PRACE GEOGRAFICZNE, zeszyt 105

Instytut Geografii UJ
Kraków 2000

Marek Drewnik

ECTOHUMUS HORIZONS AND THE RATE OF ORGANIC MATTER DECOMPOSITION IN THE CARPATHIAN SOILS

Abstract: The paper presents the properties of humus horizons of the soils in particular geoecological belts in the Polish Carpathians. The research was carried out using the cellulose filters method in the Tatras, Babia Góra, Gorce and Bieszczady Mts as well as in the Wieliczka Foothills. The forming of ectohumus horizons is shown as an effect of a reduced rate of organic matter decomposition and the impact of lithological, climatic and vegetation factors is discussed.

Key words: mountain soils, ectohumus horizons, decomposition.

1. Introduction

One of the factors determining the specifity of mountain soils is their humus horizons – different from the ones in lowland soils.

In 1933 Wąsowicz described the humus of the mountain soils of the Tatras as „climatogenic" (Wąsowicz 1933). More recent research, however, indicates that the diversity of the properties of forest soils humus is related to bedrock and vegetation (Niemyska-Łukaszuk 1977). Humus horizons in relation to climatic and vegetation conditions were described in the crystalline and limestone parts of the Tatras (Skiba 1977, 1983). In the Outer Carpathians humus horizons were described in the Babia Góra (Adamczyk 1983), Gorce (Adamczyk 1966) and Western Bieszczady Mts areas (Drewnik 1997). A detailed characteristics of mountain soils humus was also presented for the Sudety Mts (Kowaliński et al. 1973) and transformations of humus compounds were described in the degraded ecosystems in the Karkonosze Mts (Drozd 1995). The properties of ectohumus horizons in the soils of different mountain regions in Poland were compared in 1997 (Skiba et al. 1997).

Development of humus horizons is connected with the issue of the rate of organic matter decomposition. The relationship between the rate of organic matter decomposition and the altitude above sea level was described by Shanks and Olson (1961) for the Appalachian forest soils. Meetenmeyer (1978), determining the diversity of organic matter decomposition rate in five areas with different climatic conditions, pointed out the importance of climate and the role of the content of lignin in the substrate in that issue.

Information on the rate of organic matter decomposition of the soils of the Tatras (Grodzińska-Jurczak 1994) and Karkonosze Mts (Fischer, Kidawa 1992) can be found in ecological papers. The research, however, was aimed at the determination of the influence of pollution on the environment and the specifity of the mountain soils pedogenesis was not taken into account.

The purpose of this paper is to show the properties of ectohumus horizons in mountain soils against the background of the rate of the decomposition of organic matter.

2. Objects and methods of research

22 soil profiles located in several areas of the Polish Carpathians were chosen for the study (Fig. 1). They represent soils characteristic of a given region and altitude (climate and vegetation) belt (Tab. 1). The sampling points, where the soil profiles were examined, were located in transects. Laboratory analyses of soil properties (organic carbon content, total nitrogen content) were made on the samples using common pedological methods. In addition, analyses of the composition of humus compounds forms were made (Duchaufour & Jacquin method).

The rate of the organic matter decomposition was determined at the research points with the cellulose filters method (Bieńkowski 1990) in three periods: 10 weeks (Jun-Aug 1994), 20 weeks (Jun-Oct 1994) and through the whole year (Jun 1994-Jun 1995). The determination was repeated 10 times for each of the research periods at each of the points. The cellulose discs were placed vertically within the surface horizon of soil at the depth of 0-8 cm.

3. Results and discussion

On the dolomitic limestone bedrock in the Tatras different sub-types of *Rendzic Leptosols* occur, on the Tatras granitoides – *Lithic Leptosols* and *Orthic Podzols*, on the flysch of the Babia Góra, Gorce and Bieszczady – *Lithic Cambic Leptosols* and different sub-types of *Cambisols*. *Luvisols* developed on the loess-like formations of the Wieliczka Foothills and on the loess of the vicinity of Kraków – *Eutric Cambisols* (Tab. 1). The characteristic feature of the studied soils is, among others, the diversity of their humus horizons.

