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ENZYMOLOGY OF OIL-CONTAMINATED SOILS

ŞTEFAN KISS*

SUMMARY. — The paper is a review of the investigations dealing with the effects of oil contamination of soils and remediation of oil-contaminated soils on their enzymatic activities. The review follows the chronological order of investigations: accidental oil contamination of soils, field and laboratory experiments for modelling oil contamination of soils and remediation of these soils. Soils contaminated with crude oil, oil products, oil field wastewaters or oil well-drilling fluid additives will be considered separately.

1. Introduction

The modern society largely depends on petroleum products used as fuels or as raw materials for synthesis of plastics, surfactants, dyestuffs, drugs, pesticides etc.

Contamination of soils with crude oil, drilling muds, oil well waters, petroleum products and wastes can occur in many places (oil fields, refineries, chemical and other industrial plants, farms, highways, railroads etc.), during processing, transport, storage and utilisation, due to spillage and leakage.

Oil contamination of soils negatively affects agricultural productivity, health of plants, animals and humans. Oil from the contaminated soils can penetrate into ground- and surface waters, polluting them. Some components of oil from the contaminated soils can volatilise, causing air pollution.

Investigation of the soil-biological effects of oil contamination and remediation of oil-contaminated soils are urgent tasks for environmental scientists all over the world.

Enzymological methods are used, besides other methods, to evaluate the soil-biological effects of oil contamination and the efficiency of the remediation technologies applied. The present work reviews these soil-enzymological investigations as no comprehensive review on these investigations has appeared so far in the universal literature.

Söhngen [32] was the first to prove in 1913 that there are microorganisms in soils capable of degrading oil hydrocarbons using them as carbon and energy sources. Later, it was established that many soil bacteria, actinomycetes, yeasts and filamentous fungi take part in the degradation of both aliphatic and aromatic hydrocarbons (*e.g.*, *Davis* [9]; Atlas [4]). Bioremediation of oil-contaminated soils is based on this degrading activity of soil microbiota and, therefore, the remediation

* *Babeş-Bolyai University, Department of Plant Physiology, Laboratory for Environmental Enzymology and Microbiology, 3400 Cluj, Romania*

technologies should enhance the growth of the native and/or introduced hydrocarbon-degrading microorganisms in the contaminated soils.

The first data on soil enzyme activities as related to counts of oil-degrading soil bacteria were published by Kiss [26] in 1957. It was found that in the four soils studied there was a parallelism between values of invertase activity and counts of paraffin-degrading, acid-fast mycobacteria.

The first enzymological investigation of a soil contaminated with oil following the accident of a fuel oil-transporting vehicle was described by Steubing [35] in 1967. Ten years later, Aliev and Gadzhiev [1] published the first enzymological results obtained in a soil contaminated experimentally with crude oil. The aim of this experiment was to better understand the soil-biological effects of oil contamination which is necessary for elaborating efficient remediation technologies.

At present, a rich literature on enzyme activities in oil-contaminated soils is available from East, Central and West Europe, North America and Asia.

In reviewing this literature, the chronological course of the investigations will be followed. First, the soil-enzymological effects of accidental oil contamination were studied, then oil contamination of soils and remediation of oil-contaminated soils were modelled by field experiments and, for obtaining deeper knowledge, by laboratory experiments.

2. Soil Enzyme Activities as Affected by Accidental Oil Contamination

Contamination with crude oil

Mukatanov and Rivkin [28] have studied three soils contaminated with crude oil due to pipeline leaks and the adjacent non-contamined, control plots in the Bashkirian Pre-Urals. The first two soils, belonging to the steppe zone, were contaminated with crude oil in 1974 and 1976, respectively; they were used as a pasture and as an arable land cultivated with oats, respectively. The third soil, located on the forest-steppe zone, was contaminated with crude oil in 1974; following contamination, the pine trees growing on this soil died out. In 1978, the soils were sampled for determining their dehydrogenase and catalase activities. Dehydrogenase activity in the first and third contaminated soils was a little higher than in the controls, whereas the reverse was true for the second soil. At the same time, catalase activity was lower in each contaminated soil than in the controls (see also pages 5—9 in [2]).

The nine soil plots studied by Andreson and Khaziev [2] were weakly or strongly contaminated with crude oil due to pipeline leaks in the areas of the Ishimbai and Arlan oil fields located on the steppe and forest-steppe zones of the Bashkirian Pre-Urals, respectively. Noncontaminated plots served for comparison. The effects of oil contamination on dehydrogenase, catalase and invertase activities greatly depended on the soil type: in chernozems exhibiting a high buffering

capacity the activities remained stable, whereas in those with low buffering capacity (humid meadow dark-brown, soddy podzolic and gray forest soils) the activities decreased after oil contamination (see also [23]).

Samosova *et al.* [30] have analysed the chernozem soil in a rye-field contaminated with Romashkin crude oil (Tataria) in March 1977. Degree of contamination was 7.8%. The oil accumulated in the surface soil layers. In the most contaminated places the rye plants died out. An adjacent, noncontaminated soil was the control. The soil samples, taken on 15th May and 6th July 1977, were analysed to determine their dehydrogenease, protease and urease activities and counts of bacteria, actinomycetes, fungi and cellulose-degrading microorganisms. At both sampling dates, the contaminated soil was less dehydrogenase- and protease-active and more urease-active than the control soil. Counts of all microbial groups increased following contamination; the highest increase occurred in the count of bacteria growing on a nutrient medium containing crude oil. Comparative analysis of the crude oil and the residual oil extracted from the contaminated soil revealed that *n*-alkanes were the most easily biodegradable oil components which is in concordance with literature data (*e.g.* [4, 9]).

A similar soil-enzymological and -microbiological study was carried out by Fil'chenkova [11]. An arable land and a pasture, both on calcareous chernozems in the area of the Kama River (Tataria), were studied. Degree of contamination with crude oil was higher on the arable land (3.2%) then on the pasture (0.12%). Noncontaminated plots were the controls. In both soils, oil contamination resulted in a decrease of dehydrogenase and protease activities and of the counts of nitrifying bacteria and actinomycetes and in an increase of the global count of bacteria. Due to the oil pollution, the count of cellulolytic microorganisms decreased in the arable soil and increased in the pasture soil. With time, the negative effects of oil contamination tended to diminish.

The seven soils studied by Antonenko and Zanina [3] were mostly meadow-swampy alluvial soils located along the central zones of the Ob River (West Siberia). Four of the soils were contaminated with crude oil due to pipeline leaks. The 0—10-cm layer of the contaminated soils contained 0.1—0.4 g hydrocarbons/100 g soil. Dehydrogenase, invertase, protease and urease activities were low in both contaminated and noncontaminated soils. But activities of polyphenol oxidase and peroxidase (enzymes playing a role in the formation of humic acids) were higher in the contaminated than in the noncontaminated soils. The activities showed a decreasing trend with increasing soil depth, excepting polyphenol oxidase activity in one contaminated soil and peroxidase activity in two contaminated soils, in which these activities manifested a reverse trend.

Contamination with crude oil and oil products

Two yellow peaty gley soil plots and two meadow swampy soil plots located on the Colchis Lowland in West Georgia and contaminated

with crude oil and oil products were selected by Yashvili *et al.* [39] for enzymological and microbiological analyses. In comparison with the adjacent noncontaminated soils, the contaminated ones, especially their surface layers, were more enzyme-active (dehydrogenase, catalase and invertase) and richer in microorganisms. The highest increase was registred in the counts of bacteria utilising organic and inorganic nitrogen, and the lowest increase in the count of fungi.

Contamination with oil products

The accident of a vehicle transporting heating oil on the Gießen-Lich highway (Germany) on 19th September 1963 led to an 18,000-liter oil spill. The oil as a stream contaminated the adjacent areas, including an about 2×12-m site in the neighbouring mixed forest. The soil on this site and that on a noncontaminated site at 15-m distance from the contaminated site were sampled from their 0—5-, 10—15-, 20—25- and 45—50-cm depths in March 1964. Both contaminated and control soils were of pseudogley type. The samples were submitted to enzymological and microbiological analyses. Dehydrogenase activity, respiration (CO_2 evolution) and ammonification were found to be higher in the oil-contaminated soil than in the control one, at each depth. At the same time, the cellulose-degrading capacity and global counts of bacteria, fungi and algae were smaller in the contaminated soil, especially in its 0—5-cm layer, than in the control soil. But the count of hydrocarbon-degrading mycobacteria increased in the contaminated soil which explains the higher dehydrogenase activity, respiration and ammonification in this soil (Steubing [35]).

Contamination with oil field wastewaters

Soil-enzymological effects of contamination with oil field wastewaters were studied by Samosova *et al.* [31]. They have determined dehydrogenase, urease and protease activities in soils contaminated with wastewaters from the oil field areas of Tataria. The high salt content (especially Na^+, Ca^{2+}, Cl^-, SO_4^{2-}) of these waters caused salinisation of soils. Thus, Na^+ content was 150—200 times higher in strongly contaminated than in the control soils. Mobile Mn, Cu and Zn contents increased 2—3 times in the contaminated soils which became phytotoxic. These changes brought about by contamination were accompanied by great diminutions of dehydrogenase and urease activities and disappearance of protease activity. Global counts of soil microorganisms were also smaller in the contaminated than in the noncontaminated soils.

3. Enzymological Evaluation of the Biological Effects of Oil Contamination of Soils in Experimental Models

A. Field Experiments

Contamination with crude oil

Aliev and Gadzhiev [1] added different amounts of crude oil (0, 10, 20 40 and 100 kg/m^2) to plots of a gray forest soil in the oil field area of the Apsheron Peninsula (Azerbaijan) and determined

periodically soil enzyme (catalase, polyphenol oxidase, invertase, protease and phosphatase) activities and counts of microorganisms during three years (1972—1975). The results obtained in enzymological analyses have shown that the enzyme activities decreased in parallel with the rate of crude oil addition. The only exception was catalase, the activity of which increased when the soil was treated with crude oil at the two low rates (10 and 20 kg/m^2); however, this activity also decreased at the rates of 40 and 100 kg crude oil/m^2. The global counts of microorganisms (bacteria, actinomycetes and fungi) and intensity of respiration (CO_2 evolution), like catalase activity, were highest in the plots treated with 10 and 20 kg crude oil/m^2 and exceeded to a large extent the values registered in the control soil. These findings indicate that small amounts of crude oil were not toxic to microorganisms of the soil studied; contrarily, the crude oil stimulated the microbial growth under these conditions.

In the area of the Apsheron oil fields, Ismailov [15] has initiated a new experiment in July 1978. Plots of a gray-brown soil were contaminated with Binagadin crude oil (20 kg/m^2). Noncontaminated plots served for comparison. Soil samples were taken for analyses after 3 days, 3, 9, 12, 15 and 22 months from the beginning of the experiment. Sampling depths were 0—3, 3—13, 13—23 and 23—48 cm. Crude oil contamination led to increased soil catalase and urease activities and respiration (CO_2 evolution), while dehydrogenase, invertase and protease activities decreased. After 22 months, more than 60% of crude oil was degraded, but dehydrogenase activity remained low in contrast to invertase and protease activities which, especially in the deeper soil layers, tended to increase to values registered in the control plots. At each soil depth, counts of bacteria plus actinomycetes and separate counts of bacteria were greater in the contaminated plots than in the control ones during the whole experimental period. The maximum counts were obtained after 9 and 15 months, respectively. Counts of yeasts (*Candida* and *Torulopsis*) increased only in the higher soil layers. Increase in the counts of bacteria growing on nutrient media containing crude oil or oil products was remarkable in each soil layer. These bacteria represented an average of 46% of the total bacterial counts in control plots and 76% in the contaminated plots. However, the soil in contaminated plots remained toxic for higher plants during the whole experimental period (see also [17]).

In this experiment, nitrate reductase and protease activities, counts of denitrifying, ammonifying, N_2-fixing and nitrifying microorganisms were also determined by Ismailov [16]. It has been found that nitrate reductase activity (expressed in mg NO_3^-/10 g soil/24 hours) gave much lower values in strongly and moderately contaminated soil samples (10 and 60, respectively) than in the noncontaminated control soil (150). The oil-caused decrease in the activity of accumulated soil nitrate reductase was compensated by oil-stimulated proliferation of denitrifying microorganisms producing new nitrate reductase molecules and maintaining denitrification at a high level. Similarly, inhibition

of accumulated soil protease activity by oil was compensated by its stimulatory effect on the growth of ammonifying microorganisms producing new protease molecules. Oil contamination also led to higher counts of aerobic and anaerobic N_2-fixers and to suppression of nitrifiers (see also [17]).

Linkins *et al.* [27] have selected study sites in the polygonal coastal Arctic tundra at Barrow, Alaska, in typical high centre and low centre polygon complexes. Ambient temperature Prudhoe Bay crude oil was uniformly surface-applied at a 5 or 12 l/m^2 rate on high centre polygon centres and low centre rim, trough and basin systems on 30th June 1975. Mid-season samples were taken between 4 and 16 July 1975, 1976 and 1977, and used for determination of endo- and exocellulase and aryl hydrocarbon (benzo[a]pyrene) hydroxylase activities, soil and vascular plant root respiration. Untreated soils served as controls.

In the soils treated with 5 l oil/m^2, endo- and exocellulase activity decreased, aryl hydrocarbon hydroxylase activity and soil respiration (O_2 consumption and CO_2 evolution) increased, indicating a shift in the catabolic activity of soil microbiota. These trends were paralleled in the soils treated with 12 l oil/m^2, but usually after a lag period of one year, which was attributed to some toxic effect of the oil at high concentration. These results suggest that tundra soil microbiota can actively modify oil and can utilise it to support metabolism. Higher respiration rates in oiled soils than in control soils indicate that soil microbiota degrades and utilise oil faster than the normal residual plant material. Oil at each rate reduced root respiration in each soil during the first and second years, but in the third season root respiration was greater than or equal to that of the control roots. However, the plant root adaptation to oil was incomplete. This was shown by the annual decrease in viable root biomass after exposure to oil.

Zimenka and Kartyzhova [41, 42] have installed microplots on a soddy-podzolic soil of light loam texture. The microplots were treated with crude oil (0.5 or 3 l/m^2) from the Rechitsa oil field (Byelorussia). Untreated plots served for comparison. The experiment lasted three years (1983—1985). The test plant was Kondor oat variety. Oil contamination at the low rate (0.5 l/m^2) had little effect on soil catalase and dehydrogenase activities, but affected urease activity which increased during the first two years of the experiment. At this oil rate, the nitrifying bacteria, actinomycetes and fungi were not affected significantly and some stimulation occurred in the growth of cellulolytic microorganisms, whereas growth of ammonifying and denitrifying microorganisms was inhibited and growth and development of oat plants were retarded. Soil respiration (CO_2 evolution) decreased in 1983 and showed increased values in 1984 and 1985. It was estimated that self-decontamination of these oil-contaminated plots requires 30 months.

Oil contamination at the higher rate (3 l/m^2) resulted in decreased catalase and increased urease activity during the whole experimental period. Dehydrogenase activity decreased in 1983, had values close to those of the control soil in 1984 and greatly increased in 1985. Counts

of most microbial groups (ammonifiers, denitrifiers, cellulose-degraders, actinomycetes, fungi) increased, but counts of nitrifiers decreased. Respiration decreased in 1983, increased in 1984 and was similar to that of the control plots in 1985. Due to the poor growth and development of oat plants, great losses occurred in grain yield in each year. The loss was minimal (13%) in 1985. For self-decontamination of these plots more than three years are necessary.

The experiment described by Khaziev *et al.* [25] was carried out on a dark-gray forest soil of semi-loam texture (Bashkiria). Rates of crude oil contamination were 0, 8, 16 and 25 l/m^2. For analyses, samples were taken from three soil depths (0—20, 20—30 and 40—50 cm) after 3 days and one year from the beginning of the experiment. Catalase and dehydrogenase activities decreased at each crude oil rate on day 3, but after one year both activities showed increased values and, at the lowest oil rate, their values were close to those recorded in the noncontaminated soil. On day 3, invertase activity was not significantly affected by any of the oil rates, but after one year it exhibited a little higher values at the 8 and 16 l oil m^2 rates. Decrease and increase in enzyme activities were always more evident in the 0—20-cm layer than in the deeper ones. After 3 days, no nitrate and mobile phophorus were detectable in the oil-contaminated soil, but after one year they were present in each soil layer; their amounts were highest in the 0—20-cm layer.

Contamination with oil products

Janke *et al.* [21] have installed 25 lysimeters on the experimental field of the Institute of Plant Ecology in Gießen (Germany). Each lysimeter was filled with about 10 l of topsoil (0—10 cm) taken from a fallow land on loamy sand soil. The soil was contaminated with 200 ml heating oil (10 lysimeters) and with 400 ml heating oil (10 lysimeters); the remaining 5 lysimeters served as controls. Soil samples were collected at 4-week intervals during 10 months in 1990 and 9 months in 1991. Dehydrogenase and catalase activities, respiration (CO_2 evolution), nitrification and microbial counts were determined. After an about 5-month lag period, dehydrogenase activity in the oil-contaminated soil increased and the increase was more pronunced in 1991 than in 1990. Beginning with the 9th month, dehydrogenase activity increased to a larger extent in the heavily than in the slightly contaminated soil. Catalase activity in the oil-contaminated soil exceeded the control values during the last 7 months. But catalase activity was influenced to a lesser extent by the rate oil contamination than was dehydrogenase activity. Respiration behaved essentially like dehydrogenase activity. However, respiration of the contaminated soil became largely different from that of the control soil only in month 6 and remained nearly at this level up to the end of the experiment. The respiration-increasing effect of oil was more evident in 1991 than in 1990. Oil contamination at both rates resulted in strong inhibition of nitrification during the whole experimental period. Global count of heterotrophic bacteria and

that of fungi were practically not affected by oil contamination, but the counts of streptomycetes, especially during the last months, were much smaller in the contaminated than in the control soil.

In parallel with these field experiments, „storage" experiments were also carried out (Weißmann and Kunze [37]). The same soil (loamy sand topsoil) and oil product (heating oil) were used in both types of experiments. In the storage experiments, 10-kg quantities of soil were left uncontaminated or contaminated with 200 and 400 ml heating oil, respectively, then kept at 60% of maximum water-holding capacity at ambient temperature. The soils were sampled at 4-week intervals, during 18 months in the April 1990-September 1991 period. The samples were analysed for dehydrogenase and catalase activities, nitrification capacity and selected *n*-alkanes (chain lengths with 14—22 C atoms).

