mail: baksic@sumfak.hr

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## Abstract

***Background and Purpose:*** *Cambisol is the best represented soil in Dinaric beech-fir forests. The paper presents and compares properties of cambisol in the areas of northern Velebit and Gorski Kotar.*

***Materials and Methods:*** *Localities with cambisols over limestone were selected on Velebit and Gorski Kotar. All the localities were reconnoitred and their affiliation to the association* Omphalodo-Fagetum *was established. Soil samples were taken in 47 pedological profiles. The following were analyzed: pH values, organic carbon and total nitrogen content, nitrate and ammonia nitrogen content, physiologically active phosphorus and potassium content, and soil texture. The data were statistically processed by Statistica 7.1.*

***Results:*** *Cambisol on Velebit is deeper than cambisol in Gorski Kotar. A lower pH value was recorded in cambisol on Velebit. Cambisols of Velebit and Gorski Kotar belong to humus-rich soils and soils that are very rich in total nitrogen content. A statistically significantly higher* $NH_4^+$ *content was recorded within the entire cambisol profiles in Gorski Kotar. The A horizon of cambisol profiles opened on Velebit is poorly supplied with physiologically active phosphorus, whereas in Gorski Kotar the supply ranges from poor to good. With regard to texture, cambisol in the A horizon on Velebit and in Gorski Kotar is predominantly silty clay loam and in the B horizon it is light clay.*

***Conclusion:*** *Based on the obtained results, the pH value of cambisol on Velebit is lower (more acid) than in all the other localities in Gorski Kotar.*

*In terms of* $NH_4^+$ *content, a statistically significant difference between Velebit and Gorski Kotar was established with the t-test and the variance analysis.*

## INTRODUCTION

In forests of the Republic of Croatia silver fir occurs in six clearly defined and described forest communities over approximately 200,000 ha.

The most important among them is the Dinaric beech-fir forest (*Omphalodo-Fagetum* Marinček *et al.* 1993). It occurs in the Dinaric

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[1] In terms of WRB classification it is Leptic Cambisol (Humic), and in terms of most other classifications it is calmbisol over limestone

vegetation zone of the European altimontane vegetation belt within the Euro-Siberian – North-American region. The tree layer regularly features *Abies alba* and *Fagus sylvatica*, with *Picea abies* and *Acer pseudoplatanus* also making frequent appearances. The most important species in the shrub layer, apart from the species from the tree layer, are *Rhamnus fallax*, *Lonicera alpigena*, *Lonicera xilosteum*, *Daphne mezereum*, *Daphne laureola*, *Sorbus aucuparia* and others. The ground vegetation is dominated by characteristic species of the alliance *Aremonio-Fagion* (I. Horvat 1938) Török, Podani et Borhidi 1989 and the order *Fagetalia* Pawl. in Pawl. *et al.* 1928. Species of the Illyrian floristic geoelement, which differentiate Dinaric beech-fir forests from other related European forests, have particular significance. These species are *Aremonia agrimonoides*, *Omphalodes verna*, *Lamium orvala*, *Calamintha grandiflora*, *Hacquetia epipactis*, *Cardamine trifolia*, *Cardamine enneaphyllos*, *Cyclamen purpurascens*, *Scopolia carniolica*, *Euphorbia carniolica*, *Geranium nodosum* and others. They determine the syntaxonomic affiliation of the association *Omphalodo-Fagetum* to the suballiance *Lamio orvalae-Fagenion* Borhidi ex Marinček et al. 1993 within the alliance *Aremonio-Fagion (1, 2, 3, 4)*. Dinaric beech-fir forests in Croatia occur in Lika, which is dominated by the massifs of Velebit and Plješevica, then in Velika and Mala Kapela, and in Gorski Kotar.

The synergy of pedogenetic factors such as parent material, climatic conditions and vegetation, relief and, finally, anthropogenic impacts have over time led to the formation of soils with varying physiography and taxonomic affiliations, which are currently covered by Dinaric beech-fir forests.

The parent material in Dinaric beech-fir forests is for the most part composed of limestones and dolomites. Their solubility and the quantity of insoluble residue, as well as the layered character of the parent rock is an invaluable factor in understanding the role of limestones and dolomites in pedogenesis. The thickness, distinctness, homogeneity and position of layers on the rocks of identical lithological and geological affiliation are responsible for the formation of related, but sometimes highly different soils in the physiographic sense *(5)*. Climatic conditions have a direct influence on both the soil and the vegetation. The position in the relief is important due to the specific conditions of soil formation and is manifested through the distribution of thermal energy and water in the soil.