The properties of humus presented in the paper indicate their very distinct connection with geoecological conditions (Fig. 2).

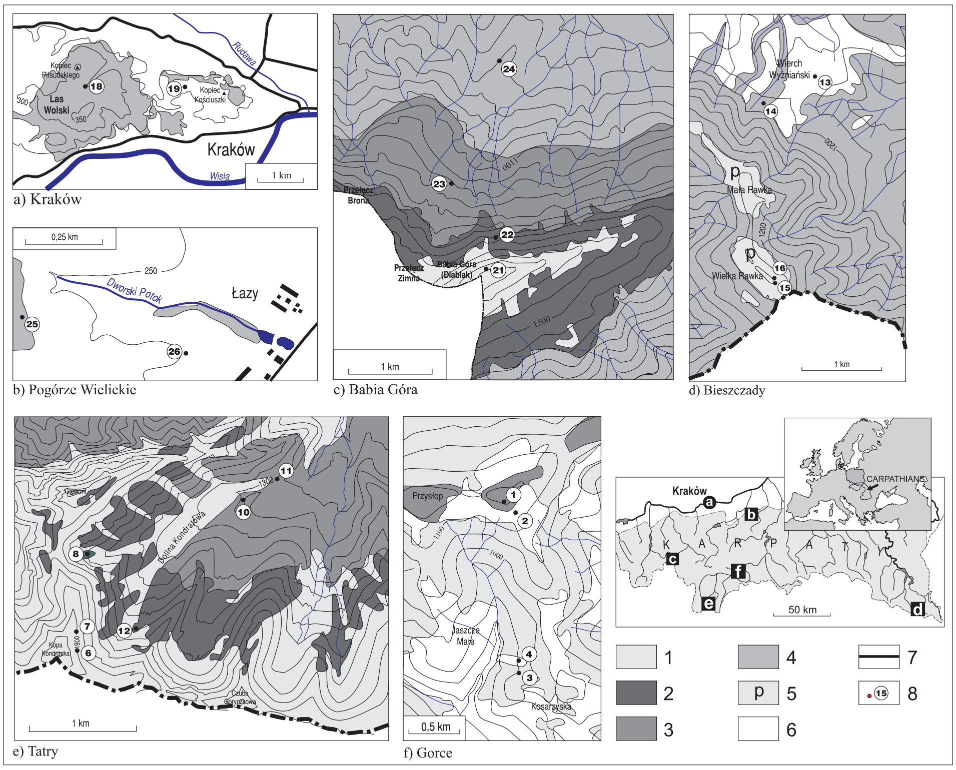

Fig. 1. Localization of the research area:
1 – alpine meadows; 2 – subalpine dwarf pine; 3 – upper forest; 4 – lower forest;
5 – „poloninas"; 6 – other land use; 7 – main roads; 8 – sampling points.

Ryc. 1. Lokalizacja obszaru badań:
1 – łąki alpejskie; 2 – kosodrzewina; 3 – lasy górnoreglowe; 4 – lasy dolnoreglowe;
5 – połoniny; 6 – pozostałe użytki; 7 – ważniejsze drogi; 8 – punkty badawcze.

3.1. Soils of the alpine meadow belt

In those soils, independently of the parent material, organic matter of the *alpine moder* type occurs. It is characterized by the organic carbon content of more than 10% and the thickness of humus horizons is more than 10 cm. The C:N ratio is around 15. The organic matter is weakly bound to the mineral part of the soil (up to 10% of the bound fraction) and the humification index is diversified from approximately 10% to ca 60%.

Tab. 1. Sampling points characterization.

Tab. 1. Charakterystyka punktów badawczych.