During the first 5 months, values of dehydrogenase and catalase activities in uncontaminated and contaminated field and storage soils did not significantly differ from each other. Thereafter, both activities in the contaminated soils increased continuously up to the end of the experimental period. The increase in dehydrogenase activity was lower and that in the catalase activity was higher in the field than in the storage soils. In each case, the increasing effect of oil was more pronounced at its higher than at its lower rate.

Nitrification was almost completely depressed by both oil rates in both field and storage soils. A 25% recovery of nitrification capacity occurred only in the field soils towards the end of summer 1991.

In the field soils, contents of C_{14}—C_{22} *n*-alkanes strongly decreased, and the decrease correlated with the increase in dehydrogenase and catalase activities. Unexpectedly, no changes in contents of C_{14}—C_{22} *n*-alkanes were observed in the storage soils. However, the possibility that other oil components were degraded in these soils is not excluded.

Growth of vegetation, studied under field conditions, was severely retarded in the contaminated soils.

B. Laboratory Experiments

Contamination with crude oil

Demidienko and Demurdzhan [10] have treated samples of a noncontaminated common chernozem with crude oil from the Bitkov oil field located in the Dnieper-Donets Depression (the Ukraine). Rate of oil addition was 1% (on soil weight basis). The enzymological analyses of the soil-crude oil mixtures and control samples showed that, due to the crude oil, protease activity slightly and nitrite reductase activity strongly decreased, whereas invertase and nitrate reductase activities slightly and urease and hydroxylamine reductase activities strongly increased.

Contamination with crude oil and oil products

Frankenberger and Johanson [13] have used surface samples of three Californian soils, selected to obtain a wide range of pH, organic carbon content and texture, for studying the effect of crude oil and refined oil products on soil dehydrogenase activity. Field-moist samples of 5 g each were treated with crude oil, leaded gasoline, kerosene, diesel fuel and motor oil at 0, 20, 40 and 60% loading rates (weight of oil/weight of dry soil), then incubated under aerobic conditions at room temperature (24± 2°C) for 30 days. Dehydrogenase activity was measured after 0, 3, 7, 14 and 30 days of incubation. The activity was found to increase with the rate of crude oil and refined oil application. Generally, maximum value of dehydrogenase activity was registered after 30 days of incubation in the case of crude oil-treated soils and after 7 days in soils treated with refined oil products. When all soils and treatments were considered, maximum values of dehydrogenase activity (expressed in mg triphenylformazan/g soil per 24 hours) were the following: crude oil, 1,180; leaded gasoline, 56; diesel fuel, 56; motor oil, 37; kerosene, 32. In other words, the crude oil was more stimulatory than the refined oil products. These findings suggest that the additives present in refined oil products may have a major influence on the dehydrogenase reaction in soils.

Ismailov [15] has treated samples of a garden soil with crude oil from the Apsheron oil fields or with oil components (*n*-hexadecane, cyclohexane, aromatic hydrocarbons, asphalt) at 1% rate (on field-moist soil weight basis). Four enzyme activities (catalase, dehydrogenase, invertase and urease) and respiration (CO_2 evolution) were determined in the mixtures and in the untreated, control soil. Crude oil stimulated dehydrogenase and urease activities, had little effect on catalase activity and inhibited invertase activity and respiration. *n*-Hexadecane had a stimulating effect on catalase, dehydrogenase and urease activities and an inhibiting one on invertase activity and respiration. In the cyclohexane-treated samples, catalase activity increased, dehydrogenase and invertase activities decreased, whereas urease activity and respiration remained unchanged. The aromatic hydrocarbons decreased each enzyme activity and respiration. The asphalt treatment led to decreased catalase and dehydrogenase activities and to increased respiration. (The effects of asphalt on invertase and urease activities were not studied). One can deduce from these findings that the effects of *n*-alkanes and cycloalkanes are less inhibitory on soil biological activity than those of the aromatic hydrocarbons (see also [17]).

For explaining phytotoxicity of such oil-contaminated soils in which the amount of hydrocarbons greatly decreased due to their biodegradation, Ismailov *et al.* [20] have carried out an experiment using samples of a noncontaminated gray-brown soil from the Apsheron oil field area. The soil samples were treated with crude oil and *n*-hexadecane (at 1% rate, on weight/weight basis) and with four partial oxidative degradation products of oil hydrocarbons (at 0.5% rate), then analysed for determination of their dehydrogenase activity (expressed

in mg triphenylformazan/10 g soil). The following values were recorded in the untreated and treated soil samples: 9.0 (untreated); 9.5 (crude oil); 11.8 (*n*-hexadecane); 10.0 (1-hexadecanol); 8.6 (palmitic acid); 0.1 (benzoic acid); 0 (salicylic acid). It is evident from these values that the crude oil, *n*-hexadecane and 1-hexadecanol stimulated, whereas the organic acids inhibited dehydrogenase activity. The acids can accumulate in soil and exhibit phytotoxic effects (see also [17]).

Contamination with oil products

Z h o u *et al.* [40] treated samples of a Chinese soil with oil hydrocarbons at rates of 0, 100, 250 and 500 ppm, then incubated them under normal soil moisture or water-logged conditions for 90 days. The residual hydrocarbon content and the enzyme activities in the samples were determined after 0, 7, 21, 45 and 90 days of incubation. The results have shown that biodegradation of hydrocarbons was a faster process at their lower than at their higher concentrations, and under normal soil moisture than under water-logged conditions. For example, half-life times of the aliphatic hydrocarbons applied at 250 and 500 ppm were 18 and 20 days, respectively, under normal soil moisture conditions, and 51 and 70 days, respectively, under water-logged conditions. The corresponding half-lime times of the aromatic hydrocarbons were greater, namely 22 and 25, and 90 and > 90 days, respectively. The enzyme activities measured (invertase, protease, phosphatase and peroxidase) were higher under normal soil moisture, than under water-logged conditions. During the incubation period, the hydrocarbon content decreased in parallel with the decrease of invertase activity. The other activities rather increased during incubation. This is why Z h o u *et al.* consider that by measuring invertase activity in hydrocarbon-contaminated soils useful data can be obtained for evaluating the capacity of these soils to degrade the contaminants.

B a u e r *et al.* [5—7] and P e n n e r s t o r f e r *et al.* [29] have compared the sensitivity of different soil-microbiological and -enzymological methods to assess the biological effects of oil contamination. Soil was collected from the top 50 cm of an Austrian agricultural field and passed through a 2-mm sieve. A part of the samples were contaminated with heating oil (2%, volume/weight) and the contamination was repeated twice during the experiment after 3 and 6 weeks, respectively. The moisture content of the samples was kept constant during the 8-week incubation period. The following methods were applied weekly: soil respiration, glucose-induced respiration, capacity to reduce 2, 3, 5,-triphenyltetrazolium chloride (TTC-dehydrogenase activity), 2-(*p*-iodophenyl)-3-(*p*-nitrophenyl)-5-phenyltetrazolium chloride (INT-dehydrogenase activity) and dimethylsulphoxide (DMSO reduction).

Excepting glucose-induced respiration, the other methods gave higher values in the oil-contaminated than in the control samples. Sensitivity indicator of the methods (i.e., ratio between the value in contaminated soil and that in the control soil taken as 1) increased in the order: glucose-induced respiration (0.965), DMSO reduction (1.228),

soil respiration (1.425), INT-dehydrogenase activity (1.458) and TTC-dehydrogenase activity (2.464). This means that, of the methods applied, measurement of TTC-dehydrogenase activity in the most sensitive one for assessing biological effects of oil contamination of soil.

Bauer *et al.* [6], Pennerstorfer *et al.* [29] and Kandeler *et al.* [22] have studied five Lower-Austrian agricultural soils having different textures, chemical and biological properties (pH, humus, respiration, TTC-dehydrogenase activity) (soils: 1 — calcareous chernozem; 2 — degraded chernozem; 3 — regorendzina; 4 — calcareous chernozem; 5 — gleyic chernozem). The sieved (2 mm) soil samples moistened to 40% of their water-holding capacity were contaminated with a mixture of *n*-tetradecane, 5-methyl-3-heptanone and naphthalene (1:3.67:1.08) modelling the benzine. Rate of application was 3% (weight/weight). Noncontaminated samples were used as controls. During incubation (at 20°C) that lasted 20 weeks, TTC-dehydrogenase and alkaline phosphatase activities, respiration, glucose-induced respiration, nitrogen mineralisation and residual hydrocarbon content were determined at 2- to 4-week intervals.

All soils reacted similarly to contamination, but with different intensities. Soil 1 (calcareous chernozem) was the least sensitive and soil 2 (degraded chernozem) was the most sensitive to contamination. In comparison with the control samples, the biological parameters decreased immediately after contamination, but later increased reaching very high values during weeks 4—8 (dehydrogenase activity, respiration) or during weeks 8—12 (phosphatase activity, N mineralisation) and, thereafter, showed, in general, a decreasing trend. Determination of the residual contaminants indicated that complete decontamination occurred in each soil. Average and maximum decontamination times were 13.6 and 20 weeks, respectively.

Contamination with oil well-drilling fluid additives

Effects of the oil well-drilling fluid additives on soil enzyme activities were studied by Demidienko and Demurdzhan [10]. Twenty inorganic and organic compounds and mixtures used for the preparation of oil well-drilling fluids were added to samples of a noncontaminated common chernozom from the Dnieper-Donets Depression, at a rate of 1% (weight/weight). In comparison with the untreated control samples, each fluid additive exerted a negative or positive effect at least on one of the six enzyme activities studied (invertase; urease; protease; nitrate, nitrite and hydroxylamine reductase). Majority of the fluid additives decreased invertase, nitrate and hydroxylamine reductase activities and increased the other activities. The increase was most pronounced in the case of urease activity.

4. Enzymological Evaluation of the Biological Effects of the Remediation of Oil-Contaminated Soils in Experimental Models

A. Field Experiments

Contamination with crude oil

In the spring of 1979, Ismailov *et al.* [18] have installed microplots (1 m^2 each) on a gray-brown soil (located in the dry subtropical area of Azerbaijan) and contaminated them with 4.4 l crude oil/m^2. The control microplots were not contaminated. Then, the microplots were submitted to remediation treatments in a series of variants. N and P fertilisers were used as aqueous solutions of $(NH_4)_2SO_4$ and KH_2PO_4 at rates of 12 g N and 9 g P_2O_5/m^2, respectively. Cultures of three hydrocarbon-degrading microorganisms (*Candida guilliermondii* 916, *Pseudomonas aeruginosa* 30 and an unidentified bacterium, strain 7) were applied as inocula (0.8 g dry microbial biomass/m^2). Two biopreparations were also tested. They were obtained from grape marc cut into small pieces or sawdust and a suspension of *C. guilliermondii* (0.5 g dry yeast biomass to 200 g grape marc or to 100 g sawdust). During the experiment (at months 8, 19 and 32), soil enzyme activities (catalase, dehydrogenase, invertase, urease and protease), respiration (O_2 consumption and CO_2 evolution) and phytomass were determined. Global counts of bacteria, yeasts and filamentous fungi and the residual oil content were also determined periodically.

All treatments applied to oil-contaminated soil led to increased activity of each enzyme, excepting protease activity which was very low in all variants. Four treatments, namely addition of biopreparation 1 (grape marc) or 2 (sawdust), mixture of the three hydrocarbon-degrading microorganisms and $(NH_4)_2SO_4$ plus KH_2PO_4, gave especially good results in increasing the enzymatic potential of oil-contaminated soil. The enzymatic activities correlated with respiration and microbial counts. The phytomass obtained after 32 months was 3.3 g/m^2 in oil-contaminated microplots and increased to 7.0—48.8 g/m^2 in oil-contaminated and treated microplots, but the phytomass of noncontaminated microplots (65 g/m^2) was not achieved. Oil degradation was enhanced by each treatment. In 8 months, 56—76% of hydrocarbons were degraded in the treated microplots, but only 49% in those receiving no remediation treatment. After 8 months as after 20 months, the smallest amounts of residual oil were found in microplots treated with biopreparation 1 or inoculated with the mixture of the three microbial cultures. Biodegradation of aliphatic hydrocarbons was faster than that of the other oil components.

In another experiment, Ismailov *et al.* [18] used whey and baker's yeast factory wastewater for remediation of oil-contaminated microplots (0.5 × 0.5 m) on gray-brown soil. The microplots contaminated with crude oil (2 l/microplot) were left untreated for 9 months, then treated with whey or wastewater (2 l/microplot) and this treat-

ment was repeated after 4 months. Both whey and wastewater had beneficial effects on soil dehydrogenase activity, respiration (CO_2 evolution) and oil degradation. Thus, during 6 months after the first treatment, oil degradation increased from 16 to 28—29% (in microplots in which before oil contamination the vegetation was practically lacking) and from 11 to 42—44% (in microplots having herbaceous vegetation before oil contamination).

For remediation of an oil-contaminated soil, Khaziev *et al.* [25] used mineral fertilisers and farmyard manure. Plots were installed on a Bashkirian gray forest soil of silty clay texture. Rates of crude oil contamination were 0, 8, 16 and 25 l/m^2. Mineral fertilizers (N, P and K) were applied at rates of 40, 50 and 45 kg/ha, respectively, and farmyard manure at a rate of 40 t/ha. Unfertilised plots served for comparison. The test plants were oats. Five enzyme activities (catalase, dehydrogenase, invertase, urease and phosphatase) were measured after one year.

Comparison of nonfertilised plots showed that oil contamination at each rate decreased catalase, invertase and phosphatase activities and increased dehydrogenase activity. Urease activity was stimulated at 8 l crude oil/m^2 and inhibited at the two higher rates. In the NPK-fertilised plots, the enzyme activities (excepting urease activity) were lower in the contaminated than in the noncontaminated soil. In farmyard manured plots, the contaminated soil was less catalase-, invertase- and phosphatase-active and more dehydrogenase- and urease-active than the noncontaminated soil. In the plots treated with both NPK and farmyard manure, two activities (invertase and phosphatase) were lower and three (catalase, dehydrogenase and urease) were higher in the contaminated than in the noncontaminated soil.

The favourable effects of fertilisation on the counts of different microbial groups in the oil-contaminated soil plots increased in the order: NPK < farmyard manure < NPK + farmyard manure.

It is evident from these findings that application of NPK fertilisers and farmyard manure was a more efficient measure for increasing the enzymatic and microbial potential of oil-contaminated soil than was NPK fertilisation or farmyard manuring alone. Nevertheless, the biological potential of the noncontaminated soil was never attained in the oil-contaminated soil during this one-year experiment. Similarly, the grain yield of oats increased in fertilised contaminated plots but never reached the yield obtained in the corresponding noncontaminated plots.

Gainutdinov *et al.* [14] have dealt with the problems of remediation of the oil-contaminated soils in the forest-steppe zone of Tataria. They carried out a crop rotation experiment (bare fallow, winter rye, spring wheat, peas), in which plots were contaminated with crude oil (2.5, 6.3, 12.5 and 25 l/m^2) and submitted to remediation (mineral and organic fertilisation, liming, soil loosening) in the first year. At 2.5—12.5 l oil/m^2 rates, mineral (N+P) fertilisation plus farmyard manuring resulted in increased soil dehydrogenase and protease activities and this increase correlated with the decrease of oil content and was

accompanied by higher counts of hydrocarbon-degrading microorganisms.

Contamination with Oil Products

In the investigations performed by Wang and Bartha [36] at the New Jersey Agricultural Experiment Station, 10 lysimeters (each having a surface area of 90 by 90 cm and a depth of 60 cm) were used. The soil provided in bulk from nearby construction sites needed improvement to approach the water-holding capacity and organic matter content of topsoil. The improvement was achieved by adding to the soil at the approximate rate of 5% by volume a peat-sand-perlite mixture (equal parts). A 20-cm thick sand layer was placed on the bottom of lysimeters which were then filled with soil (thickness of soil layer was 35 cm). The free rim of lysimeters was 5 cm high.

Sets of three lysimeters were contaminated with jet fuel, heating oil and diesel oil, respectively, at a rate of 2.3 ml/cm^2, corresponding to 50—70 mg oil product/g soil. The soil in all lysimeters was watered weekly by hand at 2.6 ml/cm^2.

From the sets of three identically contaminated lysimeters, one was left untreated except for weekly watering. One was, in addition, tilled weekly by a hand shovel to a depth of 15 cm. The third received full bioremediation treatment consisting of liming (55 mg powdered agricultural limestone/cm^2) to raise soil pH from 6.7 to 7.4, fertilisation (10 mg urea and 4.3 mg superphospate/cm^2), and weekly tilling and watering. The last (No. 10) lysimeter, receiving no oil product and no treatment except for watering, served as source of uncontaminated control soil.

The experiments lasted 20 weeks, from late April to late September 1988. Periodically, the lysimeter soils were sampled to a depth of 15 cm to determine their residual hydrocarbon content (by quantitative gas chromatography), fluorescein diacetate (FDA) hydrolysis activity (which is due to soil enzymes) and toxicity (Microtox test assessing acute toxicity by measuring reduction in light emission by a *Photobacterium phosphoreum* preparation; ryegrass and soybean seed germination and plant growth).

The determinations have shown that the uncontaminated control soil did not contain hydrocarbons in measurable amounts. During the 20-week experimental period, the hydrocarbon content decreased in the contaminated soils. The decrease was smallest in the untreated soil, intermediary in the tilled soil, and greatest in the treated (limed, fertilized and tilled) soil. Consequently, tilling was less efficient than the full bioremediation treatment. This order of hydrocarbon disappearance was recorded with each of the three oil products. But their persistence increased in the order: jet fuel < heating oil < diesel oil. However, 20 weeks of bioremediation treatment lowered hydrocarbon concentration to below 5 mg/g soil for even the most persistent diesel oil, while in the untreated soil diesel oil concentration was still at 21.8 mg/g.

FDA hydrolysis activity showed only very slight fluctuations in the uncontaminated control soil. In the contaminated soils, after a 6-week lag, the activity increased in the same order as hydrocarbon biodegradation, *i.e.*, untreated < tilled < treated soil. The activity was inversely correlated with oil persistence: jet fuel stimulated activity the most, heating oil and diesel oil to lesser degrees. The 6-week lag in activity was caused by hydrocarbon biodegradation intermediates which strongly inhibited the activity. Therefore, the stimulation became apparent only after most of the inhibitory intermediates had disappeared. This is why the activity peaked at week 12.