According to pedological research conducted within typological research, the soils occurring in the distribution range of beech-fir forests are luvic cambisol, luvisol and colluvic regosol in the lower parts of slopes and in sinkholes, different varieties of cambisol on slopes, and mollic leptosol (brunic and humic) on limestone or dolo-

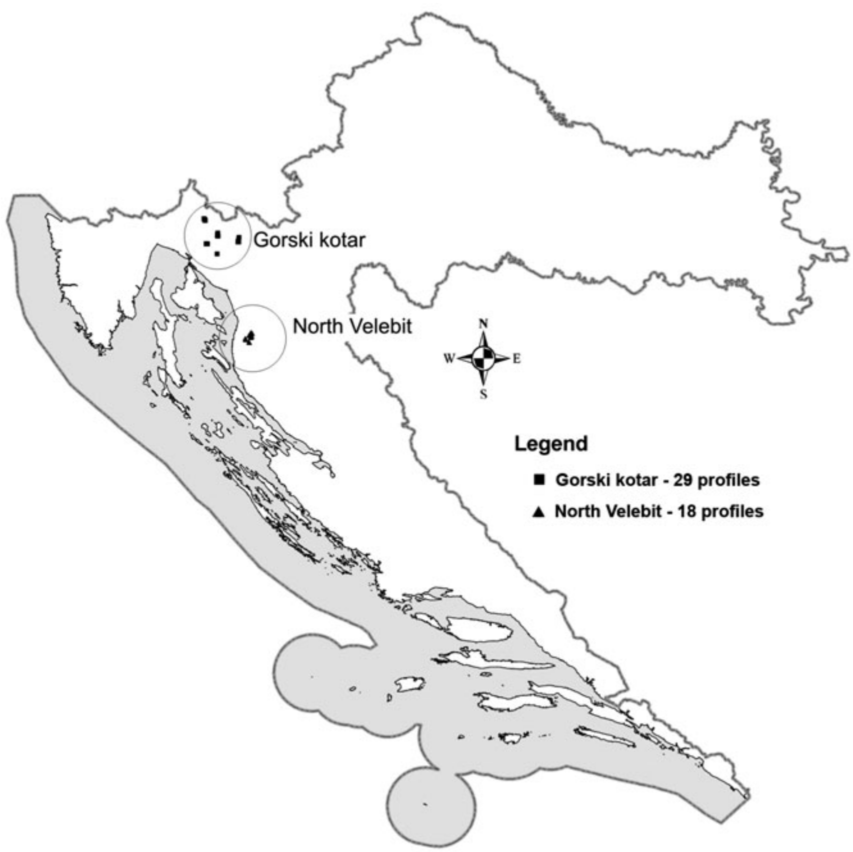


**Figure 1.** *Research area.*

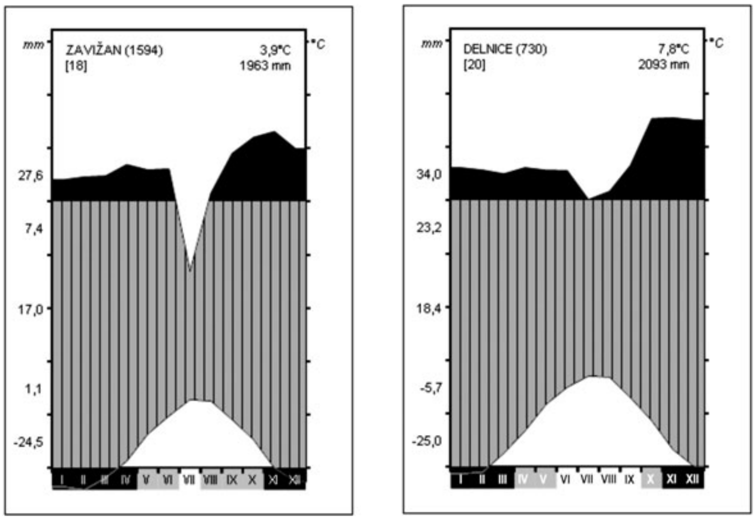


**Figure 2.** *Climatic diagrams (according to Walter) for North Velebit (Zavižan) and Gorski Kotar (Delnice).*

mitic blocks, ridges and top parts of slopes, while rendzic leptosol is found on dolomite gruses *(6, 7, 8)*.