No. Nr	**Localization Położenie**		**Bedrock Podłoże geologiczne**	**Climatic vertical zone Piętro klimatyczne**	**Vegetation Roślinność**	**Typ i podtyp gleby**
1	Gorce	1150 m a.s.l. - npm, 3-5° E	Carpathian flysch (sandstones and shales) zlepieńce, piaskowce i łupki fliszowe	Cool chłodne	*Piceetum tatricum subnormale*	Ranker brunatny (z nadkł. butwinowym) Umbric Leptosol (Cambic Ranker)
2		1150 m a.s.l. - npm, 3-5° E			*Hieracio-Nardetum*	Ranker brunatny Lithic-Dystric Cambisol
3		905 m a.s.l. - npm, 15° W		Temperate cool umiarkowanie chłodne	*Fagetum carpaticum typicum*, wariant ubogi	Gl. brunatna kwaśna Dystric Cambisol
4		890 m a.s.l. - npm, 15° W			*Calluno-Nardetum strictae*	Gl. brunatna kwaśna Dystric Cambisol
6	Tatras - Tatry	1900 m a.s.l. - npm, 20° NE	granitoides granitoidy	Temperate cold umiarkowanie zimne	*Oreochloo distichae-Juncetum trifidi*	Ranker bielicowy Dystric Leptosol (Podzolic Ranker)
7		1900 m a.s.l. - npm, 20° NE	dolomitic limestones wapienie dolomityczne		*Festuco versicoloris-Seslerietum tatrae*	Rędzina próchniczna górska Umbric-Rendzic Leptosol
12		1600 m a.s.l. - npm, 10° N	granitoides granitoidy	Very cool bardzo chłodne	*Pinetum mughi carpaticum*	Ranker butwinowy (tangel-ranker) Dystric Leptosol (Tangel Ranker)
8		1560 m a.s.l. - npm, 10° E	dolomitic limestones wapienie dolomityczne	Very cool bardzo chłodne	*Pinetum mughi carpaticum*	Rędzina butwinowa górska (tangel-rędzina) Rendzic Leptosol (Tangel Rendzina)

10		1260 m a.s.l. - npm, 3-5° N	granitoides granitoidy	Cool chłodne	*Plagiothecio-Piceetum*	Bielica próchniczno-żelazista Orthic Podzols
11		1260 m a.s.l. - npm, 15° S	dolomitic limestones wapienie dolomityczne		*Polysticho-Piceetum*	Rędzina próchniczna górska Umbric-Rendzic Leptosol
13	Bieszczady	910 m a.s.l. - npm, 3° E	Carpathian flysch (sandstones and shales) piaskowce i łupki fliszowe	Temperate cool umiarkowanie chłodne	*Agrostietum vulgaris typicum*	Gleba brunatna właściwa wyługowana Eutric Cambisol
14		930 m a.s.l. - npm, 3-5° N			*Luzulo nemorosae-Fagetum vaccinietosum*	Gleba brunatna kwaśna typowa Dystric Cambisol
15		1300 m a.s.l. - npm, 5° NE	Carpathian flysch (sandstones and shales) piaskowce i łupki fliszowe	Cool chłodne	*Melampyro-Vaccinietum gentianetosum asclepiadeae*	Ranker butwinowy (tangel-ranker) Dystric Leptosol (Tangel Ranker)
16		1300 m a.s.l. - npm, 5° NE			meadow communities - traworośla *Calamagrostis villosa*	Ranker brunatny Lithic-Dystric Cambisol
18	Cracow - Kraków	320 m a.s.l. - npm, 3° N	loess less	Temperate warm umiarkoanie ciepłe	*Tilio-Carpinetum*	Gleba brunatna właściwa wyługowana Eutric Cambisol
19		270 m a.s.l. - npm, 3-5° N			meadow communities - traworośla	Gleba brunatna właściwa wyługowana Eutric Cambisol
21	Babia Góra	1715 m a.s.l. - npm, 10° N	Carpathian flysch (sandstones and shales) piaskowce i łupki fliszowe	Temperate cold umiarkowanie zimne	*Trifido-Supinetum*	Ranker bielicowy Lithic-Dystric Leptosol (Spodic Ranker)