The Microtox measurements have revealed that at time 0 all three oil contaminants exhibited moderate toxicity. But their subsequent behaviours differed in terms of toxicity. Jet fuel was rapidly detoxified: toxicity values of the treated and untreated soils returned in 2 and 6 weeks, respectively, to background value of the control soil. Toxicity of heating oil increased during the initial phase of the experiment, but started to decrease after 6 and 12 weeks for the treated and untreated soils, respectively. By week 20, both soils returned to background toxicity value. Diesel oil exhibited a similar toxicity pattern to heating oil, but even in a more pronounced manner. Toxicity declined to background level by 20 weeks only in treated soil. Significant residual toxicity was still evident in the untreated soil, correlating with the detection of polycyclic aromatic residues in this but not in the treated soil.

Seed germination and plant growth data were consistent with the hydrocarbon residue and Microtox measurements.

It has been drawn the conclusion that the full bioremediation treatment applied can restore oil-contaminated soils in 4—6 weeks to a degree that they can support plant cover; recovery of the soil is complete in 20 weeks.

Contamination with oil field wastewaters

For remediation of soils affected by salts due to their contamination with oil field wastewaters, Gainutdinov *et al.* [14] selected contaminated and noncontaminated, control plots on a calcareous chernozem of heavy loam texture. Washing of contaminated plots with fresh-water (2,000—3,000 m^3/ha, repeated three times), their treatment with gypsum (22 t/ha) or acidification (12.5 t sulphuric acid/ha) were applied for remediation. Soil enzymatic activities (dehydrogenase, protease, urease) were determined during two years and plant productivity was estimated during 4 years. Washing had little effect on enzymatic activities, whereas gypsum and sulphuric acid rather depressed them. Washing alone did not improve plant productivity, but in combination with gypsum or sulphuric acid treatment had a beneficial effect on plant biomass production. In the 4th year, however, plant productivity in each contaminated and treated plot remained lower than that registered in the control plots.

B. Laboratory Experiments

Contamination with crude oil

Andreson and Khaziev [2] have contaminated samples of a chernozemic soil with West-Siberian crude oil at rates of 0, 5 and 25 g/100 g soil, then treated them with NH_4NO_3 or $(NH_4)_2SO_4$ and superphosphate (10 mg N and 10 mg P_2O_5/100 g soil). An emulsifier of pellicular oil (EPN-5) was also tested. EPN-5 was applied as a concentrated (100%) aqueous solution or as aqueous dilutions (corresponding to 20 to 80% concentrations). Soil humidity was adjusted to 40% of water-holding capacity. Incubation took place at room temperature; its duration was 4 weeks.

Dehydrogenase and catalase activities increased 1.5—2 times under the influence of EPN-5 at 20% concentration and decreased by 80 and 100% EPN-5, at both rates of crude oil addition. Similarly, 20—40% EPN-5 stimulated the growth of soil bacteria and fungi, whereas EPN-5 at 60 to 100% concentrations caused reduction of microbial counts, at both rates of oil contamination. Dehydrogenase activity showed 1.5—2-fold increases in samples treated with N fertilisers and lower increases in the superphosphate-treated samples. These increases occurred at both rates of oil contamination. NH_4NO_3 was a better N source than $(NH_4)_2SO_4$.

But in a similar experiment with a dark-gray forest soil, the negative effects of crude oil on phytase activity could not be removed by N or P fertilisation or emulsifier application [23].

Ismailov *et al.* [19] have verified the effect of the hydrocarbon-degrading yeast strain (*Candida guilliermondii* 916) on the remediation of oil-contaminated soils (see page 14). 0.5-kg samples of a gray-brown soil from the Apsheron Peninsula were contaminated with 10% (on soil weight basis) Binagadin crude oil and inoculated with a yeast suspension (10^6 or 10^9 cells/g soil) using grape marc (cut into small pieces) as a carrier of yeast cells. Rates of grape marc application were 0.5 and 2% (on soil weight basis). N and P fertilisers (12 g N and 9 g P_2O_5/m^2 surface) were also added to the samples. Oil-contaminated but untreated samples served as controls. Incubation took place at optium humidity and aeration conditions at 28°C and lasted 60 days, during which the samples were periodically submitted to enzymological, microbiological and chemical analyses.

Dehydrogenase activity, respiration (CO_2 evolution) and oil degradation were most intense in the sample treated with 10^9 yeast cells/g soil + 0.5% grape marc and their values in this sample were especially high during the first 25 days of incubation and decreased later. During the 60-day incubation, counts of the inoculated yeast cells continuously decreased from 10^9 to $\sim 10^3$/g soil and from 10^6 to $\sim 10^2$, respectively, but counts of the heterotrophic bacteria became higher in the yeast-treated soil samples than in the untreated control. Finally, oil degradation was 30% in the treatment with 10^9 yeast cells/g soil + 0.5% grape marc, whereas it was only 8 % in the untreated control.

Although the contamination of the soil studied by Xu and Johnson [38] resulted from a crude oil spill due to pipeline break, their experiment could not be dealt with in Chapter 2, because the oil-contaminated soil used for enzymological and other analyses had previously been submitted to different remediation treatments. Therefore, the direct effects of oil contamination on soil properties as compared to those of uncontaminated soil could not be evaluated. See also the footnote on this page.

The crude oil spill occurred in 1990 on a black chernozem located near Erskine, Alberta, Canada. The spill site sloped into slough; the upper portion was planted to grain crops while the lower area was seeded to forage. At the spill site, the surface soil (0—15 cm) was excavated, homogenised and stockpiled. The oil-contaminated soil studied by Xu and Johnson was sampled from the stockpile. It contained 55 g of total petroleum hydrocarbons/kg soil. Previously bioremediated and solvent-treated samples of the oil-contaminated soil were also studied. The bioremediated soil had been treated in a bioremediation facility for 15 months This treatment reduced the oil content to 25 g hydrocarbons/kg soil. The solvent-treated soil contained oil and solvent (naphtha) residues of 5 g hydrocarbons/kg soil. The uncontaminated soil used as a control was collected adjacent to the spill site. This soil contained no detectable petroleum hydrocarbons.

Samples of the four soils (oil-contaminated, bioremediated, solvent-treated and uncontaminated) were sieved (2-mm screen) and packed in plastic cylinders (25 cm in height and 20 cm in diameter). Three seeds of barley (*Hordeum vulgare*) or field pea (*Pisum arvense*) were planted per cylinder. Urea, superphosphate and potassium sulphate (300 mg N, 65 mg P and 125 mg K/kg soil, respectively) were placed 3 cm below the seeds at the time of seeding. The plants were grown in a growth chamber. Sampling was conducted four times on each plant during the growing period: tillering stage (day 25), stem extension stage (day 40), heading stage (day 60) and ripening stage (day 80) for barley. Field pea was sampled at the same time. On each sampling date, the shoots were excised at the surface of the soil, and the roots were separated from the soil by hand, washed and then dried (at 75°C for 12 hours). The soils were homogenised and used for enzymological and other analyses*.

The root mass of barley was significantly greater than that of field pea over the growing period in each of the four soils studied. At the end of the growing period, the barley root mass had values significantly decreasing in the order: uncontaminated soil > solvent-treated soil > bioremediated soil > oil-contaminated soil; the root mass of

* It should be emphasised that at time 0, *i.e.*, before fertilising and seeding no enzymological analyses were carried out. Thus, the direct soil-enzymological effects of crude oil contamination could not be assessed. The soils, their enzymological and other properties analysed after 25, 40, 60 and 80 days of plant growth had already been exposed to the complex influence of their hydrocarbon content, the fertilisers applied and the growing plants.

field pea was also significantly greater in the uncontaminated soil than in the order three soils, in which the field pea root mass decreased, but unsignificantly, in the same order as the barley root mass. The shoot mass of both plants had a similar trend to the root mass.

In comparison with the root mass, the microbial biomass-C content in soils under both plants presented, during the growing period, a rather reversed order: oil-contaminated soil $\leqslant$ bioremediated soil $>$ solvent-treated soil $\leqslant$ uncontaminated soil, the differences being significant only between the oil-contaminated or bioremediated soil and the solvent-treated or uncontaminated soil.

The microbial respired C corresponding to respiration of soils, from which the barley and field pea plants were removed, was significantly higher in the oil-contaminated than in the other soils during the whole growing period: oil-contaminated soil $>$ bioremediated soil $\leqslant$ solvent-treated soil $\leqslant$ uncontaminated soil.

The average acid phosphatase activity in the four soils under barley was significantly greater than under field pea. Under barley, the activity was highest in the oil-contaminated soil at tillering stage, in the uncontaminated soil at stem extension and ripening stages, and in the bioremediated soil at heading stage. The activity was lowest in the bioremediated soil during the growing period except at the heading stage.

The pattern of acid phosphatase activity in soils under field pea was not as complicated as under barley. The activity was always highest in the oil-contaminated soil and lowest in the solvent-treated soil. Acid phosphatase activity in the four soils under the two plants significantly correlated with the microbial respired C: the linear correlation coefficient between the two measurements was 0.3373 ($p < 0.05$) under barley and 0.6282 ($p < 0.001$) under field pea.

It is evident from these findings that oil contamination had a negative effect on the growth of both plants (the effect being stronger on barley than on field pea) and a positive effect on soil microorganisms and phosphatase production. This means that, under the conditions of this experiment, the soil microorganisms, although stimulated by the contaminating oil, did not detoxify the soil or, at least, the detoxification was not complete.

Contamination with oil products

Frankenberger [12] has dealt with the use of urea as a nitrogen fertiliser in remediation of soils contaminated with refined oil products. Surface samples (0—15 cm) of three Californian soils of different pH, organic carbon content and texture were studied. Field-moist soil samples (5 g each) were treated with 0, 5, 10 and 25% (weight/weight) of leaded gasoline, kerosene, diesel oil and motor oil, and incubated at 25°C for 14 days, then submitted to urease activity determination. The results have shown that the oil products inhibited soil urease activity. The degree of inhibition ranged from 23% (kerosene) to 61% (leaded gasoline). The greater the loading rate, the less effec-

tive urea becomes as a nitrogen fertiliser. Because inhibition of urease activity is so high, availability of NH_4^+ derived from urea would be greatly delayed and, thus, growth of hydrocarbon-degrading microorganisms would be hindered. The conclusion is that urea should not be recommended as a nitrogen fertiliser to remediate oil-contaminated soils, because it would do little benefit in bioremediation of such soils.

Remediation of a gray forest soil contaminated with oil products was the objective of the investigations described by K h a z i e v *et al.* [24]. Light gasoline (LG), extract of two oily fractions (EOF) and mixture of EOF and asphalt (A) in equal proportion were the contaminants. They were tested at the following rates: LG and EOF — 0.5, 1, 4 and 6%, EOF + A — 0.5+0.5, 4+4 and 6+6% (percentage means ml/100 g air-dry soil). The control samples received no contaminants. For remediation, mineral fertilisers (N 120, P 180 and K 180 kg/ha) plus farmyard manure (140 t/ha) were used. The soil samples moistened to 60% of water-holding capacity and incubated at room temperature were analysed after 24 hours and 3 months.

After 24 hours of incubation, oil product additions to soil samples resulted in reduced enzyme (catalase, dehydrogenase, invertase and urease) activities and in smaller numbers of bacteria, actinomycetes and fungi. The effects were dependent on contaminant concentration. LG was more toxic to enzymes than were the other oil products. Invertase was found to be the most sensitive enzyme to contamination. The only parameter that increased under the influence of contaminants was soil respiration (CO_2 evolution). Treatment with NPK plus farmyard manure did not remove the negative effects of oil products on ezyme activities, but respiration was further enhanced.

After 3 months, the oil products at 0.5 and 1% rates stimulated catalase and dehydrogenase activities, but the higher rates remained inhibitory. Oil contamination also resulted in higher global microbial counts. In contaminated soil samples treated with NPK plus farmyard manure, urease activity, global microbial counts and respiration showed increased values.

In the remediation experiments described by S o n g *et al.* [34] and S o n g and B a r t h a [33], fluorescein diacetate (FDA) hydrolysis activity was also determined together with some soil microbial parameters. A loam soil from the grounds of the Bayway Refinery, New Jersey (Exxon USA) previously not exposed to oil spill was studied. Soil samples (60 g dry weight) were placed in 600-ml beakers in a layer that was less than 2-cm thick for free access of oxygen. They were contaminated with jet fuel at a low (50 mg/g soil) and a high (135 mg/g soil) concentration. For bioremediation, some of the fuel-contaminated samples were limed (10 mg $CaCO_3$/g soil), fertilised with 60 μmol of N as NH_4NO_3 and 5 μmol of P as K_2HPO_4/g soil and „tilled" by a stainless steel wire loop. Moisture content of the soil was adjusted to 50% of water-holding capacity. For inactivating microorganisms and enzymes, some samples were poisoned with 2% $HgCl_2$. All samples were then in-

cubated at 27°C for 18 weeks. During incubation, the samples were aerated and their moisture was maintained at a constant level.

FDA hydrolysis activity was determined at 2-week intervals. In uncontaminated soil the activity remained practically unchanged during 18 weeks of incubation. $HgCl_2$ poisoning resulted in a 90% inhibition of the activity. Jet fuel contamination, without bioremediation, led to a lasting depression of the activity at both fuel concentrations which was attributed to inhibition of the FDA assay by jet fuel degradation products. In soils submitted to bioremediation, jet fuel contamination first depressed the activity, but this brief depression was followed by a strong increase. The increase was of 3-week duration at the low contamination level, but the activity kept increasing for 14 weeks in the case of the higher contamination level. Thus, the benefit of bioremediation in terms of FDA hydrolysis activity was obvious.

Although jet fuel contamination alone depressed FDA hydrolysis activity, it increased bacterial numbers and fungal mycelial length by 2 to 2.5 orders of magnitude. At the same time, combination of jet fuel contamination with bioremediation increased these microbial parameters by 3 to 4 orders of magnitude. Interestingly, the contamination level (50 or 135 mg jet fuel/g soil) made little difference in microbial parameters. During incubation a great part of the added jet fuel disappeared.

Bauer *et al.* [6] and Pennerstorfer *et al.* [29] have studied the effects of organic amendments (bark compost, bark mulch and garbage compost) on bioremediation of heating oil-contaminated samples of two Austrian soils (calcareous chernozem and degraded chernozem). In other experiments (see page 13), these soils were found to be the least and the most sensitive, respectively, to oil contamination. In the bioremediation experiments, the soil samples were treated with organic amendments in a proportion of 4 parts of soil to 1 part of organic amendment, and contaminated with heating oil at a rate of 3.75% (oil weight/soil weight). The control samples received no organic amendment and/or no oil. The mixtures were incubated for 8 weeks. Soil respiration and TTC-dehydrogenase activity were determined weekly. The residual oil content was analysed at the end of the incubation period.

The two soils studied behaved differently. In the oil-contaminated calcareous chernozem, bark and garbage composts increased and bark mulch decreased respiration and dehydrogenase activity; these effects were remarkable only during the first two weeks of incubation. Degradation of oil increased in the order: no organic amendment $<$ bark mulch $<$ garbage compost $\approx$ bark compost. In other words, the organic amendments enhanced bioremediation of the oil-contaminated calcareous chernozem.

In the oil-contaminated degraded chernozem, the organic amendments decreased respiration and dehydrogenase activity, especially during the first 4 weeks of incubation. Degradation of oil increased in

the order: bark mulch < bark compost < garbage compost < no organic amendment. This means that the organic amendments inhibited bioremediation of the oil-contaminated degraded chernozem.

5. Concluding Remarks

The investigations reviewed show that the soil-enzymological and -microbiological effects of oil contamination are dependent on site (soil, vegetation, climate, relief etc.) and on chemical composition and amount of oil contaminants. These factors also determine the rate and extent of bioremediation of oil-contaminated soils, *i.e.* degradation of oil contaminants by the native and/or introduced microorganisms in soils. Therefore, it is difficult to generalise from one case to another [8]. However, the soil enzymatic activities, that are easily measurable, may indicate toxicity of oil contaminants on soil life and also the capacity of the soil microbiota to catalyse self-decontamination of soil. The multidisciplinary investigation of oil contamination of soils and of their remediation should always comprise enzymological measurements, too.

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VEGETAŢIA REGIUNII SOVATA—PRAID—DEALU. II. FORMAŢIUNILE PRATICOLE

IOAN POP* şi ZOE BUZ**

SUMMARY. — Vegetation of the Sovata-Praid-Dealu Area, II. Herbaceous Formations. The investigated area is situated at the Southwest of the Gurghiu Mountains. It has a relief characteristic for a volcanic plateau, ranging between 525 and 1050 m altitude. The analysed herbaceous vegetation was distributed within the following 10 associations: *Agrostio tenuis-Nardetum strictae* Resmeriţă et Texter 1956, Paucă *et al.* 1960, *Campanulo abietinae-Festucetum rubrae* Anghel *et al.* 1956 *-nardetosum strictae*, *Scirpetum sylvatici* Schwick. 1944, *Junco-Molinietum coeruleae* 1951, *Holcetum lanati* Issler 1936, *Festucetum pratensis* Soó (1938) 1957, *Agrostio-Festucetum rubrae* Horv. (1951) 1952, *Anthoxantho-Agrostietum tenuis* Sillinger 1933, Jurko 1969, *Arrhenatheretum elatioris* Br.-Bl. 1919, *Festucetum rupicolae* Burduja *et al.* 1956.

1. Distribuţia vegetaţiei erbacee pe cuprinsul teritoriului cercetat.

Pe lângă vegetaţia silvestră analizată de noi [14], pajiştile reprezintă a doua bogăţie naturală de mare însemnătate economică pentru sectorul zoo-agricol al platoului vulcanic Sovata-Praid-Dealu.

Fitocenozele praticole ocupă suprafeţe întinse, începând din vestul platoului şi până pe vârf [4]. Dintre pajiştile cu productivitate ridicată atât cantitativ, cât şi calitativ, se remarcă fitocenozele edificate de păiuşuri şi de ovăscior (*Campanulo abietinae-Festucetum rubrae, Agrostio-Festucetum rubrae, Anthoxantho-Agrostietum tenuis, Arrhenatheretum elatioris*). Pajiştile slab productive sau fără valoare furajeră ocupă în regiunea cercetată cele mai mari suprafeţe (*Agrostio tenuis-Nardetum strictae, Holcetum lanati, Junco-Molinietum coeruleae* etc.).

Alături de plantele furajere în pajiştile din regiunea studiată mai vegetează şi alte multe specii importante din punct de vedere melifer, alimentar, medicinal, industrial etc.