Based on the 106 pedological profiles opened in the community *Omphalodo-Fagetum*, the best represented soil was found to be cambisol on limestone with 45% (48 profiles), followed by very similarly represented cambisol on dolomite with 17% (18 profiles), mollic leptosol on limestone with 16% (17 profiles), and luvisol with 13% (14 profiles). Rendzic leptosol on dolomite with 8% (9 profiles) was found to be the least represented soil *(9, 10, 11)*.

The objective of this research was to determine properties of the best represented soil type in beech-fir forests – cambisol on limestone, and compare physiographic soil features of the two areas inhabited by large, coherent complexes of beech-fir forests: Velebit and Gorski Kotar.

## RESEARCH AREA

The paper encompasses pedological profiles (47 profiles) opened in cambisol over limestone in the distribution range of Dinaric beech-fir forest on northern Velebit and in Gorski Kotar. On northern Velebit, field pedological research was conducted in the management units Nadžak Bilo (4 profiles), Kordinac (6 profiles) and Jelovac (8 profiles), all located in Krasno Forest Office. In Gorski Kotar, field pedological research was undertaken in the management units Brloško (9 profiles) and Bitoraj (1 profile) in Fužine Forest Office, in the management unit Vršice (8 profiles) in Gerovo Forest Office, in the management unit Delnice (6 profiles) in Delnice Forest Office, and in the management unit Ravna Gora (5 profiles) in Ravna Gora Forest Office (Figure 1).

Pedological profiles on northern Velebit were opened at altitudes ranging from 965 m to 1,240 m, and in Gorski Kotar at altitudes from 710 m to 1,140 m. Both northern and southern expositions were equally represented.

The climatic conditions prevailing in the area of Northern Velebit and Gorski Kotar are best expressed by the data of climatological stations at Zavižan and Delnice. It should be pointed out, however, that the climatological station of Zavižan is situated above the belt of beech-fir forests, thus contributing to the slightly lower average annual air temperature values (Figure 2). According to Bertović and Seletković *(12, 13),* the average air temperature for the Dinaric beech-fir forests occurring in the belt between 500 and 1,200 m is about 7.5 °C, and the average precipitation quantity is 2,243 mm.

## MATERIAL AND METHODS

Prior to field research, geological and pedological maps were used to select the localities with a limestone lithological base that supports cambisol within the distribution range of beech-fir forests on Velebit and in Gorski Kotar.

In order to determine phytocoenological affiliations of the localities in which pedological profiles were opened, all were reconnoitred and their affiliation to the association *Omphalodo-Fagetum* was established. These sites are characterized by relatively low variability in floral composition and a significant proportion of diagnostically important species.

Based on the data taken from management plans for the compartments in which research was conducted, the growing stock per hectare is more or less equal, amounting to 351.9 $m^3$/ha for the area of Northern Velebit and 353.8 $m^3$/ha for that of Gorski Kotar; however, the tree mixture ratios are different. Of the principal tree species, beech accounts for 54.9% and fir for 45.1% of the tree mixture ratio in Northern Velebit, while in the tree mixture ratio of Gorski Kotar beech accounts for 31.4%, fir for 60.0%, other hard broadleaves (predominantly sycamore and Wych elm) for 8.2%, and spruce for 0.4%.

Soil samples were taken by pedogenetic horizons A and B in the pedological profile. The profiles were opened in the outer third crown projection of the dominant tree in the middle of the slope. Soil analysis was made on

**TABLE 1**

T-test of soil parameters of cambisol on Velebit and in Gorski Kotar.