Tab. 1. continued

Tab. 1. ciąg dalszy

No. Nr	Localization Położenie		Bedrock Podłoże geologiczne	Climatic vertical zone Piętro klimatyczne	Vegetation Roślinność	Typ i podtyp gleby
22	Babia Góra	1460 m a.s.l. - npm, 5° N	Carpathian flysch (sandstones and shales) piaskowce i łupki fliszowe	Very cool bardzo chłodne	*Pinetum mughi carpaticum*	Ranker butwinowy górski (tangel-ranker) Dystric Leptosol (Tangel Ranker)
23		1210 m a.s.l. - npm, 10° N		Cool chłodne	*Piceetum excelsae typicum*	Ranker butwinowy górski (tangel-ranker) Dystric Leptosol (Tangel Ranker)
24		900 m a.s.l. - npm, 5° N		Temperate cool umiarkowanie chłodne	*Dentario glandulosae-Fagetum typicum*	Gleba brunatna właściwa wyługowana Eutric Cambisol
25	Wieliczka Foothills Pogórze Wielickie	260 m a.s.l. - npm, 3-5° W	loess-like formations utwory lessopodobne	Temperate warm umiarkoanie ciepłe	*Tilio-Carpinetum*	Gleba płowa opadowo-glejowa Stagnic Luvisol
26		245 m a.s.l. - npm, 3° N			meadow communities - traworośla	Gleba płowa opadowo-glejowa Stagnic Luvisol