Fitocenozele erbacee analizate aparţinând la 10 asociaţii sunt încadrate în următorul sistem cenotaxonomic [5, 13, 20]:

Nardo-Callunetea Prsg. 1949

Nardetalia (Oberd. 1949) Prsg. 1949

Potentillo ternatae-Nardion strictae Simon 1957

1. *Agrostio tenuis-Nardetum strictae* Resmeriţă et Texter 1956, Paucă *et al. 1960*
2. *Campanulo abietinae-Festucetum rubrae* Anghel *et al.* 1965

* *Universitatea Babeş-Bolyai, Catedra de biologie vegetală, 3400 Cluj-Napoca, România*
** *Biblioteca Centrală Universitară „Lucian Blaga", 3400 Cluj-Napoca, România*

Molinio-Arrhenatheretea Tx. 1937
Molinietalia W. Koch 1926
Calthion palustris Tx. 1936, 1937
3. *Scirpetum sylvatici* Schwick. 1944
Molinion coeruleae W. Koch 1926
4. *Junco-Molinietum coeruleae* Prsg. 1951
Holco-Juncion Pass. 1964
5. *Holcetum lanati* Issler 1936
Agrostion stoloniferae Soó (1933) 1971
6. *Festucetum pratensis* Soó (1938) 1957
Arrhenatheretalia Pawl. 1928
Cynosurion cristati Tx. 1947
7. *Agrostio-Festucetum rubrae* Horv. (1951) 1952
8. *Anthoxantho-Agrostietum tenuis* Sillinger 1933, Jurko 1969
Arrhenatherion elatioris (Br.-Bl. 1925) W. Koch 1926
9. *Arrhenatheretum elatioris* Br.-Bl. 1919
Festuco-Brometea Br.-Bl. et Tx. 1943
Festucetalia valesiacae Br.-Bl. et Tx. 1943
Festucion rupicolae Soó 1964
10. *Festucetum rupicolae* Burduja *et al.* 1956

Prescurtări folosite pentru cenotaxonii din Tabelele 1—3: Na-Cln. = Nardo-Callunetea, P-Na = Potentillo ternatae-Nardion strictae, M-Arr. = Molinio-Arrhenatheretea, M-J = Molinio-Juncetea, M = Molinietalia, Arr. = Arrhenatheretalia, F-Br. = Festuco-Brometea, F.v. = Festucetalia valesiacae, Ca.d. = Caricetalia davallianae, F-Sd. = Festuco-Sedetalia, S.-F.p. = Stipo eriocaulis-Festucetalia pallentis, Sch.-C. = Scheuchzerio-Caricetalia nigrae, Phr. = Phragmitetea, Q-F = Querco-Fagetea, Al.-P. = Alno-Padion, Q.pb.p. = Quercetea pubescenti-petraeae, Be.-Ad. = Betulo-Adenostyletea, J.-P.m. = Junipero-Pinetalia mugi, Ep. = Epilobietea angustifolii, Ins. = Însoțitoare.

Tabel 1

1. *Agrostio tenuis-Nardetum strictae* Resmeriță et Texter 1956, Paucă *et al.* 1960
2. *Campanulo abietinae-Festucetum rubrae* Anghel *et al.* 1965 — *nardetosum*

Cenotax.	Asociația	1	2
	Altitudinea în m	1050	850—1050
	Înclinarea pantei în grade	5	3—10
	Expoziția	NV, SE	N, NV, E
Arr.	Agrostis tenuis	+ — 2V	—
Na—Cln	Nardus stricta	4 V	2—4 V
Arr.	Festuca rubra	1—2 V	1—3 V
Na—Cln	Campanula abietina	—	+ V
P—Na	Lycopodium clavatum	+ II	—
,,	Sieglingia decumbens	+ V	+ I
,,	Luzula multiflora	+ II	—

Tabel 1 (continuare)

P—Na	Carex pallescens	+ II	+ I
,,	Viola canina	+ III	+ I
,,	Alchemilla vulgaris	+ IV	+ I
,,	Potentilla erecta	+—1 IV	+ I
,,	Genista sagittalis	+ II	+—1 V
,,	Hypericum maculatum	+ I	—
,,	Euphrasia stricta	+ I	+ I
,,	Antennaria dioica	+ II	+ II
,,	Hieracium aurantiacum	+ I	+ II
,,	Hieracium laevigatum	+ I	—
,,	Deschampsia caespitosa	—	+ II
,,	Carex lepidocarpa	—	+ II
Ca.d.	Carex flava	—	+ III
Arr.	Ranunculus nemorosus	+ II	—
,,	Primula veris	—	+ I
,,	Campanula patula	—	+ I
M—Arr.	Anthoxanthum odoratum	+—1 IV	+ III
,,	Briza media	+ II	+ V
,,	Festuca pratensis	—	+ I
,,	Phleum pratense	+ I	+ I
,,	Luzula campestre	+ V	+ III
,,	Gymnadenia conopsea	—	+ I
,,	Rumex acetosa	—	+ V
,,	Ranunculus acris	—	+ III
,,	Cerastium fontanum	+ II	+ I
,,	Lychnis flos-cuculi	—	+ I
,,	Stellaria graminea	+ IV	+ I
,,	Trifolium pratense	+ II	+ V
,,	Trifolium repens	+ III	+ I
,,	Polygala vulgaris	+ II	+ V
,,	Plantago lanceolata	+ II	+ II
,,	Betonica officinalis	+ III	—
,,	Thymus pulegioides	+ I	+ I
,,	Rhinanthus angustifolius	—	+ I
,,	Rhinanthus minor	—	+ II
,,	Achillea millefolium	+ IV	+ III
,,	Carlina acaulis	+ II	—
,,	Centaurea phrygia	—	+ I
M—Arr.	Chrysanthemum leucanthemum	+ V	+—1 V
,,	Hypochoeris radicata	—	+ II
,,	Leontodon autumnalis	+ II	+ I
,,	Leontodon hispidus	+ III	+ I
F—Br.	Lotus corniculatus	+ IV	+ I
,,	Pimpinella saxifraga	+ II	+—1 II

Tabel 1 (continuare)

F—Br.	Plantago media	—	+ I
,,	Galium mollugo	—	+ I
,,	Galium verum	+ II	+ I
,,	Thymus marschallianus	—	+ I
,,	Carlina vulgaris	+ II	—
,,	Hieracium pilosella	+ III	+ I
Q—F	Veronica officinalis	+ I	+ II
Qpb.p.	Ranunculus polyanthemos	+ II	—
,,	Genista tinctoria	+ II	+ III
J.—P.m.	Juniperus communis	+ V	—
Ep.	Solidago virgaurea	+ II	—
Ins.	Rumex acetosella	—	+ II
,,	Helianthemum hirsutum	—	+ I
,,	Lysimachia nummularia	+ II	—
,,	Prunella vulgaris	+ III	+ II

Specii rar întâlnite: 2. Ranunculus flammula, Carex stellulata.
Localități: 1. Stâncel. 2. Podul de Hârtie—Fântâna Brazilor.

Tabel 2

1. *Scirpetum sylvatici* Schwick. 1944
2. *Junco-Molinietum coeruleae* Preissing 1951
3. *Holcetum lanati* Issler 1936
4. *Festucetum pratensis* Soó (1938) 1957
5. *Agrostio-Festucetum rubrae* Horv. (1951) 1952
6. *Anthoxantho-Agrostietum tenuis* Sillinger 1933, Jurko 1969
7. *Arrhenatheretum elatoiris* (Br.-Bl. 1900 s.l.) Scherrer 1925, Soó 1969

	Asociația	1	2	3	4	5	6	7
	Altitudinea în m	1050	1000	525,	500, 600	650, 950	500—575	525, 675
Cenotax.	Înclinarea pantei în grade	—	—	15	5	5—25	5—20	5—15
	Expoziția	—	—	V	SV	NV, V	S, SV, V	E, V
M—J	Scirpus sylvaticus	4	—	—	—	—	—	—
M	Juncus conglomeratus	1	1—2	—	—	—	—	—
M	Molinia coerulea	—	2—4	—	—	—	—	—
M—Arr	Holcus lanatus	—	—	3—4	—	—	+ II	+—1
,,	Festuca pratensis	—	—	+	5	—	+—1 IV	—
Arr	Festuca rubra	—	—	—	—	3—4	+ III	+
,,	Agrostis tenuis	—	—	—	—	2—4	3—5 V	1
M—Arr	Anthoxanthum odoratum	—	—	—	—	+	1—2 V	—

Tabel 2 (continuar e\

Arr	Arrhenatherum elatius	—	—	—	—	—	—	[4]
Phr	Lysimachia vulgaris	+	+	—	—	—	—	—
M	Agrostis stolonifera	1	+	—	—	—	—	—
,,	Deschampsia caespitosa	+	+—2	+	—	+	+—1 III	—
,,	Carex lepidocarpa	—	+—1	+	+	—	+ III	—
,,	Narcissus stellaris	—	+—3	—	—	—	—	—
,,	Caltha palustris	+	+	—	—	—	—	—
,,	Valeriana simplicifolia	+	+	—	—	—	—	—
,,	Filipendula ulmaria	—	+	—	—	—	—	—
,,	Geum rivale	+	+	—	—	—	—	—
,,	Trifolium hybridum	—	—	+	—	—	+ II	—
,,	Galium uliginosum	+	+	—	—	—	—	—
,,	Cirsium canum	—	+	+	—	—	+ III	—
,,	Cirsium rivulare	—	+	—	—	—	—	—
Arr	Bromus commutatus	—	—	—	+	—	+ II	—
,,	Cynosurus cristatus	—	+	1	+	+	+—1 III	+
,,	Carum carvi	—	—	—	—	—	+ III	+
,,	Primula veris	—	—	—	—	+	+	—
,,	Campanula patula	—	+	+	—	+	+ IV	+
M—Arr	Briza media	—	+	+	—	+—1	+—1 II	+
M—Arr	Dactylis glomerata	—	—	+	—	—	+ I	+—1
,,	Festuca pratensis	—	—	—	—	—	+—1 IV	—
,,	Phleum pratense	—	—	—	—	+	—	—
,,	Luzula campestris	—	—	—	—	+	+ II	—
,,	Colchicum autumnale	—	—	—	—	—	+ IV	—
,,	Gymnadenia conopsea	—	—	—	—	+	—	—
,,	Rumex acetosa	—	—	+	—	+	+ II	+
,,	Ranunculus acris	—	+	—	—	+	+ IV	+
,,	Cerastium fontanum	—	+	—	—	+	—	—
,,	Lychnis flos-cuculi	+	+	—	—	—	+ I	—
,,	Stellaria graminea	—	—	—	+	+	+ IV	—
,,	Lynum catharticum	—	—	—	—	—	+ II	+
,,	Polygala vulgaris	—	—	—	—	+	+	—
,,	Medicago lupulina	—	—	—	—	—	+ III	—
,,	Trifolium pratense	—	—	+	—	—	+ V	1—2
,,	Trifolium repens	—	—	+	+	+	+ III	—
,,	Trifolium spadiceum	—	—	—	—	+	+ I	+
,,	Plantago lanceolata	—	+	+	—	—	+ IV	+
,,	Rhynanthus angustifolius	—	—	—	+	—	—	+
,,	Rhynanthus rumelicus	—	+	—	—	2	1—2 V	2
,,	Betonica officinalis	—	+	+	—	—	+ I	—
,,	Thymus pulegioides	—	—	—	—	+	+ I	—
,,	Achillea millefolium	—	+	+	1	+	+—1 V	+
,,	Centaurea jacea	—	—	—	—	—	+ II	+
,,	Centaurea phrygia	—	—	—	—	+	+ IV	—
,,	Chrysanthemum leucanthemum	—	+	+	—	+	+ V	+
,,	Hypochoeris radicata	—	—	+	—	+	+ II	+
,,	Leontodon autumnalis	—	—	+	—	—	+ I	+
,,	Taraxacum officinale	—	—	+	+	—	+ IV	—
Na—Cln	Nardus stricta	—	—	—	—	2	—	—
,,	Sieglingia decumbens	—	—	—	—	+	—	—

(*Tabel 2* (continuare)

Ne—Cln	Carex pallescens	+	—	—	—	—	+ II	—
,,	Alchemilla vulgaris	—	—	—	—	+	—	+
,,	Potentilla erecta	+	+	—	—	+	1 I	—
,,	Genista sagittalis	—	—	—	—	+	—	—
,,	Campanula abietina	—	—	—	—	+	—	—
,,	Euphrasia stricta	—	—	—	—	+	+	—
Sch—C	Carex nigra	—	+—3	—	—	—	—	—
,,	Carex stellulata	—	+	—	—	—	—	—
	Ranunculus flammula	+	+	—	—	—	—	—
Ca.d.	Carex flava	—	—	—	—	—	+ III	—
F—Br.	Euphorbia cyparissias	—	—	—	+	+	+ I	+
,,	Dianthus cathusianorum	—	—	—	—	—	+ I	+
,,	Filipendula vulgaris	—	—	+	—	—	+ IV	—
,,	Lotus corniculatus	—	—	+	+	+	+—2 IV	+
,,	Plantago media	—	—	+	—	+	+—1 III	+
,,	Galium mollugo	—	—	+	+	—	+ II	+
,,	Galium verum	—	+	+	—	—	+ III	+
,,	Thymus marschallianus	—	—	—	—	+	+ I	—
Al.—P.	Equisetum telmateja	+	—	+	—	—	—	—
Qpb.p.	Genista tinctoria	—	—	+	+	+	—	+
Ins.	Equisetum arvense	—	—	—	—	—	+ III	—
,,	Rumex crispus	—	—	—	—	—	+ II	+
,,	Helianthemum hirsutum	—	—	—	—	+	—	+
,,	Lysimachia vulgaris	+	+	—	—	—	—	—
,,	Cruciata glabra	—	—	—	—	+	+ I	—
,,	Plantago major	—	—	—	—	—	+ II	—
,,	Veronica officinalis	—	—	—	—	+	—	+
,,	Mentha arvensis	+	+	—	—	—	—	—
,,	Prunella vulgaris	—	—	+	—	+	+ IV	—
,,	Erigeron annuus	—	—	+	—	—	+ III	—
,,	Juncus effusus	1	+	—	—	—	—	—
	Briofite							
M	Climacium dendroides	+	+	—	—	—	—	—
Arr.	Acrocladium cuspidatum	+	+—3	—	—	—	—	—
Sch—C	Sphagnum subsecundum	4	+—3	—	—	—	—	—
Ins.	Sphagnum russovii	—	+	—	—	—	—	—

Specii rar întâlnite: 1. Trisetum flavescens, Lysimachia nummularia, Crepis paludosa, 2. Juncus articulatus, Iris sibirica, Ranunculus repens, Sanguisorba officinalis, Trifoum strepens. 3. Carex flava, Rumex acetosella, Carum carvi, Cichorium intybus. 6. Ranunculus repens, Vicia cracca, Convolvulus arvensis, Cichorium intybus. 7. Equisetum telmateja.
Localități: 1. Sâncel. 2. Dealu. 3—4. Ocna de Sus. 5. Valea Corundului și Podul de Hârtie. 6. Praid. Ocna de Sus, Corund. 7. Ocna de Sus.

Tabel 3

1. *Festucetum rupicolae* Burduja *et al.* 1956

Cenotax.	Asociaţia	1
	Altitudinea în m	526
	Înclinarea pantei în grade	40—65
	Expoziţia	S, SV
F.v.	Festuca rupicola	1—4
,,	Dorycnium herbaceum	+
,,	Verbascum chaixi	+
,,	Veronica orchidea	+
,,	Anthemis tinctoria	+
,,	Aster amellus	+
,,	Centaurea micranthos	+
F.—Br.	Phleum montanum	+
,,	Phleum phleoides	+
,,	Dianthus carthusianorum	+
,,	Silene vulgaris	+
,,	Euphorbia cyparissias	+
,,	Agrimonia eupatoria	+
,,	Filipendula vulgaris	+
,,	Potentilla argentea	+—1
,,	Potentilla recta	+
,,	Coronilla varia	+
,,	Trifolium campestre	+
,,	Trifolium ochroleucum	+
,,	Trifolium strepens	+
,,	Pimpinella saxifraga	+
,,	Galium mollugo	+—1
,,	Gentiana cruciata	+
,,	Plantago media	+
,,	Ajuga genevensis	+
,,	Calamintha acinos	+
,,	Prunella laciniata	+
,,	Salvia pratensis	+
,,	Teucrium chamaedrys	+
,,	Thymus marschallianus	+
Na—Cln.	Genista sagittalis	+
M—Arr.	Rorippa pyrenaica	+—1
,,	Veronica chamaedrys	+
,,	Knautia arvensis	+
,,	Achillea millefolium	+
,,	Hypochoeris radicata	+
F—Sd.	Silene armeria	+
,,	Sedum acre	+—2

Tabel 3 (continuare)

S—F.p.	Sedum hispanicum	+
Q—F	Brachypodium silvaticum	+
,,	Epipactis helleborine	+
,,	Sedum maximum	+
,,	Trifolium alpestre	+
,,	Calamintha clinopodium	+
Qpb.p.	Genista tinctoria	+
,,	Calamintha silvatica	+
Be.—Ad.	Myosotis silvatica	+
Ins.	Rumex acetosella	+
,,	Silene dubia	+ — 1
,,	Vaccaria pyramidata	+
,,	Echium vulgare	+
,,	Erig ron acer	+

Specii rar întâlnite: Crataegus monogyna, Prunus spinosa, Rosa canina, Hypericum perforatum, Cytisus nigricans, Origanum vulgare, Asplenium septentrionale, Leucedon sciuroides.

Localități: Praid.

2. Analiza vegetației erbacee din regiunea studiată

Agrostio tenuis-Nardetum strictae Resmeriță et Texter 1956, Paucă *et al.* 1960. Fitocenozele asociației de firuță cu țepoșică ocupă cele mai mari suprafețe în partea centrală a platoului de la Sâncel, la altitudinea de 1050 m. Ele populează terenurile plane sau puțin înclinate cu sol tasat, mai mult sau mai puțin umed. În țară ele sunt menționate ca frecvente în județele Harghita, Covasna și Cluj, unde ocupă suprafețe apreciabile [6, 7, 10, 16, 18, 19].

Pajiștile secundare menționate au provenit din fitocenozele asociației *Campanulo abietinae-Festucetum rubrae* prin degradare, în urma tasării si creșterii reacției acide a solului, cauzate de pășunatul excesiv. Aceste procese din sol au favorizat dezvoltarea poaceului oligotrof *Nardus stricta,* dezavantajând pe *Festuca rubra* care și-a redus considerabil abundența (Tabel 1,1).