| Variable | Unit | VELEBIT N | Mean | Min | Max | Std.Dev. | GORSKI KOTAR N | Mean | Min | Max | Std.Dev. | t-value | df | p | F-ratio Variances | p Variances | U | Z | p-level |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Slope | % | 18 | 46,4 | 30,00 | 60,00 | 9,17887 | 29 | 37,4 | 20,00 | 56,00 | 8,9106 | 3,3059 | 45 | 0,00187 | 1,06112 | 0,864337 | | | |
| Surface rockiness | % | 18 | 27,0 | 5,00 | 60,00 | 18,55992 | 29 | 11,7 | 0,00 | 50,00 | 13,7241 | 3,2371 | 45 | 0,00227 | 1,82889 | 0,152058 | | | |
| Surface stoniness | % | 18 | 1,9 | 0,00 | 5,00 | 1,73111 | 29 | 2,2 | 0,00 | 15,00 | 4,0678 | -0,2927 | 45 | 0,77108 | 5,52161 | 0,000565 | 207,0000 | 1,18176 | 0,23730 |
| **A horizon** | | | | | | | | | | | | | | | | | | | |
| Horizon thickness | cm | 18 | 7,3 | 5,00 | 13,00 | 2,06611 | 29 | 6,9 | 3,00 | 13,00 | 2,5602 | 0,5473 | 45 | 0,58689 | 1,53552 | 0,357803 | | | |
| pH ($H_2O$) | | 18 | 5,60 | 4,62 | 6,30 | 0,50727 | 29 | 6,06 | 5,15 | 7,19 | 0,6658 | -2,4985 | 45 | 0,01619 | 1,72246 | 0,242976 | | | |
| pH ($CaCl_2$) | | 18 | 5,21 | 4,23 | 6,18 | 0,61220 | 29 | 5,65 | 4,72 | 7,08 | 0,7171 | -2,1630 | 45 | 0,03589 | 1,37222 | 0,500722 | | | |
| Org C | g kg-1 | 18 | 91,6 | 55,50 | 163,15 | 26,12198 | 29 | 94,9 | 50,25 | 151,19 | 24,2053 | -0,4420 | 45 | 0,66058 | 1,16464 | 0,700839 | | | |
| Total N | g kg-1 | 18 | 6,1 | 4,70 | 12,90 | 1,82065 | 29 | 6,8 | 4,02 | 10,20 | 1,7850 | -1,3688 | 45 | 0,17785 | 1,04039 | 0,899861 | | | |
| C:N | | 18 | 15 | 9,74 | 20,15 | 2,98881 | 29 | 14 | 7,28 | 17,79 | 2,5944 | 1,3000 | 45 | 0,20022 | 1,32721 | 0,492894 | | | |
| $NO_3$ | mg kg-1 | 18 | 3,2 | 1,27 | 6,46 | 1,36056 | 29 | 2,6 | 0,36 | 5,06 | 1,2872 | 1,7062 | 45 | 0,09486 | 1,11723 | 0,772745 | | | |
| $NH_4$ | mg kg-1 | 18 | 36,4 | 10,09 | 81,87 | 20,15452 | 29 | 74,0 | 34,45 | 119,50 | 19,8640 | -6,2621 | 45 | 0,00000 | 1,02946 | 0,918951 | | | |
| Mineral N | mg kg-1 | 18 | 39,6 | 12,03 | 87,20 | 20,90902 | 29 | 76,5 | 36,96 | 123,59 | 20,4222 | -5,9608 | 45 | 0,00000 | 1,04824 | 0,886301 | | | |
| $P_2O_5$ | mg kg-1 | 18 | 20,9 | 0,00 | 61,10 | 21,48767 | 29 | 69,6 | 0,00 | 241,10 | 68,8709 | -2,9045 | 45 | 0,00568 | 10,27290 | 0,000007 | 131,0000 | -2,84497 | 0,00444 |
| $K_2O$ | mg kg-1 | 18 | 174,8 | 76,00 | 370,00 | 61,44587 | 29 | 160,1 | 89,00 | 275,00 | 49,2873 | 0,9023 | 45 | 0,37173 | 1,55423 | 0,292545 | | | |
| $CaCO_3$ | g kg-1 | 0 | | | | | 4 | 20,3 | 14,23 | 25,96 | 4,8038 | | 2 | | 0,00000 | 1,000000 | | | |
| Particle size distribution >2 mm | mas. % | 18 | 1,8 | 0,70 | 4,30 | 1,00308 | 29 | 3,5 | 1,30 | 8,30 | 1,8119 | -3,6281 | 45 | 0,00073 | 3,26297 | 0,013387 | 86,5000 | -3,81883 | 0,00013 |
| Particle size distribution 0.2-2.0 mm | mas. % | 18 | 39,4 | 23,70 | 50,70 | 6,14264 | 29 | 38,6 | 16,30 | 62,20 | 10,0438 | 0,2717 | 45 | 0,78708 | 2,67352 | 0,037510 | | | |
| Particle size distribution 0.02-0.2 mm | mas. % | 18 | 39,4 | 24,70 | 57,20 | 8,04470 | 29 | 38,7 | 11,70 | 64,40 | 11,3849 | 0,2473 | 45 | 0,80578 | 2,00281 | 0,136926 | | | |