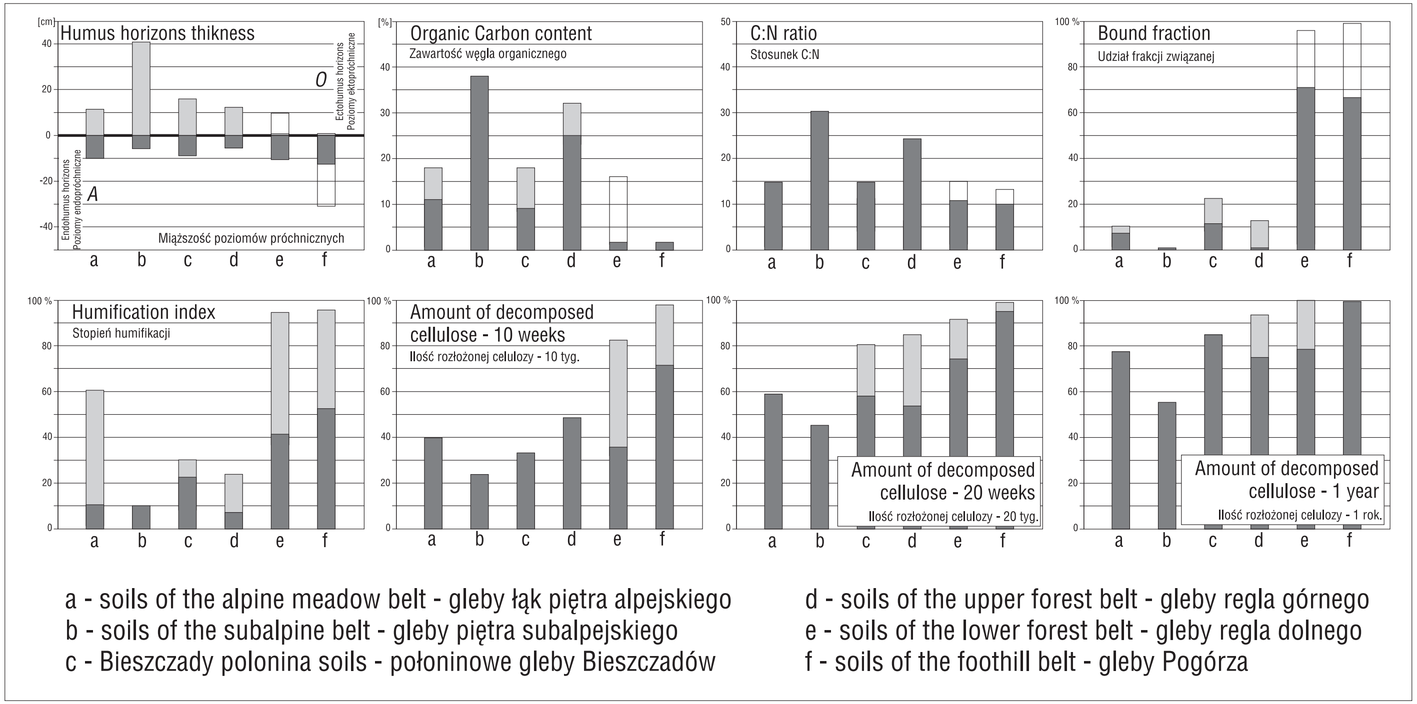

Fig. 2. Selected properties of humus horizons and decomposition rate (generalized for particular geoecological belts).

Ryc. 2. Wybrane właściwości poziomów próchnicznych oraz tempo rozkładu celulozy w badanych glebach (dane uogólnione dla poszczególnych pięter geoekologicznych).

The characteristics of those soils are a result of a reduced rate of organic matter decomposition under the conditions of severe mountain climate. The amount of decomposed cellulose within 10 weeks was around 40%, within 20 weeks around 60% and after the whole year around 80%. The lack of any thick ectohumus horizons can be explained by the susceptibility to decomposition of herb detritus with a low content of lignin and tannins. Soils located in that geoecological belt are as a rule subject to intensive morphogenetic processes that take off the soil material from the surface.

3.2. Soils of the subalpine belt

In the soils developed under dwarf pine occur very well developed ectohumus horizons - *tangelmor*. The thickness of the *Ofh* together with *Oh* and *Ah* horizons is more than 30 cm. They contain more than 30% of organic carbon. Also in that geoecological belt parent material does not influence the properties of humus horizons. Organic matter in those horizons is mainly in the free fraction. The C:N ratio is around 30. The humification index is very low - ca 10%, which manifests a low intensity of the process of humification of detritus.

The characteristics of humus horizons of those soils are a result of the influence of climatic conditions as well as vegetation (detritus) contribution in the reducing of the rate of organic matter decomposition. The amount of decomposed cellulose was the lowest of all the studied soils in each of the research periods. Within 10 weeks it was below 30%, within 20 weeks below 50% and after the whole year ca 60%. The dwarf pine supplies the soil with an acid substrate (needles) having a large content of tannins. It is difficult to break down and may also be a cause of the accumulation of weakly decomposed organic matter. The large thickness of ectohumus horizons may also be due to the stopping of erosional offtake of organic matter by the close sprouts of the dwarf pine.

In the Bieszczady *polonina* soils the thickness of ectohumus horizons including *Oh* and *Ah* is between 10 and 20 cm and also 10-centimetre-thick endohumus horizons occur here. The properties of humus of the soils being described are similar to the ones of the alpine belt soils. The humus under *Vaccinietum pocuticum myrtilli* was described as *moder* while under meadow communities as *moder/mull*.

3.3. Soils of the upper forest belt

In those soils the thickness of ectohumus horizons with *Oh* and *Ah* is slightly more than 10 cm. Under spruces occur raw humus *Ofh* horizons whose morphology is similar to that of the raw humus horizons in the subalpine zone although they are not as thick. The organic carbon content is also very high - 20-30%. Organic matter occurs mainly in the free fraction and the C:N ratio reaches 25 which manifests a low intensity of decomposition processes. The humification index in those horizons is very low (ca 7-24%) which proves a low intensity of humification processes. The humus in those soils was described as *mor* or *mor/moder*.

The specifity of humus horizons of the soils originated under the upper forest spruces is caused by the influence of climatic conditions on the reducing of the rate of organic matter decomposition and the impact of vegetation. Within 10 weeks more than 40% of cellulose was decomposed, within 20 weeks around 60% and after the whole year almost 80%. The participation of the vegetation factor in the development of humus horizons of those soils is, similarly as in the case of the subalpine belt soils under dwarf pine, due to the plant substrate – conifer needles. The lesser thickness of ectohumus horizons may be explained by milder climate conditions than in the subalpine belt – higher temperatures and a longer vegetation period which influence decomposition processes.