Compoziția floristică a asociației este eterogenă. Alături de speciile dominante, caracteristice cenotaxonilor *Nardo-Callunetea, Nardetalia, Potentillo ternatae-Nardion strictae* (30%) la care aparține asociația analizată, se remarcă și reprezentanții subunităților clasei *Molinio-Arrhenatheretea* (37%), cu a căror comunități vegetale se învecinează.

În asociație se remarcă prin abundență și frecvență speciile mezofile (50%), xero-mezofile (33,5%), micro-mezoterme (35,3%), amfitolerante termic (37,5%), euriionice (45,8%), acidofile și acid-neutrofile (45,8%).

Campanulo abietinae-Festucetum rubrae Anghel et al. 1965 **-nardetosum strictae**

(Syn.: as. *Festuca rubra fallax-Campanula abietina* Anghel *et al.* 1965; *Festucetum rubrae montanum* Csűrös et Resmeriță 1960; *Festucetum rubrae fallax* Pușcaru *et al.* 1956 etc.)

Fitocenozele asociației sunt distribuite în etajul montan între altitudinile de 850 și 1050 m. Ele au fost identificate la Corund, Fântâna Brazilor, dealul Calonda (Sâncel) etc., populând solurile brune acide montane, rareori podzolite. În România, fitocenozele acestei asociații sunt răspândite în etajul montan [3, 8, 9, 11, 12].

Pajiștile de păiuș roșu analizate sunt situate la limita altitudinală inferioară, fapt atestat și de numărul remarcabil al speciilor transgresive, caracteristice cenotaxonilor (49%) *Cynosurion. cristati, Arrhenatheretalia* și *Molinio-Arrhenatheretea* (Tabel 1, 2).

Plantele specifice unităților cenotaxonomice din clasa *Nardo-Callunetea* în care este încadrată și asociația de referință, deși se găsesc într-un procent redus (20%) față de reprezentanții clasei *Molinio-Arrhenatheretea,* ele se diferențiază evident de fitocenozele edificate de păiușul roșu încadrate în alianța *Cynosurion cristati.*

În unele fitocenoze de păiuș roșu se remarcă prin abundență *Nardus stricta* care ajunge codominant cu *Festuca rubra.* Acest stadiu aflat în procesul evoluției este considerat ca o subasociație distinctivă *-nardetosum strictae* (Syn.: *Festuco-Nardetum strictae montanum* Csűrös et Resmeriță 1960).

Pajiștile de *Festuca rubra* în codominanță cu *Nardus stricta* răspândite în etajul subalpin au fost încadrate de Boscaiu [2] în asociația *Campanulo-Nardo-Festucetum rubrae* Boșcaiu 1971.

Fitocenozele de păiuș roșu analizate au un caracter mezofil (54,2%), micro-mezoterm (37,2%) spre microterm (24,2%), acid-neutrofil (27,7%).

Pajiștile cu păiuș roșu sunt utilizate ca fânațuri. Din cauza pășunatului intensiv o parte dintre acestea sunt degradate.

Scirpetum sylvatici Schwick. 1944. Fitocenozele asociației populează microdepresiunile cu exces de umiditate situate pe cuprinsul luncilor de la Sâncel (Dealu). Ele se învecinează atât cu molidișuri, cât și cu rogozișuri, dezvoltându-se preferențial pe soluri aluvionare, argiloase și gleizate, acoperite uneori cu un strat subțire discontinuu de turbă.

Flora acestor comunități higrofile este săracă, formată din cca 20 specii (Tabel 2,1), dintre care domină plantele caracteristice ordinului *Molinietalia* (40%), căruia îi aparține și asociația de referință. De asemenea, în fitocenozele analizate se distinge și un strat de briofite dominat de *Sphagnum subsecundum.*

Din punct de vedere ecologic, fitocenozele analizate sunt dominate de plantele mezo-higrofile (50%), micro-mezoterme (58,3%) și euriionice (62,5%).

Junco-Molinietum coeruleae Preissing 1951. Până în prezent, fitocenozele de iarbă albastră cu pipirig au fost identificate în mlaștinile

montane distribuite numai pe cuprinsul Carpaților Orientali [1, 4, 10, 17]. Menționăm că vegetația mlaștinilor eutrofe din regiunea cercetată o completează pe aceea din bazinul Bilborului [15].

În regiunea studiată de noi, aceste comunități vegetale populează frecvent terenurile mlăștinoase aferente Pârâului Alb, la cca 1 000 m altitudine.

Dintre cele cca 30 specii componente ale asociației (Tabel 2,2), în unele mlaștini se remarcă prin abundență narcisele (*-narcissetosum*), care în perioada antezei (primăvara) imprimă poienilor un aspect feeric.

În schimb, în alte mlaștini rogozul negru (*-caricetosum nigrae*) abundă, imprimându-le o fizionomie monotonă.

Majoritatea plantelor componente ale fitocenozelor sunt caracteristice cenotaxonilor care subordonează asociația. Stratul de mușchi este dominat de *Acrocladium cuspidatum* și de *Sphagnum subsecundum*.

Comunitățile vegetale analizate sunt dominate de mezo-higrofite și higrofite, care împreună cu mezofitele dețin primatul (57,3%). Dintre celelalte categorii ecologice se remarcă în asociație plantele micro-mezoterme (51,8%), euriionice (59,2%) și acid-neutrofile (25,9%).

Holcetum lanati Issler 1936. Pajiștile de flocoșică au fost identificate în regiunea Sovata-Praid-Dealu numai pe cursul superior al Corundului din etajul colinar, între localitățile Ocna de Sus și Corund.

Fitocenozele asociației ocupă terenurile plane sau ușor înclinate cu soluri aluvionare și brune podzolite. Flora asociației este sărăcăcioasă (Tabel 2,3), fiind dominată prin abundență numai de poaceul *Holcus lanatus*.

Spectrul indicilor ecologici evidențiază caracterul mezofil (54,7%), micromezoterm (47,6%), euriionic (59,5%) și slab acid-neutrofil (21,4%) al asociației.

Festucetum pratensis Soó (1938), 1957. Fitocenozele păiușului de livadă, puțin răspândite în regiunea cercetată, populează suprafețele mai ridicate care vin în contact cu denivelările de teren, existente pe dealul de la Ocna de Sus. Suprafața ocupată de aceste fitocenoze se prezintă sub forma unei fâșii longitudinale plane sau ușor înclinate, venind în contact cu terenul populat cu pajiști de păiuș cu frunze înguste.

Flora pajiștilor analizate este săracă în specii (Tabel 2,4), fiind dominată de *Festuca pratensis*. Din punct de vedere ecologic, asociația prezintă un caracter mezofil (46,1%), amfitolerant termic (46%) și euriionic (76%).

Agrostio-Festucetum rubrae Horv. (1951) 1952. Pajiștile de păiuș roșu cu păiuș îngust au fost identificate atât în etajul colinar pe Valea Corundului în apropierea izvorului Rovașlic (650 m alt.), cât și în cel montan la Podul de Hârtie-Fântâna Brazilor (950 m alt.).

Fitocenozele asociației ocupă solurile brune, podzolite, profunde, cu reacție chimică mai mult sau mai puțin acidă.

Flora fitocenozelor este eterogenă (cca 40 specii), remarcându-se prin abundență și frecvență (57,5%) plantele caracteristice cenotaxonilor care subordonează asociația (Tabel 2,5). Alături de speciile edificatoare, caracteristice asociației (*Festuca rubra, Agrostis tenuis*) se evidențiază semiparazitul *Rhinanthus rumelicus* și poaceul *Nardus stricta* (pe solurile acide), ambele contribuind la deprecierea pajiștilor.

Asociația analizată are un caracter mezofil (53,4%), micro-mezoterm (39,5%), acid-neutrofil (32,4%) și euriionic (46,5%).

Anthoxantho-Agrostietum tenuis Sillinger 1933, Jurko 1969. Pajiștile de păiuș cu frunze înguste sunt răspândite în etajul colinar între Praid și Corund, la altitudinea de 500—575 m.

Flora fitocenozelor (Tabel 2,6) este variată (cca 60 specii), fiind dominată de speciile caracteristice ordinului *Arrhenatheretalia* și clasei *Molinio-Arrhenatheretea* (62%).

În asociație se remarcă prin abundență și frecvență plantele mezofile (51,3%), micro-mezoterme (42,3%), euriionice (57,7%) și slab acid-neutrofile.

Arrhenatheretum elatioris Br.-Bl. 1919. Fitocenozele asociației populează solurile profunde, moderat umede, bogate în substanțe minerale nutritive.

În regiunea studiată pajiștile de ovăscior sunt puțin răspândite, fiind identificate pe Dealul Petri de la Ocna de Sus, între altitudinile de 525 și 675 m (Tabel 2,7).

Asociația de ovăscior are un caracter mezofil (51,3%), micro-mezoterm (35,1%) și slab acid-neutrofil (21,6%). În aceste pajiști ca și în precedentele se remarcă numeric și speciile euriionice (40,5%).

Deși pajiștile de ovăscior sunt apreciate ca foarte bune atât din punct de vedere cantitativ, cât și calitativ, în regiunea Sovata-Praid-Dealu, datorită suprafețelor foarte mici pe care le ocupă, ele prezintă o importanță secundară.

Festucetura rupicolae Burduja *et al.* 1956. Pajiștile de păiuș rupicol au fost identificate pe stâncăriile însorite din etajul colinar de la Praid, învecinate cu o plantație de pin roșu. Deși ecotopul este mai puțin favorabil, în fitocenozele de păiuș rupicol vegetează un număr apreciabil de plante (cca 60 specii), dintre care jumătate sunt specifice cenotaxonilor care subordonează asociația (Tabel 3).

Spre deosebire de asociațiile precedente, în fitocenozele edificate de păiușul rupicol se evidențiază speciile xerofile (61,6%), micromezoterme (68,3%) și slab acid-neutrofile (36,6%).

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VEGETAŢIA REGIUNII SOVATA—PRAID DEALU. III. FORMAŢIUNILE PALUSTRE ŞI RUDERALE

IOAN POP* şi ZOE BUZ**

SUMMARY. — Vegetation of the Sovata-Praid-Dealu Area. III. Palustrine and Ruderal Formations. In the investigated area, 11 associations have been identified and analysed. Eight of them are palustrine and three are ruderal.

The palustrine associations (eutrophic, mesotrophic and oligotropic) shelter the following glacial relicts: *Andromeda polifolia, Empetrum nigrum, Vaccinium oxycoccos, Drosera rotundifolia, Ligularia sibirica, Carex appropinquata, Carex diandra, Carex dioica, Carex elongata, Carex pauciflora, Calamagrostis canescens* and *Calla palustris.*

1. Distribuţia fitocenozelor palustre pe cuprinsul teritoriului cercetat.

Clima răcoroasă cu precipitaţii abundente, cuplată cu diversitatea formelor de relief, au favorizat dezvoltarea pe cuprinsul platoului vulcanic Sovata-Praid-Dealu a unei bogate reţele hidrografice, alcătuită din numeroase izvoare (dintre care multe minerale), pâraie, lacuri şi mlaştini, distribuite între altitudinile de 530 şi 1050 m [2].

Pe cuprinsul mlaştinilor s-a dezvoltat o vegetaţie palustră eutrofă, mezotrofă şi oligotrofă. Majoritatea fitocenozelor palustre analizate sunt mezotrofe, aflate în stadiul de tranziţie de la tipul eutrof spre cel oligotrof [2, 9].

Trestiişurile şi o parte dintre rogozişuri aparţin de categoria vegetaţiei eutrofe. În fitocenozele de trestiiş şi rogoziş (*Caricetum appropinquatae*) situate pe cuprinsul Pârâului Alb şi Pârâului Noroios de lângă localitatea Fântâna Brazilor s-a format un strat de *Sphagnum contortum* indicând tranziţia acestor comunităţi spre o vegetaţie mezotrofă, care în final va evolua spre asociaţii oligotrofe [2].

Vegetaţia oligotrofă este reprezentată de tinovul Ruţ, singurul pe platou, populat de fitocenozele asociaţiei *Eriophoro vaginati — Sphagnetum recurvi-magellanici.*

Toate mlaştinile acoperite cu vegetaţie mezotrofă şi oligotrofă au la bază sedimente minerale lacustre, atestând proveniența lor din mlaştinile eutrofe finiglaciare [2].

Cele mai frecvente fitocenoze palustre identificate aparţin asociaţiilor *Sphagno-Caricetum rostratae, Carici flavae-Eriophoretum latifoliae* şi *Eriophoro vaginati-Sphagnetum recurvi-magellanici.*

In mlaştinile de pe cuprinsul regiunii Sovata-Praid-Dealu au fost identificate următoarele relicte glaciare: *Andromeda polifolia, Empetrum*

* *Universitatea Babeş-Bolyai, Catedra de biologie vegetală, 3400 Cluj-Napoca, România*
** *Biblioteca Centrală Universitară „Lucian Blaga", 3400 Cluj-Napoca, România*

nigrum, Vaccinium oxycoccos, Drosera rotundifolia, Ligularia sibirica, Carex appropinquata, Carex diandra, Carex dioica, Carex elongata, Carex pauciflora, Calamagrostis canescens și *Calla palustris.*

Până în prezent au fost efectuate mai multe studii fitocenologice asupra mlaștinilor cu vegetație mezotrofă și oligotrofă din țara noastră, publicate în diferite monografii și reviste de specialitate [1, 3—7, 9—12, 14].

În regiunea studiată de noi au fost identificate 8 asociații palustre și 3 ruderale, încadrate în următorul sistem cenotaxonomic [8, 13, 15]:

Phragmitetea Tx. et Prsg. 1942
Phragmitetalia W. Koch 1926, em. Pignatti 1953
Phragmition australis W. Koch 1926, Br.-Bl. 1931
Scirpo-Phragmitetum W. Koch 1926
-equisetosum palustris Steffen 1931
Magnocaricetalia Pign. 1953
Magnocaricion elatae W. Koch 1926
Caricetum appropinquatae (W. Koch 1926) Tx. 1947
Scheuchzerio-Caricetea nigrae Nordh. 1936
Scheuchzerio-Caricetalia nigrae (W. Koch 1926) Görs et Müller ex Oberd. 1967
Caricion canescenti-nigrae (K. Koch 1926) Nordh. 1936
Caricetum nigrae Br.-Bl. (1915) 1971
Carici rostratae-Drepanocladetum fluitantis Hadač et Vana 1967
Sphagno-Caricetum rostratae Steffen 1931
Caricion lasiocarpae Van den Bergen 1949
Caricetum diandrae (Jonas 1932) Oberd. 1957
Tofieldietalia Prsg. apud Oberd. 1949
Eriophorion latifolii Br.-Bl. et Tx. 1943
Carici flavae-Eriophoretum latifolii Soó 1944
Oxycocco-Sphagnetea Br.-Bl. et Tx. 1943
Sphagnetalia Pawl. 1928
Sphagnion fusci Br.-Bl. 1920
Eriophoro vaginati-Sphagnetum recurvi-magellanici (Weber 1902) Soć (1927) 1954
Plantaginetea majoris Tx. et Prsg. 1950
Plantaginetalia majoris Tx. (1947) 1950
Agropyro-Rumicion crispi Nordh. 1940
Junco-Menthetum longifoliae Lohm. 1953
Artemisietea Lohm., Prsg. et Tx. 1947, 1950
Artemisietalia Lohm. et Tx. 1947
Arction lappae Tx. 1937 em. Siss. 1946
Sambucetum ebuli (Kaiser 1926) Felföldy 1942
Calystegietalia sepium Tx. 1950
Calystegion sepium Tx. 1947 ex Oberd. 1949
Rudbeckio-Brachypodietum silvatici Szabó 1970

Prescurtările fitotaxonilor incluși în tabelele anexate sunt următoarele: Phr. = Phragmitetea, Phragmitetalia, Mc. = Magnocaricetalia, Sch-C = Scheuchzerio-Caricetea nigrae, C.d. = Caricetalia davallianae, O-Sph = Oxycocco-Sphagnetea, Na-Cln = Nardo-Callunetea, Mo-Crd = Montio-Cardaminetea, M-Arr = Molinio-Arrhenatheretea, M = Molinietalia, F-Br. = Festuco-Brometea, Al.g = Alnetea glutinosae, Ar. = Artemisietea, Ch = Chenopodietea, Cl = Calystegietalia sepium, Pl = Plantaginetea majoris, V-Pi = Vaccinio-Piceetea, Q-F = Querco-Fagetea, Ins = Insoțitoare.

2. Analiza asociațiilor palustre

Scirpo-Phragmitetum W. Koch 1926, *equisetosum palustris* Steffen 1931. Fitocenozele asociației populează bălțile și marginea lacurilor începând din etajul colinar până în cel montan. Trestiișurile au fost identificate la marginea apelor stagnante și lin curgătoare distribuite între localitățile Praid și Ocna de Sus (650 m alt.), Lacul Mare de la Dealu (950 m alt.), precum și în centrul mlaștinii Pârâul Noroios-Fântâna Brazilor de la Corund.

Trestiișurile analizate sunt bi- sau tristratificate. Stratul inferior este dominat de briofitul *Sphagnum contortum*, peste nivelul căruia se ridică tulpinile de *Equisetum palustre* care abundă, imprimând trestiișului un caracter particular. Acest stadiu evolutiv, puțin cunoscut până în prezent în țara noastră, este încadrat în subasociația *equisetosum palustris*. Stratul superior este alcătuit sporadic din exemplare de trestie, pipirig, papură etc. (Tabel 1,1).

Trestiișurile sunt dominate de speciile higrofile și mezo-higrofile (53,7%), de micro-mezoterme (42,3%), slab acid-neutrofile (42,3%) și euriionice (46,1%).