| Particle size distribution <0.002 mm | mas. % | 18 | 19,4 | 4,50 | 26,10 | 5,74570 | 29 | 19,2 | 8,80 | 30,80 | 5,4475 | 0,1307 | 45 | 0,89656 | 1,11248 | 0,780237 | | | |
| Ch:Cf | | 8 | 0,86 | 0,36054 | 1,2809 | 0,34032 | 13 | 0,78 | 0,25503 | 1,4679 | 0,41217 | 0,45449 | 19 | 0,654627 | 1,466886 | 0,628285 | | | |
| **B horizon** | | | | | | | | | | | | | | | | | | | |
| Horizon thickness | cm | 18 | 45,7 | 32,00 | 70,00 | 9,42462 | 29 | 40,9 | 22,00 | 55,00 | 7,96297 | 1,87393 | 45 | 0,06744 | 1,40081 | 0,417453 | | | |
| pH ($H_2O$) | | 18 | 6,31 | 5,28 | 7,25 | 0,69593 | 29 | 6,64 | 5,13 | 7,53 | 0,65275 | -1,66535 | 45 | 0,10279 | 1,13666 | 0,742661 | | | |
| pH ($CaCl_2$) | | 18 | 5,71 | 4,49 | 6,88 | 0,84367 | 29 | 6,11 | 4,49 | 7,14 | 0,74464 | -1,71422 | 45 | 0,09337 | 1,28368 | 0,542814 | | | |
| Org C | g kg-1 | 18 | 33,1 | 17,25 | 54,60 | 10,51272 | 29 | 30,8 | 12,30 | 62,25 | 11,18100 | 0,67765 | 45 | 0,50146 | 1,13118 | 0,807915 | | | |
| Total N | g kg-1 | 18 | 3,9 | 2,90 | 5,60 | 0,79576 | 29 | 3,2 | 1,79 | 5,40 | 0,90873 | 2,49638 | 45 | 0,01628 | 1,30407 | 0,574958 | | | |
| C:N | | 18 | 9 | 4,79 | 17,61 | 3,19174 | 29 | 10 | 2,86 | 21,46 | 4,26847 | -1,21809 | 45 | 0,22954 | 1,78851 | 0,212031 | | | |
| $NO_3$ | mg kg-1 | 18 | 2,2 | 0,36 | 5,29 | 1,31591 | 29 | 1,6 | 0,29 | 3,75 | 0,88965 | 1,64294 | 45 | 0,10737 | 2,18784 | 0,064167 | | | |
| $NH_4$ | mg kg-1 | 18 | 19,2 | 5,59 | 50,44 | 11,12853 | 29 | 43,4 | 17,85 | 77,60 | 13,50370 | -6,36547 | 45 | 0,00000 | 1,47241 | 0,407637 | | | |
| Mineral N | mg kg-1 | 18 | 21,4 | 7,06 | 54,69 | 11,70193 | 29 | 45,1 | 19,84 | 78,17 | 13,65870 | -6,08453 | 45 | 0,00000 | 1,36240 | 0,510848 | | | |
| $P_2O_5$ | mg kg-1 | 18 | 2,5 | 0,00 | 17,70 | 5,76414 | 29 | 28,5 | 0,00 | 124,00 | 37,65092 | -2,90367 | 45 | 0,00570 | 42,66596 | 0,000000 | 133,0000 | -2,80120 | 0,00509 |
| $K_2O$ | mg kg-1 | 18 | 90,9 | 48,00 | 250,00 | 45,64115 | 29 | 75,3 | 38,00 | 135,00 | 20,60388 | 1,60353 | 45 | 0,11581 | 4,90699 | 0,000213 | 203,5000 | 1,25835 | 0,20826 |
| $CaCO_3$ | g kg-1 | 4 | 6,0 | 2,09 | 10,47 | 3,91791 | 9 | 21,4 | 1,26 | 92,10 | 29,52211 | -1,01664 | 11 | 0,33116 | 56,77862 | 0,006894 | 13,5000 | -0,69437 | 0,48745 |
| Particle size distribution >2 mm | mas. % | 18 | 0,6 | 0,30 | 1,50 | 0,27842 | 29 | 2,3 | 0,30 | 8,90 | 2,07899 | -3,39577 | 45 | 0,00144 | 55,75878 | 0,000000 | 70,0000 | -4,17992 | 0,00003 |
| Particle size distribution 0.2-2.0 mm | mas. % | 18 | 27,3 | 12,30 | 42,50 | 7,44169 | 29 | 27,0 | 1,40 | 39,30 | 8,52829 | 0,12149 | 45 | 0,90384 | 1,31335 | 0,564296 | | | |
| Particle size distribution 0.02-0.2 mm | mas. % | 18 | 40,2 | 25,10 | 58,30 | 8,80866 | 29 | 38,4 | 24,00 | 56,50 | 8,84136 | 0,66960 | 45 | 0,50654 | 1,00744 | 1,000000 | | | |
| Particle size distribution <0.002 mm | mas. % | 18 | 31,9 | 21,70 | 49,20 | 8,01586 | 29 | 32,3 | 15,20 | 52,80 | 8,05385 | -0,16184 | 45 | 0,87216 | 1,00950 | 1,000000 | | | |