The likeness of humus horizons of soils developed on different bedrock (limestones, granitoides and flysch rocks) indicates a small participation of the lithological factor in the development of humus in those soils. A larger contribution should be attributed to vegetation and climatic conditions.

3.4. Soils of the lower forest belt

In those soils there are litter horizons *Ol* but not raw humus horizons *Ofh*. Humus horizons occur here mainly as endohumus ones *(A)* whose thickness is not more than 20 cm. Under the specific biotopic conditions of *Luzulo-Fagetum* different humus horizons originate – with ectohumus horizons containing between 10 and 20% of organic carbon.

Organic matter is mainly in the bound fraction and it is fairly well decomposed which is manifested by the C:N ratio of 11-13. The organic matter is generally well humificated (the humification index is above 70%). The *mull* type of humus is prevalent.

The findings indicate a connection of the properties of humus with bioclimatical factors as well as with typological soil units. Under the climatic conditions of the lower forest belt, in beech or herb communities no ectohumus horizons can accumulate. Within the period of one year almost all cellulose was decomposed. Only in the soils of beech forests with a large contribution of *Vaccinium myrtillus* occur humus horizons with properties related to the ones of the soils of higher locations. It is in those soils where a reduced rate of organic matter decomposition is observed – the amount of cellulose decomposed within the year was below 80%. It is due to the impact of vegetation, which, bound to the habitat controlled by the parent material, modifies the activity of the soil edaphon.

3.5. Soils of the foothill belt

In the studied soils the morphology of humus horizons is similar to that of the lower forest belt soils described above. The soils described in this paper represent fertile habitats and are developed on loess-like formations or on loess. In all the soils described here the type of humus was determined as *mull*.

Organic matter is well decomposed (C:N ratio of 10-13) and to a large extent bound to the mineral part of soil. The humification index varies and depends on the type of vegetation, being higher in meadow soils and lower in forest ones.

The humus horizons of the foothill belt soils are characterized by a large similarity to the ones of lowland soils. Nearly all cellulose was decomposed within the year. Any accumulation of ectohumus does not take place in those areas under *Tilio-Carpinetum* communities.

4. Conclusions

1. The rate of organic matter (cellulose filters) decomposition in the studied soils decreases with the altitude above sea level though it is the lowest in the soils of the subalpine belt developed under dwarf pine.

2. In the soils of the alpine, sub-alpine, upper forest and polonina meadow belts it is bioclimatical factors that have the crucial influence on the rate of organic matter decomposition, whereas in the lower forest and foothill belts it is determined by lithology and vegetation.

3. The occurrence of thick and acid raw humus horizons of high-mountain soils is due to the reduced rate of organic matter decomposition caused by the impact of climatic conditions and vegetation.

Translated by Andrzej Kacprzak

References

Adamczyk B., 1966, *Studia nad kształtowaniem się związków pomiędzy podłożem skalnym i glebą, Cz. II, Gleby leśne wytworzone z utworów płaszczowiny magurskiej w Gorcach*, Acta Agr. et Silv., ser. Leśna, 6, 3-48.

Adamczyk B., 1983, *Charakterystyka gleb Babiogórskiego Parku Narodowego*, [w:] *Park Narodowy na Babiej Górze, Przyroda i Człowiek*, PWN, Warszawa-Kraków, 95-120.

Bieńkowski P., 1990, *The rate of cellulose decomposition in soils of Spitsbergen tundra*, Pol. Polar Research, 11 (1-2), 39-45.

Drewnik M., 1997, *Próchnica i tempo rozkładu materii organicznej w wybranych glebach Bieszczadzkiego Parku Narodowego*, Rocz. Bieszczadzkie, 5, 175-185.