Tabel 1

1. *Scirpo-Phragmitetum* W. Koch 1926
   — *equisetosum palustris* Steffen 1931
2. *Caricetum appropinquatae* (W. Koch 1926) Tx. 1947

Cenotax.	Asociația Altitudinea în m	1 650	2 950
Phr.	Phragmites australis	[+	—
,,	Scirpus lacustris	2	—
,,	Equisetum palustre	4]	—
Mc.	Carex appropinquata	—	[2—4 V]
Phr.	Typha latifolia	+	+ II
,,	Sparganium erectum	+	—
,,	Oenanthe aquatica	+	—
,,	Oenanthe fistulosa	+	+ I
,,	Lysimachia vulgaris	+	+ I
,,	Lycopus europaeus	+	+ I
,,	Mentha aquatica	+	+ I

Tabel 1 (continuare)

Mc.	Carex acutiformis	—	+ I
,,	Carex rostrata	+	1 I
,,	Calla palustris	—	+ — 4 III
,,	Ligularia sibirica	—	+ — 4 V
M.	Carex lepidocarpa	—	1 I
,,	Juncus conglomeratus	—	+ — 1 II
,,	Juncus inflexus	1	—
,,	Deschampsia caespitosa	+	+ — 2 II
,,	Caltha palustris	—	+ III
,,	Geranium palustre	—	+ II
,,	Filipendula ulmaria	—	+ — 3 V
,,	Geum rivale	—	+ IV
,,	Galium uliginosum	—	+ III
,,	Cirsium palustre	—	+ III
,,	Cirsiun rivulare	—	+ II
M. — Arr.	Lychnis flos-cuculi	—	+ II
Ca.d.	Eriophorum latifolium	—	1 I
,,	Carex flava	—	+ — 1 II
Sch. — C.	Carex stellulata	—	+ — 1 I
,,	Ranunculus flammula	—	+ III
,,	Potentilla palustris	—	+ IV
Na. — Cln.	Potentilla erecta	—	+ III
Pl.	Juncus effusus	+	+ — 2 III
,,	Ranunculus repens	1	—
Ins.	Alnus glutinosa	—	+ IV
,,	Salix caprea	—	+ IV
,,	Ranunculus cassubicus	—	+ II
	Briofite		
Sch. — C.	Aulacomnium palustre	—	+ II
,,	Sphagnum contortum	2	+ IV

Specii rar întâlnite: 1. Carex nigra, Juncus articulatus, Briza media, Festuca pratensis, Orchis laxiflora, Linum catharticum, Medicago minima, Medicago lupulina, Trifolium hybridum, Trifolium pratense, Lysimachia nummularia, Plantago lanceolata, Plantago media, Rhinanthus augustifolium, Myosotis scorpioides, Prunella vulgaris, Chrysanthemum leucanthemum, Cirsium canum; 2. Ranunculus acris, Epilobium alsinifolium, Vaccinium myrtillus, Vaccinium vitis-idaea, Succisa pratensis, Mentha arvensis, Bidens cernua, Crepis paludosa, Doronicum austriacum, Acrocladium cuspidatum.

Localități: 1. Praid—Ocna de Sus; 2. Mlaștina Pârâul Noroios—Fântâna Brazilir (Corund).

Caricetum appropinquatae (W. Koch 1926) Tx. 1947. Comunitățile edificate de rogozul turbicol din mlaștina Pârâul Noroios—Fântâna Brazilor (Corund, 950 m alt.) prezintă o importanță fitogeografică deosebită prin faptul că ele adăpostesc relictele glaciare: *Carex appropinquata*, *Calla palustris* și *Ligularia sibirica*.

Cele 33 de specii care intră în componența fitocenozelor analizate sunt distribuite în 3 strate eterogene (Tabel 1,2). Stratul inferior este alcătuit din briofite, stratul mijlociu din poacee și ciperacee, iar cel superior din diferite specii diferențiale, repartizate în funcție de poziția pe care o ocupă în mlaștină, formând faciesuri caracteristice.

Astfel, la contactul dintre pârâu și periferia mlaștinii se evidențiază prin abundență relictul glaciar *Calla palustris* (*-callosum*), care în

perioada antezei impresionează prin morfologia inflorescenței și contrastul coloristic al spatului, verzui la exterior și alb la interior. La marginea estică a mlaștinii se remarcă *Ligularia sibirica* alcătuind un facies caracteristic *-ligulariosum*. În partea sudică a mlaștinii, *Filipendula ulmaria* se dezvoltă exuberant formând faciesul *-filipendulosum*. Centrul mlaștinii este populat de papură (*Thyphaetum latifoliae* Soó 1927).

Asociația analizată are un caracter mezo-higrofil (40%), micro-mezoterm (55,5%), acid-neutrofil (24,4%) și euriionic (51,1%).

Caricetum nigrae Br.-Bl. (1915) 1971. Fitocenozele asociației populează microdepresiunile excesiv umede cu sol turbos acid, situate în regiunea de lagg a tinovului Rotț, precum și în mlaștina Podul de Hârtie-Fântâna Brazilor (Corund, 960—970 m alt.).

Alături de specia edificatoare — *Carex nigra* —, se remarcă, prin numărul mare de indivizi, relictul glaciar *Calla palustris*, care formează un facies caracteristic (*-callosum*, Tabel 2,1). Asociația prezintă un caracter higrofil (58,5%), micro-mezoterm (50%), acid- neutrofil (31,1%) și euriionic (33,3%).

Tabel 2

1. *Caricetum nigrae* Br.—Bl. (1915) 1971
2. *Carici rostratae — Drepanocladetum fluitantis* Hadač et Vana 1967
3. *Sphagno-Caricetum rostratae* Steffen 1931
4. *Caricetum diandrae* (Jonas 1932) Oberd. 1957
5. *Carici flavae-Eriophoretum latifolii* Soó 1944

Cenotax.	Asociația Altitudinea în m	1 970	2 850	4 950—1000	4 950	5 980—1050
Sch.-C	Carex nigra	2—4	—	+I	—	—
Mc.	Carex rostrata	+	2—3	2—5 V	+	+I
Sch.-C.	Drepanocladus fluitans	—	+	—	+	—
,,	Drepanocladus vernicosus	—	2—5	—		—
O.-Sph.	Sphagnum recurvum	+	+	3—5 V	3	+
Sch.-C.	Carex diandra	—	—	—	2—3	—
Ca.d.	Carex flava	—	—	+I	—	1—3 V
,,	Eriophorum latifolium	+—3	—	1 I	—	2—3 V
,,	Carex dioica	—	—	—	—	+II
Sch.-C.	Carex canescens	—	—	+I	—	+—1 II
,,	Carex stellulata	+	1	+IV	—	+II
,,	Agrostis canina	—	+	+IV	+	+I
,,	Ranunculus flammula	—	+	+I	—	—
,,	Epilobium palustre	+	—	+I	—	+II
,,	Potentilla palustris	—	—	—	—	1 II
,,	Valeriana simplicifolia	—	—	+—2 IV	—	+II

Tabel 2 (continuare)

Phr.	Scirpus silvaticus	—	—	+I	—	—
,,	Lythrum salicariă	—	+	+I	—	—
,,	Lysimachia vulgaris	+	—	+III	—	+II
,,	Myosotis scorpioides	—	+	+II	+	+III
,,	Lycopus europaeus	+	1	+I	+—1	—
Mc.	Equisetum limosum	—	2	—	1—2	—
,,	Eriophorum gracile	—	—	+—1 IV	—	
,,	Calla palustris	1—2	—	+—3 V	—	+I
,,	Menyanthes trifoliata	1	—	+—2 I	—	2 I
,,	Veronica scutellata	+	—	+—1 I	—	—
,,	Scutellaria galericulata	—	—	+I	—	—
M.	Narcissus angustifolius	—	—	+—2 II	—	—
,,	Juncus articulatus	+	1	+I	+—2	—
,,	Juncus conglomeratus	—	—	+I	—	1 I
,,	Carex lepidocarpa	—	—	+I	—	+II
,,	Agrostis stolonifera	—	—	—	—	+II
,,	Deschampsia caespitosa	+	—	+I	—	+II
,,	Orchis laxiflora	—	—	+I	—	+II
,,	Orchis maculata	+	—	+II	—	+I
,,	Caltha palustris	+	+	+—1 IV	+	+I
,,	Filipendula ulmaria	—	—	+II	—	+I
,,	Geum rivale	—	—	+—1 III	—	+I
,,	Chaerophyllum hirsutum	—	—	+I	—	+I
,,	Galium palustre	+—1	—	+I	—	+II
,,	Galium uliginosum	—	1	+IV	+—1	—
,,	Cirsium palustre	—	—	+III	—	—
,,	Cirsium rivulare	+	—	+I	—	+I
,,	Crepis paludosa	—	—	+II	+	+III
M.-Arr.	Briza media	—	—	+I	—	+II
,,	Holcus lanatus	—	—	—	—	+II
,,	Lychnisflos-cuculi	—	—	+II	—	+III
Mo.-Crd.	Stellaria alsine	—	—	+I	—	—
,,	Epilobium alsinifolium	—	+	+IV	—	+
Na.-Cln.	Potentilla erecta	—	—	+IV	—	+—1 V
,,	Campanula abietina	—	—	+I	—	+I
Pl.	Juncus effusus	+	+	+—1 II	—	1 II
,,	Ranunculus repens	—	+	+I	—	+I
,,	Lysimachia nummularia	—	+	—	—	—
,,	Prunella vulgaris	—	—	—	—	+II
Ins.	Equisetum silvaticum	—	—	+II	—	—
,,	Carex elongata	+	—	—	—	—
,,	Calamagrostis canescens	+—1	—	3 I	—	—
,,	Alnus glutinosa	+	—	+I	—	—
,,	Salix aurita	—	—	+II	—	—
,,	Salix cinerea	—	—	+I	+	—
,,	Salix pentandra	—	—	+I	—	—
,,	Betula pendula	—	—	+I	—	—
,,	Picea abies	—	—	+II	—	—
	Briofite					

Tabel 2 (continuare)

Sch.-C.	Aulacomnium palustre	—	+	+	+	—
,,	Sphagnum subsecundum	—	—	+—I II	—	—
,,	Sphagnum recurvum ssp. angustifolium	—	—	+I	—	—
O.-Sph.	Calliergon stramineum	—	—	+IV	—	—
,,	Polytrichum strictum	—	—	+I	—	—
,,	Sphagnum cymbifolium	—	—	+—I III	—	—
,,	Sphagnum nemoreum	—	—	+—I III	—	—
Mc.	Calliergon cordifolium	—	—	—	—	+II
,,	Marchantia polymorpha	—	+	—	+	—
Mo.-Crd.	Pellia fabbroniana	+	2	+	+	—
,,	Phylonotis caespitosa	—	+	—	—	—
Ins.	Acrocladium cuspidatum	—	+	—	+	—
,,	Mnium longirostre	—	—	—	—	+
,,	Plagiothecium ruthei	—	—	—	—	+
,,	Sphagnum centrale	—	—	+II	—	—
,,	Sphagnum russovii	—	—	+—I III	+	—

Specii rar întâlnite: 1. Luzula multiflora, Salix purpurea; 2. Alopecurus, aequalis, Typha latifolia, Lemna minor, Callitriche palustris, Mentha aquatica, Hieracium aurantiacum; 3. Juniperus sabina, Eleocharis palustris, Glyceria nemoralis, Orchis incarnata, Populus tremula, Ranunculus cassubicus, Lonicera nigra, Primula acaulis, Succisa pratensis, Bidens cernua, Drepanocladus aduncus, Pleurozium schreberi; 4. Equisetum telmateja, Luzula campestris, Juncus thomassii, Carex limosa, Veratrum album, Salix caprea, Trollius europaeus, Polygala vulgaris, Trifolium hybridum, Trifolium strepens, Peucedanum palustre, Rhinanthus rumelicus, Scutellaria hastifolia, Chrysanthemum leucanthemum, Centaurea melanocalathia, Centaurea nigrescens, Polytrichum commune.

Localităţi: 1. Obârşia Văii Calde, Podul de Hârtie, Fântâna Brazilor; 2. Lacul Mare-Dealu; 3. Podul de Hârtie, Fântâna Brazilor, Ruţ, Corund, Dealu, Valea Caldă, Obârşia Pârâului Alb; 4. Lacul Mare-Dealu; 5. Fântâna Brazilor, Podul de Hârtie, Sâncel.

Carici rostratae-Drepanocladetum fluitantis Hadač et Vana 1967. Comunităţile de rogoz rostrat cu briofite au fost identificate în sudul platoului Dealu şi anume sub vârful Laz (950 m alt.), precum şi la periferia Lacului Mare.

Fitocenozele analizate sunt bistratificate. Stratul inferior este dominat de briofitele *Drepanocladus fluitans, Drepanocladus vernicosus, Pellia fabbroniana* ş.a. În stratul superior se remarcă prin abundenţă *Carex rostrata, Carex stellulata, Equisetum limosum* etc. (Tabel 2,2)

Analiza indicilor ecologici reliefează predominarea în asociaţie a speciilor higrofile (52,6%), micro-mezoterme (63,1%), acid-neutrofile (25%) şi euriionice (57,8%).

Sphagno-Caricetum rostratae Steffen 1931 (syn. *Carici rostratae-Sphagnetum recurvi* Zólyomi 1931). În regiunea studiată sunt cele mai răspândite cenoze palustre de origine mezotrofă. Ele au fost identificate în aproape toate mlaştinile de pe platou, începând de la Fântâna Bra-

zilor și până la Dealu (obârșia Pârâului Alb) la altitudini cuprinse între 950 și 1050 m.

Din aceste considerente numărul plantelor care intră în componența asociației (62 specii) este mult mai mare decât în toate celelalte comunități vegetale studiate (Tabel 2,3).

Stratul inferior muscinal este alcătuit din 14 specii, dintre care domină *Sphagnum recurvum*. Stratul superior este reprezentat de ciperaceul *Carex rostrata*.

În aceste fitocenoze își găsesc condiții prielnice de dezvoltare, formând faciesuri, următoarele specii: *Calla palustris* (*-callosum*) prezentă în mlaștinile Ramura Corundului, Pârâul Cald, Podul de Hârtie, Arinișele de la Sâncel, *Potentilla palustris* (*-potentillosum palustris*), *Narcissus angustifolius* (*-narcissosum*) ambele prezente în mlaștinile Pârâul Alb și Sâncel; *Menyanithes trifoliata* (*-menyanthosum*) la Podul de Hârtie și Sâncel.

Asociația are un caracter mezo-higrofil (45,9%) spre higrofil (32,7%), micro-mezoterm (45,9%) spre microterm (37,7%), slab acid-neutrofil (29,5%) și euriionic (42,6%).

Caricetum diandrae (Jonas 1932) Oberd. 1957. Fitocenozele asociației ocupă o fâșie concentrică incomplet colmatată, cuprinsă între bordura și centrul Lacului Mare-Dealu. În centrul lacului se găsesc fitocenoze aparținând asociației *Typhaetum latifoliae* Soó 1927 și *Equisetetum limosi* Soó 1927.

Flora puținelor fitocenoze analizate este săracă în specii (Tabel 2,4). Stratul inferior este alcătuit din briofite, iar în cel superior se remarcă numeric relictul glaciar *Carex diandra*.

În asociație domină plantele higrofile (60%), micro-mezoterme (60%) și microterme (30%), acid-neutrofile (30%) și euriionice (60%).

Carici flavae-Eriophoretum latifolii Soó 1944. Cenozele asociației populează solurile gleizate, turboase, moderat acide, din microdepresiunile permanent acoperite cu apă, de pe cuprinsul platoului, la altitudinea de 950 și 1000 m. Fitocenozele edificate de bumbăcariță și rogozuri se întâlnesc frecvent în vecinătatea molidișului de la Fântâna Brazilor, în mlaștina de la Podul de Hârtie, unde ocupă o suprafață mai mare, precum și în sfagnetul de la Sâncel (Dealu) unde se evidențiază faciesurile cu *Menyanthes trifoliata* și *Potentilla palustris* (Tabel 2,5).

Fitocenozele analizate sunt tristratificate cu acoperire generală cuprinsă între 90 și 100%. Coeziunea cenotică este realizată de câteva specii de briofite din stratul inferior, de *Carex flava* și *Carex limosa* din stratul mijlociu și de *Eriophorum latifolium* din stratul superior.

Indicii de umiditate din spectrul ecologic reliefează predominarea în asociație a speciilor mezo-higrofile (38,1%) alături de mezofile (30,9%) și higrofile (28,9%). Din punct de vedere termic se remarcă în fitocenoze plantele micro-mezoterme (47,2%) și microterme (31,7%).

Reacția chimică a solului este reliefată de predominarea speciilor acid-neutrofile (31,7%) și a celor euriionice (52,7%).

Eriophoro vaginati-Sphagnetum recurvi-megellanici (Weber 1902) Soó (1927) 1954. Fitocenozele asociației sunt răspândite numai în etajul montan populând microdepresiunile cu turbă pronunțat acidă. Cele mai mari tinoave se întâlnesc la Ruț (12 ha) și la Ramura Corundului-Fântâna Brazilor.

Vegetația tinoavelor analizate este tristatificată. Peste stratul inferior edificat de 9 specii de briofite dintre care domină *Sphagnum recurvum* și *Sphagnum magellanicum* se suprapun tufele de afin și merișor.

Tot în acest al doilea strat mai vegetează relictele glaciare *Andromeda polifolia, Empetrum nigrum, Vaccinium oxycoccos, Drosera rotundiflolia, Carex elongata, Carex pauciflora* (Tabel 3). Stratul al treilea este format numai din bumbăcariță *-Eriophorum vaginatum.*

Tabel 3

1. *Eriophoro vaginati-Sphagnetum recurvi-magellanici* (Weber 1902) Soó (1927) 1954

Cenotax.	Asociația Altitudinea în m	1 950
O.-Sph.	Eriophorum vaginatum	+—3 V
,,	Sphagnum recurvum	+—1 IV
,,	Sphagnum magellanicum	1—3 V
,,	Sphagnum acutifolium	+1
,,	Sphagnum cuspidatum	+1
,,	Sphagnum fallax	2 1
,,	Sphagnum nemoreum	+11
,,	Polytrichum strictum	+—2 V
,,	Carex pauciflora	+111
,,	Drosera rotundifolia	+—1 V
,,	Andromeda polifolia	+111
,,	Vaccinium oxycoccos	+V
,,	Empetrum nigrum	+—2 V
Ca.d.	Eriophorum latifolium	2 1
Mc.	Stellaria longifolia	+111
V.-Pi.	Vaccinium myrtillus	+—2 V
,,	Vaccinium vitis-idaea	+—2 V
Sch.-C.	Polytrichum commune	+11
Al.g.	Carex elongata	+1
,,	Sphagnum teres	+1
Ins.	Juncus effusus	+1

Localități: Tinovul Ruț, Fântâna Brazilor.

În asociație predomină speciile higrofile și mezo-higrofile (36,3%), microterme (54,5%), extrem acidofile (45,5%) și moderat acidofile (36,2%).

Turba tinovului analizat cu grosimea de 6,5 m poate fi valorificată în scop terapeutic sau agrotehnic. Luând în considerare interesul științific pe care îl prezintă în descifrarea evoluției vegetației postglaciare, tinovul studiat a fost propus ca rezervație naturală.