**Table 2.**

Variance analysis for the variables pH, $NH_4^+$ and $P_2O_5$ by forest offices (localities).

| **A horizon** | | | **B horizon** | |
|---|---|---|---|---|
| Effects | Degr. of Freed. | | Effects | Degr. of Freed. |
| Sumarija-lok | 4 | | Sumarija-lok | 4 |
| Error | 41 | | Error | 42 |
| Total | 45 | | Total | 46 |
| | | **A horizon** | | |
| Variable | Unit | F | p | Tukey HSD test |
| pH ($H_2O$) | | 1,949 | 0,120594 | |
| pH ($CaCl_2$) | | 1,588 | 0,195761 | |
| **$NH_4$** | **mg $kg^{-1}$** | **11,3068** | **0,000003** | **(K) (F,G,D,RG)** |
| **$P_2O_5$** | **mg $kg^{-1}$** | **12,85336** | **0,000001** | **(F) (K,G,D,RG)** |
| | | **B horizon** | | |
| Variable | Unit | F | p | Tukey HSD test |
| **$NH_4$** | **mg $kg^{-1}$** | **10,0154** | **0,000009** | **(K) (F,G,D,RG)** |
| **$P_2O_5$** | **mg $kg^{-1}$** | **15,49383** | **0,000000** | **(F) (K,G,D,RG)** |

air-dried samples. The pH value of soil suspension in water, and the suspension of soil in 0.01 M $CaCl_2$ (ISO 10390) was determined, and so was the organic carbon content using the bichromatic method according to Thurin. Total nitrogen content was determined by burning with the Kjeldahl procedure and distillation by Bremner, nitrate nitrogen content was established using spectrophotometric method after extraction in 0.2 M $K_2SO_4$ and dyeing with phenoldisulphonic acid, ammonia nitrogen content was determined using spectrophotometric method after extraction in 0.2 M $K_2SO_4$ and dyeing with the Nessler reagent, the content of physiologically active forms of potassium and phosphorus was obtained with the Al-method, and particle size distribution was determined after extraction in 0.1 M $Na_4P_20_7$ using the pipette method. Descriptive statistics were given for all the analyzed variables: the number of samples, arithmetic mean, and minimum, maximum and standard deviation.

Mutual differences for the observed variables (pedological parameters) were tested with the t-test if variable homogeneity condition was satisfied (F-test), or non-parametrically using Mann-Whitney U test if variance homogeneity condition was not satisfied (14). For all testing operations, I type error (a) of 5% was considered statistically significant.

After performing the t-test, variance analysis was performed for physiographic components per forest offices. The analysis showed statistically significant differences in the t-test (pH, $NH_4^+$ and $P_2O_5$ content). As the area of Gorski Kotar was represented with 4 forest offices (4 isolated localities), we wanted to establish whether there was a statistically significant difference between the Velebit locality and each of the localities in Gorski Kotar. When the variance analysis showed a statistically significant difference for a particular variable between the localities, Tukey's Multiple Post Hoc Test was used to determine which localities were responsible for the difference *(15, 16, 17)*.