Drozd J., 1995, *Transformacja związków próchnicznych w glebach różnie zdegradowanych ekosystemów leśnych Karkonoszy*, [w:] *Problemy ekologiczne wysokogórskiej części Karkonoszy*, Z. Fischer (red.), Oficyna Wyd. Inst. Ekologii PAN w Dziekanowie Leśnym, 113-121.

Fischer Z., Kidawa A., 1992, *Kilka uwag o wskaźnikowej ocenie intensywności rozkładu materii organicznej*, [w:] *Problemy ekologiczne wysokogórskiej części Karkonoszy, I Konferencja – Wojnowice*, Z. Fischer (red.), Oficyna Wyd. Inst. Ekologii PAN w Dziekanowie Leśnym, 109-114.

Grodzińska-Jurczak M., 1994, *Wpływ kwaśnych opadów atmosferycznych na środowisko Doliny Waksmundzkiej w Polskich Tatrach*, Rozprawa doktorska wykonana w Zakładzie Ekologii Zwierząt Uniwersytetu Jagiellońskiego, Kraków.

Kowaliński S., Drozd J., Licznar M., 1973, *Mikromorfologiczna i chemiczna charakterystyka związków próchnicznych w niektórych glebach Karkonoszy*, Rocz. Gleb., 24 (1), 145-157.

Meentemeyer V., 1978, *Macroclimate and lignin control of litter decomposition rates*, Ecology, 59(3), 465-472.

Niemyska-Łukaszuk J., 1977, *Charakterystyka próchnicy niektórych leśnych gleb tatrzańskich, Cz. II, Skład frakcyjny połączeń próchnicznych*, Rocz. Gleb., 28 (1), 169-188.

Shanks R.E., Olson J.S., 1961. *First-year breakdown of leaf litter in southern appalachian forests*, Science, 134, 194-195.

Skiba S., 1977, *Studia nad glebami wytworzonymi w różnych piętrach klimatyczno-roślinnych krystalicznej części Tatr polskich*, Rocz. Gleb., 28 (1), 205-241.

Skiba S., 1983, *Tendencje do piętrowości rędzin tatrzańskich na przykładzie gleb stoków Kominiarskiego Wierchu*, Rocz. Gleb., 34 (4), 101-112.

Skiba S., Drewnik M., Drozd J., 1997, *Characteristics of the organic matter of ectohumus horizons in the soils of different mountain regions in Poland*, [w:] *The role of humic substances in the ecosystems and in environmental protection*, J. Drozd., S. Gonet, N. Senesi, J. Weber (red.), IHSS - Polish Society of Humic Substances, 497-505.

Wąsowicz T., 1933, *Badania nad glebami górskimi*, Prace Roln.-Leśne. PAU, 7, 46.

Zagadnienie rozwoju poziomów ektopróchnicznych w glebach Karpat

Streszczenie

W glebach zlokalizowanych z różnych pasmach górskich Karpat (Tab. 1, Ryc. 1) oznaczano tempo rozkładu materii organicznej metodą sączków celulozowych. Oznaczone właściwości poziomów próchnicznych (Ryc. 2) wskazują, że właściwości próchnic w badanych glebach górskich kształtowane są przez czynniki bioklimatyczne lub litologiczno-roślinne. Tempo rozkładu materii organicznej w badanych glebach generalnie maleje wraz z wysokością nad poziom morza. Najniższe jest ono w glebach piętra subalpejskiego wykształconych pod zaroślami kosodrzewiny. W glebach pięter: halnego, kosodrzewiny, regla górnego i połonin, decydujący wpływ na tempo rozkładu materii organicznej mają czynniki bioklimatyczne, natomiast w piętrze regla dolnego i pogórza tempo rozkładu kształtowane jest przez czynniki litologiczno-roślinne.

Marek Drewnik
Zakład Gleboznawstwa i Geografii Gleb Instytutu Geografii Uniwersytetu Jagiellońskiego
ul. Grodzka 64, 31-044 Kraków