3. Analiza asociațiilor palustre

In preajma așezărilor umane, la liziera pădurilor, pe lângă șanțuri și pârâie au fost identificate fitocenoze ruderale grupate în următoarele 3 asociații.

Junco-Menthetum longifoliae Lohm. 1953. Fitocenozele asociației sunt răspândite în etajul colinar și montan, la altitudini cuprinse între 570 și 940 m, populând microdepresiunile umede, sau ele urmează cursul unor ape generate de izvoare temporare, situate atât între localitățile Praid și Ocna de Sus, pe Valea Corund lângă izvorul Rovaș-lic, cât și între tinovul Ruț și molidișul învecinat.

Flora fitocenozelor este eterogenă indicând tranziția acestora spre cenoze aparținând asociației *Juncetum effusi* Soó (1931) 1949, Eggler, 1933 (Tabel 4,1).

Tabel 4

1. *Junco-Menthetum longifoliae* Lohm. 1953
2. *Sambucetum ebuli* (Kaiser 1926) Felföldy 1942
3. *Rudbeckio-Brachypodietum silvatici* Szabó 1970

Cenotax.	Asociația	1	2	3
	Altitudinea în m	570—940	660	530—630
	Înclinarea pantei în grade	5,30	25	5—15
	Expoziția	NV,V	NE	NE,E
Pl.	Juncus inflexus	+	—	—
,,	Mentha longifolia	+—3	—	—
Ar.	Sambucus ebulus	—	5	—
Cl.	Rudbeckia laciniata	—	—	3—4
Q.-F.	Brachypodium silvaticum	—	—	1—2
Pl.	Rumex crispus	+	—	+
,,	Ranunculus repens	+	—	+
,,	Lysimachia nummularia	+	—	+
,,	Plantago major	+	—	—
,,	Juncus effusus	+—3	—	—
Ar.	Equisetum arvense	+	—	—
,,	Urtica dioica	—	+	+
,,	Artemisia vulgaris	—	+	+
Cl.	Cruciata laevipes	—	+	+
,,	Galium aparine	—	1	+
,,	Calystegia sepium	—	+	+
,,	Myosoton aquaticum	—	+	+
,,	Galeopsis tetrahit	—	+	+
Ch.	Convolvulus arvensis	—	+	—
Phr.	Phragmites australis	+	—	—
,,	Scripus sylvaticus	+	—	—
,,	Lysimachia vulgaris	—	—	1
,,	Myosotis scorpioides	+	—	+
Mc.	Veronica scutellata	+	—	—
Sch.-C.	Epilobium palustre	+	—	—
Ca.d.	Eriophorum latifolium	+	—	—
,,	Epipactis palustris	—	—	+

Tabel 4 (continuare)

Na.-Cln.	Alchemilla vulgaris	+	—	—
,,	Potentilla erecta	+	—	—
M.-Arr.	Cynosurus cristatus	+	—	—
,,	Dactylis glomerata	—	—	+
,,	Holcus lanatus	+	—	—
,,	Poa trivialis	—	—	+
,,	Rumex acetosa	—	—	+
,,	Ranunculus acris	—	—	+
,,	Lychnis flos-cuculi	+	—	—
,,	Trifolium repens	+	—	—
,,	Vicia cracca	+	+	+
,,	Anthriscus silvestris	—	+	+
,,	Knautia arvensis	—	—	+
,,	Achillea millefolium	—	—	+
,,	Centaurea phrygia	+	—	—
,,	Crepis biennis	—	+	—
M.	Equisetum palustre	+	—	—
,,	Deschampsia caespitosa	+	—	—
,,	Orchis laxiflora	+	—	—
,,	Caltha palustris	+	—	—
,,	Lythrum salicaria	—	—	+
M.	Filipendula ulmaria	—	—	1
,,	Trifolium hybridum	+	—	+
,,	Valeriana officinalis	+	—	—
,,	Galium palustre	+	—	—
,,	Betonica officinalis	—	—	+
,,	Cirsium canum	+	—	—
,,	Cirsium palustre	+	—	—
F-Br.	Filipendula vulgaris	+	—	—
,,	Galium verum	—	+	—
Ins.	Leucojum vernum	—	—	+
,,	Astragalus glycyphyllos	—	—	+
,,	Aegopodium podagraria	—	—	+
,,	Chaerophyllum aromaticum	—	—	+
,,	Heracleum sphondyllium	—	+	+
,,	Pulmonaria mollis	—	—	+
,,	Glechoma hederacea	—	+	—
,,	Stachys silvatica	—	+	—
,,	Lapsana communis	—	+	—
,,	Salix triandra	—	—	+

Localităţi: 1. Fântâna Brazilor, Ruţ-Podul de Hârtie, Valea Corundului, Praid, Ocna de Sus; 2. Ocna de Jos; 3. Pârâul Miclăuş-Praid, Muntele de Sare-Sovata.

Sub aspect ecologic asociaţia analizată grupează fitocenoze mezohigrofile (75,1%), micro-mezoterme (53,1%), acid-neutrofile (43,6%) şi euriionice (50%).

Sambucetum ebuli (Kaiser, 1926) Felföldy 1942. Fitocenozele edificate de boz populează solurile bogate în azotaţi, identificate la liziera pădurii Ocna de Jos, acoperind solul în proporţie de 100%. Neexistând un nucleu de plante caracteristice asociaţiei (doar 3 specii indică clasa şi ordinul cărora ea este subordonată), bozul este însoţit de 8 specii

inigrate din comunitățile de plante învecinate. Pe baza acestor considerente se poate explica și numărul mic de specii care intră în componența fitocenozelor (Tabel 4,2).

Din analiza spectrului principalilor indici ecologici se poate trage concluzia că asociația nitrofilă are un caracter mezofil (62,5%), micro-mezoterm (62,6%) și acid-neutrofil (50%).

Rudbeckio-Brachypodietum silvatici Szabó 1970. Fitocenozele asociației au fost identificate pe platoul de la Praid de-a lungul pâraielor unde se prezintă sub forma unui brâu de zeci de metri lungime, la Sovata în vecinătatea izvoarelor situate deasupra Muntelui de Sare, precum și în luminișurile goruneto-cărpinetelor.

Până în prezent asociația a fost identificată și descrisă prima dată de către A. Szabó în anul 1970 de la Sărățel-Chiraleș-Lechința (jud. Bistrița-Năsăud).

Flora fitocenozelor analizate este eterogenă, fiind influențată de comunitățile vegetale învecinate de unde au migrat numeroase specii (Tabel 4,3).

Asociația se caracterizează ecologic prin preponderența speciilor mezofile (54,5%), micro-mezoterme (54,4%), acid-neutrofile (51,5%) și euriionice (45,4%).

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PÂRÂUL NOROIOS — O NOUĂ MLAŞTINĂ IDENTIFICATĂ PE RAZA COMUNEI FÂNTÂNA BRAZILOR — CORUND, JUDEŢUL HARGHITA

ZOE BUZ*

SUMMARY. — Pârâul Noroios — a New Identified Bog in the Area of the Village of Fântâna Brazilor—Corund, Harghita District. The paper presents the results of the palynological research of the new identified bog on the Sovata-Praid-Dealu volcanic plateau. The sediments of Pârâul Noroios bog indicate a forest succession, beginning with the *Carpinus-Picea* phase and followed by the *Fagus-Picea-Abies* phase, during the Subboreal and Subatlantic periods.

Mlaştina Pârâul Noroios (Sáros patak) o semnalăm acum pentru prima dată din regiunea Sovata-Praid-Dealu, fiind identificată de noi în 1984 cu ocazia unor cercetări botanice mai ample.

Este o înmlăştinire mică formată de-a lungul pârâului cu acelaşi nume, în spatele satului Fântâna Brazilor — comuna Corund, pe poteca spre satul Sâncel — comuna Dealu.

Situată la baza unui molidiş ce o desparte de una din ramurile mlaştinii tripartite numite popular mlaştina Caprelor, mlaştina Pârâul Noroios este cantonată într-o depresiune formată la poalele dealului din care izvorăşte Pârâul Noroios.

După aspect şi floră pare o mlaştină de trecere, aflată într-un stadiu foarte puţin avansat de evoluţie spre mezotrofism, mai mult eutrofă, dar prezenţa unicului muşchi *Sphagnum contortum* în strat subţire indică direcţia evoluţiei spre oligotrofizare.

Având o suprafaţă de aproximativ 5 ha, adâncimea turbei de 1,5 m (posibil 2 m în centru), apreciem că are un volum de circa 30.000 m^3 de turbă, sprijinită pe argile galbene nisipoase.

Prezintă o vegetaţie foarte interesantă dominată de *Carax appropinquata* cu faciesuri distincte de *Ligularia sibirica* spre Sâncel, de *Filipendula ulmaria* spre Dealu, de *Calla palustria* pe malul pârâului spre molidiş, partea sa centrală fiind ocupată de *Typhaetum latifoliae*. Nu a fost semnalată nici de Nyárádi [10] şi nici Pop [11] nu o citează.

Stratul turbos acoperă numai aproximativ 1 ha şi este compact numai în primii 100 cm grosime (de la bază începând). Din acest sediment turbos s-au recoltat 20 probe din 5 în 5 cm (Tabel 1, Fig. 1).

Analizate sub aspect sporo-polinic, spectrele orizonturilor profilului reflectă următoarele faze silvestre: faza de molid cu carpen şi faza fagului, molidului şi bradului.

Faza molidului cu carpen (Picea-Carpinus) a fost surprinsă numai în orizonturile bazale (80—100 cm). De fapt a fost surprins numai

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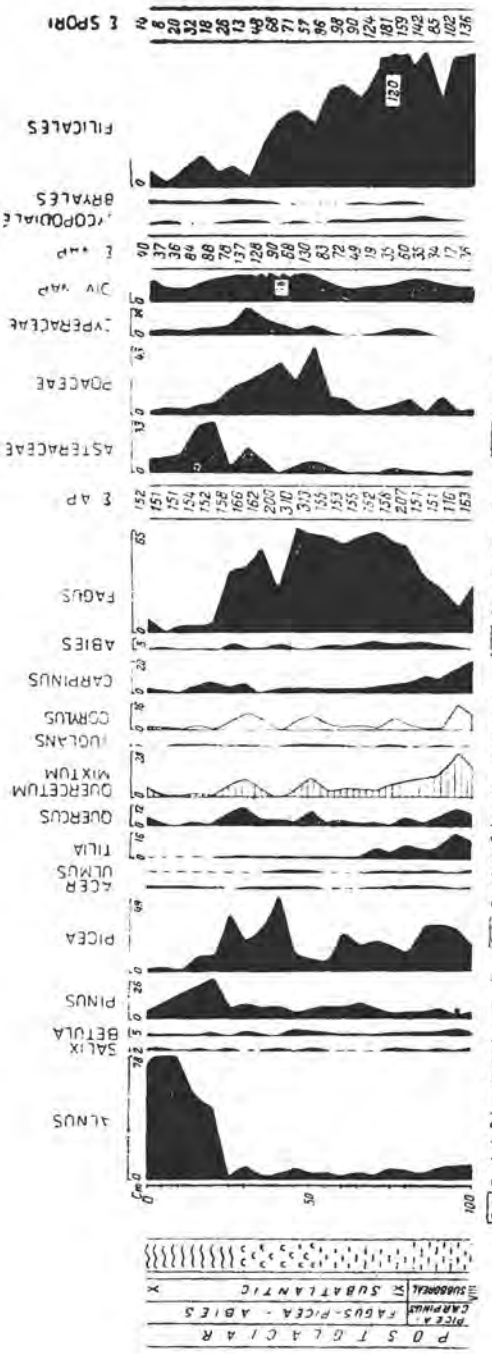

Fig. 1. *Diagrama sporo-polinică a mlaștinii Pârâul Noroios.*

amurgul acestei faze silvestre pentru că cele patru spectre polenice reflectă scăderea oscilantă a procentajului polenic al carpenului (19—8%), în timp ce polenul fagului se afirmă oscilant de la 29 la 34%.

Din această competiție sporo-polinică rezultă că asociațiile silvestre bogate în carpen (cvercto-cărpinete) au fost înlocuite cu asociații în care domină fagul. Ne bazăm această afirmație pe faptul că procentajul polenic al cvercetelor mixte, în care teiul, după procentajul polinic conservat (în medie 13%) era dominat față de stejar (în medie 12%), scade oscilant de la 19 la 12%. Fenomenul este ilustrat și din alte mlaștini din zonă [6]. În sânul acestor cvercete mixte, comparativ cu stejarul și ulmul, era dominant teiul [8].

În timpul acestui sfârșit de fază, pădurile de molid sunt și ele bine reprezentate polenic, dar cu valori care nu oscilează prea mult (27—28%), ceea ce constituie încă un argument că molidișele, la granița dintre aceste două faze silvestre (amurgul cărpinetelor și afirmarea făgetelor), nu au fost prea afectate ca suprafață.

Tot în acest sfârșit de fază trebuie să menționăm și prezența polenului de brad, a cărui frecvență nu depășește 4,6%.

Ceilalți arbori (arinul, alunul, mesteacănul, salcia și arțarul), identificați sporo-polinic, au o frecvență polinică scăzută (2—8,6%), cu excepția alunului care la orizontul 95 cm înscrie 16%. Probabil, aceste esențe lemnoase (*Acer, Corylus*) vegetau în jurul mlaștinii sau chiar în mlaștină (*Salix, Betula, Alnus*).

Dintre plantele ierboase sunt reflectate palinologic poaceele, ciperaceele, asteraceele și alte grupe NAP, dar cu valori procentuale scăzute (± 4%), evidențiind caracterul restrâns al pajiștilor, comparativ cu al pădurilor din jur.

Totuși merită menționate procentajele ridicate (54—120%), chiar de la bază până la orizontul 55 cm, ale sporilor de pteridofite. Asemenea spectre polinice bogate în spori de *Filicales* pot indica stadiul de înmlăștinare al locului respectiv.

Faza fagului, molidului și bradului (*Fagus-Picea-Abies*) este foarte bine surprinsă pe o grosime de 80 cm. Toate spectrele polinice cuprinse între grosimile 80—45 cm sunt dominate de polenul făgetelor, care oscilează între 54,5—65%, în timp ce polenul molidului se menține doar între 8,3 și 23%.

Această competiție sporo-polinică în care polenul făgetelor atinge valoarea maximă de 65%, în timp ce al molidișelor scade la 10%, reflectă de fapt larga răspândire a făgetelor în zonă, în perioada Subatlanticului rece și umed, în defavoarea molidișelor de la altitudinea de 97 cm.

Contemporan acestor făgete compacte, și polenul produs de esențele stejărișurilor mixte(*Quercus, Ulmus, Tilia*), scade valoric (4—12%), indicând depărtarea lor, mai ales pe altitudini mici, de unde polenul a fost vehiculat, de curenții de aer, peste brâul mult mai lat al făgetelor subatlantice, așa cum se întâmplă și astăzi, de fapt [4].

Spre suprafața profilului, polenul făgetelor descrește valoric (27%), în timp ce al molidișelor se afirmă ușor, oscilând între 18—48%, reflec-

tând cu siguranță o mai mare răspândire a acestora pe platoul Sovata-Praid-Dealu [1—3]

Simultan cu afirmarea procentuală a polenului de molid, crește și valoarea procentuală a polenului de pin (5—6%). Aceeași tendință de afirmare cantitativă o înregistrează și polenul esențelor lemnoase componente ale stejărișurilor amestecate, în cadrul cărora, după polenul de *Quercus* conservat (4—11%), stejarul era dominant, în timp ce teiul apare ca modest însoțitor, al cărui polen nu depășește 2%, iar ulmul probabil lipsea, nefiind atestat polenic.

Spectrele polinice din ultimii 20 cm de sediment organo-mineral sunt dominate de polenul arinului, care crește brusc la 46%, atingând chiar 73%, eclipsând contribuția sporo-polinică a pădurilor din jur.

În timpul acestor arinișe probabil pure, este bine reprezentat polenul pinului, mai ales în spectrele polinice ale orizonturilor 20—15—10 cm, unde s-a conservat în proporție de 25—20—15%. Frecvența mare a polenului de arin nu o putem interpreta decât ca o suprareprezentare locală a răzlețelor exemplare de arin care vegetează pe mlaștină și în prezent, ca în aproape toate mlaștinile platoului vulcanic Sovata-Praid-Dealu [1—3, 5, 7], precum și în alte zone ale Carpaților [9, 12].

În concluzie, putem distinge de-a lungul acestei faze un episod de fag cu molid, în timpul căruia bradul este slab reprezentat, iar spre suprafață, cu totul surprinzător, un facies cu mult *Alnus* și *Pinus*, primul suprareprezentat, iar al doilea în revertență specifică regiunii.

Luând ca reper aceste orizonturi cu mult *Alnus* într-o perioadă subrecentă și recentă, în timpul căreia cunoaștem compoziția fitocenozelor silvestre, considerăm necesară o deosebită prudență în interpretarea fitoistorică, atunci când asemenea spectre polinice apar în timpul altor faze silvestre mult mai îndepărtate zilelor noastre, spre exemplu cele din Subboreal.

În asemenea situații s-ar recomanda ca polenul produs de arin să nu se includă în suma de 150 de grăuncioare de polen. În acesată situație expresivitatea fazei fagului cu molid și brad ar fi mult mai fidelă.