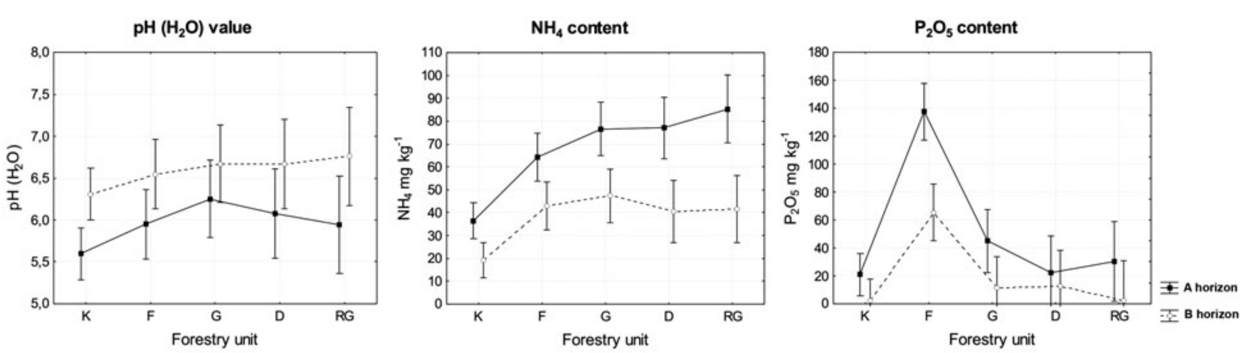


**Figure 3.** *Average pH ($H_2O$) values, values of $NH_4^+$ and $P_2O_5$ contents with regard to the localities (forest offices) under study. Velebit is represented with the forest office of Krasno (K), while Gorski Kotar is represented with forest offices of F (Fužine), G (Gerovo), D (Delnice) and RG (Ravna Gora).*

## RESULTS

As a rule, the average value of terrain slope on which cambisol is formed is higher on Velebit than in Gorski Kotar and reaches 46% (20.7°) as opposed to 37% (16.7°) in Gorski Kotar. Surface rockiness is more distinct on Velebit and amounts to 27% on average, compared to 12% in Gorski Kotar (Table 1).

The cambisol solum depth in beech-fir forests on Velebit ranged from 37 to 80 cm, whereas in Gorski Kotar it was slightly lower and varied between 27 and 66 cm. The average depth of the top mineral horizon (A) in cambisol on Velebit was 7.3 cm, and of the subsurface (B) it was 45.7 cm, while the average depth of the A horizon in Gorski Kotar was slightly lower (6.91 cm), and the average depth of the B horizon was also lower and amounts to 40.9 cm (Table 1).

In terms of soil reaction *(18)* in the A horizon, cambisol on Velebit was moderately acid. The average pH ($H_2O$) value was 5.60 and in the B horizon it was weakly acid, with average pH ($H_2O$) value reaching 6.31. The reaction of cambisol in the A horizon in Gorski Kotar was weakly acid with average pH ($H_2O$) value of 6.06, while in the B horizon it was very weakly acid with average pH ($H_2O$) value of 6.64. A statistically significantly lower pH ($H_2O$) and pH ($CaCl_2$) values were found in the A horizon cambisol on Velebit in relation to the A horizon cambisol in Gorski Kotar, while there were no statistically significant differences in the soil reaction in the B horizon (Table 1). In general, cambisol on Velebit was on average more acid within the entire profile. If we compare the pH value of cambisol on Velebit separately with each of the localities (forest offices) in Gorski Kotar, it is still more acid, but there is no statistically significant difference any more. The locality of Gerovo (Figure) has distinctly the highest pH value (Table 2, Figure 3).

In terms of organic carbon content in the A horizon, cambisol on both Velebit and in Gorski Kotar was richly humous *(19)*. In terms of total nitrogen *(20),* both were very rich. The average value of organic carbon in cambisol on Velebit was 91.5 g $kg^{-1}$ and was slightly lower than the average organic carbon content in Gorski Kotar, which is 94.9 g $kg^{-1}$. Total nitrogen content in the A horizon of cambisol on Velebit was also lower and amounted to 6.1 g $kg^{-1}$, while in Gorski Kotar it was 6.8 g $kg^{-1}$. The C/N ratio *(21)* was favorable and amounted to 14 in cambisol on Velebit and to 15 in cambisol in Gorski Kotar. As for humic and fulvic acid fraction ratio Ch:Cf in the A horizon, there were no statistically significant differences between cambisol on Velebit and that in Gorski Kotar (Table 1).

A statistically significantly higher (twice as high on average) $NH_4^+$ content was found within the entire cambisol profile in Gorski Kotar in relation to cambisol on Velebit. If cambisol on Velebit is compared with individual localities in Gorski Kotar, it differs statistically significantly from all localities (Table 1, Table 2, Figure 3).

Horizon A of all the profiles opened in cambisol on Velebit was poorly supplied with physiologically active phosphorus, whereas in Gorski Kotar the supply ranged from poor to good. A statistically significantly increased content of physiologically active phosphorus was determined, which was 3 times higher in the A horizon and 10 times higher in the B horizon in Gorski Kotar than average. A supply of physiologically active potassium varied from poor to good and was slightly higher in cambisol on Velebit. In terms of physiologically active phosphorus supply, the locality of Fužine the highest average $P_2O_5$ value (Figure 3).

As for texture, cambisol in the A horizon of both Velebit and Gorski Kotar was predominantly silty clay loam and that in the B horizon was light clay (Table 1).

## DISCUSSION AND CONCLUSIONS

The values obtained for the properties of dominant soil in beech-fir forests correspond to previous pedological research *(6, 7, 8, 22)*.

Since all the profiles were opened in the central part of a slope, this paper incorporates mainly medium deep to deep cambisols. With regard to cambisol productivity, Martinović *(23)* classifies this soil type into moderately productive soils. Cestar *et al. (7)* and Komlenović and Cestar *(24)* state that soil depth is one of the most important soil properties for fir productivity on karst. Although cambisols on Velebit are somewhat deeper, the recorded difference is not statistically significant. It should be pointed out that Velebit is much rockier; therefore, the productive soil surface is smaller.

Although the t-test of soil reaction in the A horizon showed statistically significant differences for Velebit and Gorski Kotar, no such conclusion could be drawn from variance analyses by localities. If viewed separately, all localities in Gorski Kotar have a higher pH value than Velebit, but none differs statistically significantly. Based on the obtained results, the soil reaction of cambisol on Velebit is lower (more acid) than in all localities in Gorski Kotar.

The t-test of the content of ammonia form of nitrogen and the variance analysis showed a statistically significant difference between Velebit and Gorski Kotar, and Velebit and all individual localities in Gorski Kotar. Martinović states that the status of mineral (plant available) forms of nitrogen ($NH_4^+$, $NO_3^-$, $NO_2^-$) in Croatian natural forests has been inadequately investigated so far, and that no study in Croatian literature deals with this problem matter. In the light of obtained results, it would be interesting to continue research in this direction. All recent insights indicate that the concentration and relationships of nitrogen mineral forms are currently the most dynamic geochemical phenomena.

An important link in the chain of biological cycle of mineral elements and nitrogen are the quantity and chemism of fallen tree leaves and needles. A more favorable soil reaction in Gorski Kotar, as well as the double content of the ammonia form of nitrogen, can be attributed to specific features and proportions of particular tree species in the tree mixture ratio. In the area of Gorski Kotar, the tree mixture ratio is dominated by fir, with sycamore and Wych elm also being present. According to research by Martinić, these tree species have more favorable bioelement (N, P, K, Ca, Mg) content in needles and leaves than beech *(21)* which is the best represented species in the tree mixture ratio of Northern Velebit. Moreover, climatic conditions in Northern Velebit are unfavorable: the temperature is lower and snow cover remains for prolonged periods, which affects the dynamics of humification and humization, as well as the formation of acid humus forms.

In the area of Gorski Kotar, t-test revealed the statistically significantly increased phosphorus content in the entire profile. Variance analysis showed that this difference was due to the locality Fužine which has a significantly higher content of physiologically active phosphorus than all the other localities.

Cambisols on Velebit and in Gorski Kotar have very similar textural characteristics. Differences in the coarse sand content may be neglected since the proportion of this fraction is very small (Table 1). From the aspect of physical and chemical soil properties, the clayey fraction is the most important. In cambisols, it is almost identical within the entire profile in both localities.

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