Polenul plantelor ierboase este prezent, dominant fiind cel al poaceelor, ciperaceelor, asteraceelor, în timp ce sporii de *Filicales* scad procentual spre suprafață, ajungând chiar la 3%. Restul sporilor de mușchi și licopodiale sunt surprinși în toate spectrele polinice, valorile lor fiind mici

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Tabel 1

Spectrul polinic obținut din sedimentele organo-minerale ale mlaștinii Pârâul Norelor

Fitotaxoni cm	Alnus	Salix	Betula	Pinus	Picea	Acer	Ulmus	Tilia	Quercus	Quercetum mixtum	Juglans	Corylus	Carpinus	Abies	Fagus	Asteraceae	Poaceae	Cyperaceae	Div. NAP	Lycopodiales	Filicales	Bryales
0	72,0	0,6	1,3	6,0	2,0	0,6	—	—	4,6	4,6	—	1,3	3,3	0,6	8,6	8,6	2,6	2,0	12,0	—	8,6	0,6
5	77,3	0,6	0,6	11,3	2,6	0,6	—	—	1,3	1,3	—	0,6	2,0	2,0	1,3	10,0	3,3	2,6	8,6	0,6	3,3	1,3
10	76,0	—	0,6	15,3	0,6	0,6	—	—	0,6	0,6	0,6	0,6	1,3	—	4,0	11,3	2,0	2,0	8,0	—	12,6	0,6
15	53,3	0,6	1,3	20,0	10,6	0,6	—	—	2,0	2,0	0,6	2,6	5,3	1,3	4,0	30,6	6,6	4,0	13,3	—	20,6	0,6
20	46,0	—	2,6	25,3	10,0	0,6	—	—	1,3	1,3	0,6	1,3	7,3	0,6	5,3	32,6	6,6	4,0	15,3	—	8,6	1,3
25	0,6	0,6	—	6,6	36,0	—	—	0,6	8,0	8,6	—	5,3	4,0	4,6	39,3	4,0	17,3	6,0	24,6	1,3	13,3	2,6
30	8,6	—	2,6	8,6	18,0	0,6	—	0,6	11,3	12,0	0,6	10,0	6,0	1,3	40,6	16,6	21,3	18,0	42,6	1,3	7,3	0,6
35	3,0	—	2,0	5,0	27,0	0,6	—	0,6	4,3	5,0	—	8,0	1,0	1,6	54,3	7,3	26,6	10,0	41,3	0,6	30,6	0,6
40	3,5	0,5	1,0	7,0	48,5	0,5	0,5	0,5	5,0	1,3	—	—	3,5	2,5	27,0	—	34,0	7,5	18,5	—	45,5	—
45	8,0	—	5,3	2,3	10,0	0,3	0,3	0,6	3,6	4,6	0,3	6,6	3,3	1,0	65,0	5,3	23,3	3,3	13,3	0,6	47,3	—
50	4,6	0,6	2,6	3,6	9,3	—	1,6	1,6	9,0	12,3	0,6	8,6	3,3	1,0	61,0	8,0	43,3	4,6	30,6	—	38,0	—
55	4,6	—	3,3	6,3	8,3	—	—	0,6	3,0	3,6	0,3	3,3	3,3	2,3	60,3	4,6	11,3	0,6	38,6	0,6	63,3	—
60	3,3	—	—	6,0	23,3	—	—	—	5,3	5,3	0,6	2,0	2,0	2,0	56,0	0,6	10,0	—	58,6	2,6	66,0	—
65	4,0	—	0,6	8,6	16,6	0,3	—	2,0	2,0	4,0	—	3,3	2,6	3,3	60,0	0,6	3,3	—	25,6	1,3	58,0	0,6
70	2,3	—	1,0	5,3	18,3	0,3	0,3	1,0	3,0	4,3	—	1,3	2,6	5,0	63,3	0,6	5,3	0,6	6,6	2,0	77,3	—
75	6,3	0,3	1,3	2,6	14,3	0,6	1,0	6,6	1,6	9,3	0,6	8,0	5,0	3,0	56,6	4,0	6,6	2,6	8,6	2,0	120,0	0,6
80	5,5	1,0	2,5	3,5	11,5	0,5	1,5	4,0	6,0	11,5	—	3,5	5,5	4,0	54,5	2,5	11,0	3,5	13,0	2,0	77,5	1,5
85	4,6	—	2,0	3,3	28,0	0,6	1,3	8,0	3,3	12,6	—	0,6	10,0	4,6	34,0	2,6	2,6	1,3	16,6	4,6	90,0	—
90	8,0	1,3	3,3	4,6	28,0	1,3	2,0	6,0	6,0	14,0	0,6	1,3	8,0	2,6	28,0	—	12,6	—	10,0	2,0	54,6	—
95	8,0	—	5,0	1,0	27,0	—	—	16,0	12,0	28,0	—	16,0	15,0	1,0	15,0	3,0	3,0	3,0	8,0	2,0	100,0	—
100	8,6	2,0	3,3	2,6	13,3	2,0	0,6	10,6	8,0	19,3	—	8,6	19,3	—	29,3	2,6	4,6	—	10,0	—	90,0	—

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ANALIZA PALINOLOGICĂ A UNOR MLAŞTINI DE TURBĂ DIN MUNŢII CĂLIMAN

SORINA MITROESCU—FÂRCAŞ*

SUMMARY. — Palynological Analysis of Some Peat Bogs from the Căliman Mountains. The paper presents preliminary results obtained in some peat bogs from the Căliman Mountains. General data refer to the genesis of the Căliman—Harghita volcanoes and to the location of some bogs, respectively. Images of forest history in Holocene, as it was revealed in the Poiana Boilor and Răchitiş peat bogs, are described.

Mlaştinile de turbă, deşi pot fi foarte vechi, s-au dezvoltat în special în perioada geologică actuală, Cuaternarul, perioadă de schimbări evolutive şi ecologice rapide, culminând cu prezenta structură şi diversitate a ecosistemelor. Astăzi este posibil nu numai să se coreleze aceste schimbări cu fluctuaţiile climatice, dar şi să se concluzioneze influenţa timpurie a omului. Mediul de viaţă cuaternar poate fi reconstituit pe baza înregistrărilor de fosile şi sedimentare, care oferă o evidenţă a condiţiilor de mediu trecute, a evoluţiei vegetaţiei, în corelaţie cu climatele trecutului.

Metodele de abordare a cuaternarului sunt foarte numeroase, constituind domenii de cercetare distincte. Dintre acestea fac parte metodele: geomorfologică, paleontologică, sedimentologică, arheologică, paleomagnetică, radiometrică, dendrocronologică, tefrocronologică, lichenometrică etc. Deoarece o parte dintre aceste metode nu au fost abordate în ţara noastră, metoda palinologică, bazată pe recunoaşterea polenului fosil, devine cu atât mai importantă [2].

In decursul ultimelor două decenii, analiza palinologică s-a impus puternic ca o disciplină capabilă să furnizeze informaţii privitoare atât la istoria vegetaţiei şi a climatului, cât şi la paleogeografie şi stratigrafie. Bazele acestui succes sunt duble: analiza palinologică este o metodă cantitativă bazată pe recunoaşterea şi însumarea unui număr mare de grăuncioare de polen şi, prin variaţiile procentajelor relative ale diferiţilor taxoni recunoscuţi, pot fi distinse cele care reflectă modificările intervenite în vegetaţie; graţie studiului seriilor lungi şi continue, analiza polinică permite aprecierea efectelor fluctuaţiilor climatului şi, în consecinţă, reconstituirea istoriei climatului însuşi. Aceste două proprietăţi caracterizează studiile efectuate asupra multor serii continentale, în special turbării şi sedimente lacustre [4].

În prezenta lucrare vom încerca să exemplificăm primul din aceste două aspecte referitor la reconstituirea istoriei vegetaţiei din ţara noastră, pe baza unor analize de polen efectuate în Munţii Căliman.

* *Institutul de Cercetări Biologice, 3400 Cluj-Napoca, România*

Geneza lanțului muntos Căliman-Gurghiu-Harghita (150 km lungime, 50 km lățime), situat pe bordura vestică a Carpaților Orientali centrali, pe o direcție nord-nord-vest — sud-sud-est, e puternic legată de erupțiile vulcanice desfășurate din Tortonian și până în Cuaternarul inferior. Lanțul muntos s-a „așezat" de-a lungul liniilor de fractură apărute între formațiunile cristaline ale Carpaților Orientali și Depresiunea Transilvaniei, prin coborârea acesteia din urmă. Această mare zonă eruptivă cuprinde, de la nord la sud, următoarele masive:

— munții Căliman, care ocupă nordul lanțului muntos, prelungindu-se spre sud până la Valea Mureșului;

— munții Gurghiului, de la Valea Mureșului până la Valea Târnavei Mari;

— munții Harghita, de la Valea Târnavei Mari până la Tușnad și chiar mai la est, ca o fâșie îngustă, așezată peste cretacicul munților Bodoc.

Munții Căliman sunt munții eruptivi cei mai înalți din țara noastră (2102 m altitudine — vârful Pietrosul Căliman). Caracteristica esențială a acestui masiv o constituie podișul, cu aspect dreptunghiular și presărat cu numeroase conuri și largi cratere vulcanice. Toate craterele apar astăzi deschise de eroziune, iar din ele pornesc diferite pâraie.

Asemănător și altor munți din țara noastră, glaciațiunile pleistocene și-au pus puternic amprenta în Munții Căliman, mai ales pe versantul nordic, unde apar numeroase căldări glaciare, de regulă suspendate la altitudinea de cca 900—1 200 m. Asemenea formațiuni glaciare au fost sculptate de ghețarii pleistoceni, ale căror lungimi puteau atinge 2—3 km și constituie astăzi bazinele torențiale din care își au originea Dornișoara, Neagra Șarului, Neagra Broștenilor etc.

Sub aspect petrografic Munții Căliman se înscriu în categoria munților vulcanici de tip mixt, în care pânzele de lavă pornesc de la cratere diferite, încălecându-se, dar coborând pante line pe diferite distanțe; între ele apar intercalații de aglomerate vulcanice. Constituția petrografică este reprezentată, în mare parte, din lave andezitice, andezite bazaltice, rar cu bazalte și foarte rar cu dacite. În zonele de mare altitudine, aglomeratele andezitice ocupă suprafețe întinse, imprimând aspecte caracteristice Masivului Căliman, în timp ce platoul este rezultatul scurgerilor succesive de lavă. Ansamblul acestor scurgeri conferă aspectul teraselor „în trepte", atât de caracteristice versantului sudic al masivului [1].

Mlaștinile de turbă din Munții Căliman. Edafonul eruptiv, precum și climatul răcoros și bogat în precipitații oferă Munților Căliman condiții favorabile instalării mlaștinilor de turbă, predominant oligotrofe. Toate mlaștinile de turbă semnalate până acum aici sunt localizate între 1250—1700 m altitudine, la adăpostul temperaturilor nu prea coborâte și al vânturilor nu prea puternice. În literatura de specialitate mlaștinile de turbă din Munții Căliman sunt cunoscute ca formațiuni biostratigrafice de dimensiuni mici, dar cu o floră extrem de interesantă.

Pop descrie, în monografia „Mlaștinile de turbă din R.P.R." [3], trei complexe mlăștinoase:

a) Poiana Cailor (= Bouărie) la obârşia Văii Neagra altitudinea 1 500 m;

b) Răchitişul de sus — cunoscut de ciobani ca Rătitiş — situat pe platou, la sud şi sub Vârful Răchitiş — altitudinea 1 680—1 700 m, şi

c) Cica Mare, spre vest de Răchitiş, la 1 700—1 720 m altitudine.

În aceste trei grupuri de tinoave se înregistrau aproximativ 100.000 m^3 de turbă, la o suprafaţă de aproximativ 9 ha.

Ulterior, B. Diaconeasa[1] a cutreierat Munţii Căliman identificând noi complexe mlăştinoase, neinventariate şi necercetate sub aspect botanic, fitocenologic şi palinologic. Aceste mlaştini sunt accesibile pe drumul forestier care porneşte din Drăgoiasa, de-a lungul Văii Homorodului care-şi are obârşia sub vârful Căliman, vărsându-se în Neagra Broştenilor (Fig. 1).

d) Tinovul de la Izvoarele pârâului Puturosul, situat la cca. 1 700 m altitudine, la limita dintre etajul molidului şi cel al jneapănului. Se găseşte între Cica Mare şi Răchitişul de sus, într-un jnepeniş defrişat. Este uşor bombat şi traversat de mai multe pâraie. Are cca 1 ha suprafaţă şi o grosime de 100 cm. Turba este alcătuită din resturi de *Sphagnum*, iar vegetaţia actuală este caracteristică mlaştinilor oligotrofe.

e) „Căliman Exploatare" au fost numite mai multe înmlăştiniri înfiripate de-a lungul a numeroase pârâiaşe. Înmlăştinirile au caracterul unor bahne cu tendinţă de oligotrofie, care s-au instalat pe versantul nordic la altitudinea de aproximativ 1 700 m, sub Vârful Răchitiş şi deasupra „Exploatării de sulf" din Căliman. Grosimea stratului turbos şi a sedimentului pelitic din bază variază între 80—150 cm.

f) Mlaştina Iezerul Căliman se află la 1 650 m altitudine şi îşi are obârşia într-un lac vulcanic, colmatat parţial de-a lungul Holocenului. Din fostul ecosistem lacustru, ce nu depăşea, probabil, 1,5 ha suprafaţă a mai rămas un ochi de apă, tivit pe margini de brâul de ciperacee care îl strangulează pe flancul nord-estic.

Stratul de turbă are o grosime de 210 cm şi s-a depus peste un sediment pelitic de cca 280 cm grosime. Este o turbă de *Sphagnum*, invadată în vremurile mai recente de jnepeniş.

g) Poiana Boilor este un platou situat la cca. 1 250 — 1 300 m altitudine şi presărat cu numeroase înmlăştiniri mezotrofe, având la suprafaţă perini de *Sphagnum*. Pe fondul unei vegetaţii lemnoase reprezentată de molizi piperniciţi s-a instalat o vegetaţie luxuriantă alcătuită din diverse specii de ciperacee şi graminee. Pe acest platou, numit de ciobani Poiana Boilor, se observă cel mai bine complicatul proces de înmlăştinire a molidişelor.

În acest studiu sunt prezentate rezultatele analizelor sporo-polinice preliminare, efectuate în două din aceste mlaştini de turbă, Poiana Boilor şi Răchitiş.

Probele au fost colectate cu ajutorul unei sonde de mână Hiller.

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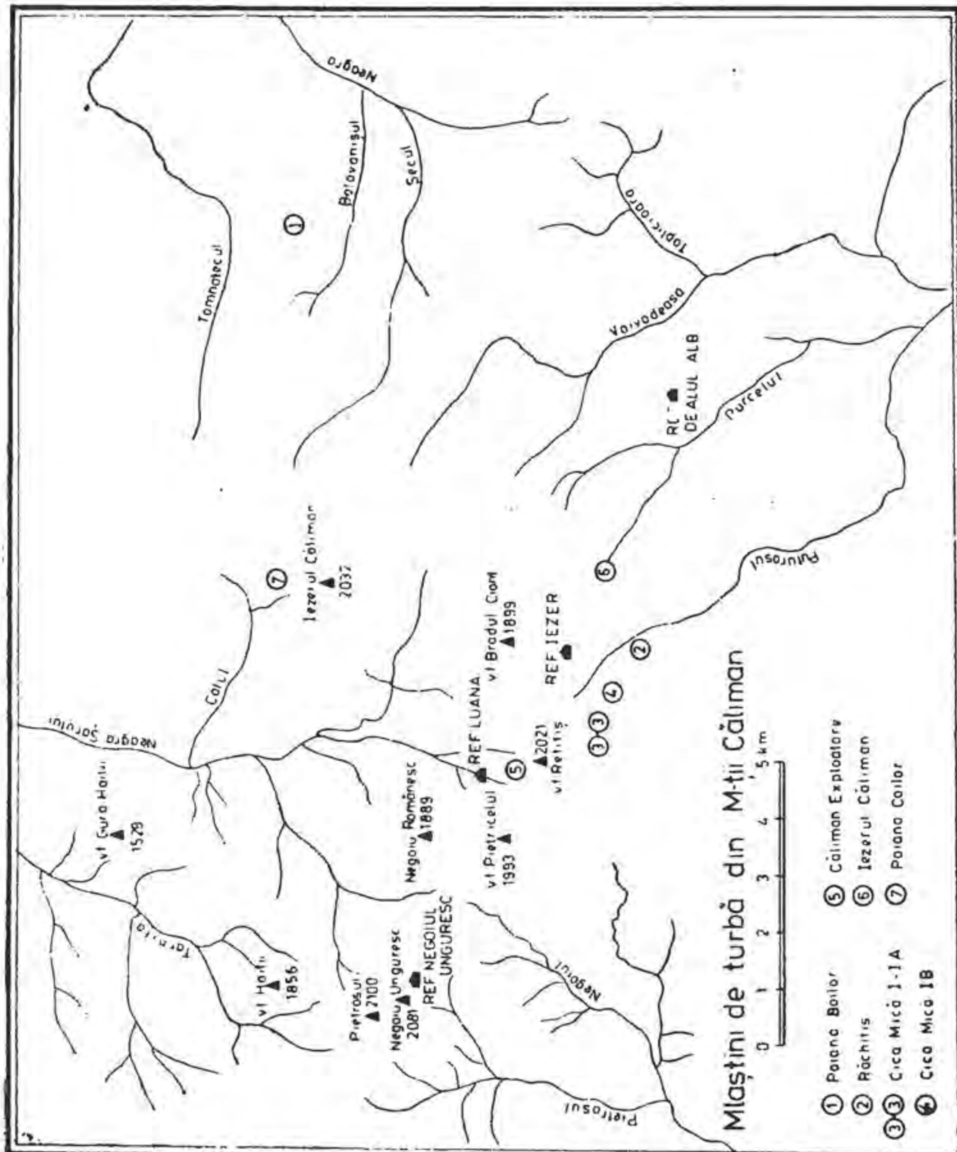
[1] Mulţumesc încă o dată Domnului Profesor B. Diaconeasa pentru datele furnizate.



F i g. 1. *Mlaştini de turbă din Munţii Călimani.*

Din mlaștina de turbă Poiana Boilor au fost extrase un număr de 16 probe, dintr-un profil, de la adâncimea de 118 cm până la 20 cm suprafață. Din mlaștina de turbă Răchitiș au fost de asemenea extrase probe dintr-un singur profil, de la 20 cm până la 127 cm adâncime, însumând un număr de 13 probe.

Pentru prelucrarea probelor în laborator s-a folosit metoda Erdtman. Din probele astfel prelucrate s-au realizat preparatele microscopice fixe. S-au citit polenul de arbori, arbuști, plante ierboase, precum și sporii de *Sphagnum* și *Filices*. Calculul procentual s-a efectuat în două moduri: atât polenul de arbori cât și cel de arbuști, plante ierboase, precum și sporii, au fost raportate la ΣA.P.; raportarea s-a făcut și la ΣA.P. + ΣN.A.P., în care au fost incluși și sporii (A.P. = arborum pollen; N.A.P. = non arborum pollen). S-au obținut astfel spectrele polinice ale tuturor orizonturilor cercetate, care au fost reprezentate în Tabelele 1--8. De asemenea, s-a calculat și ponderea procentuală a polenului de arbori, raportat la totalitatea polenului și a sporilor, pentru a ilustra mai bine tipul de ecosistem predominant.

Rezultate și concluzii. În urma analizei palinologice a stratului de la Poiana Boilor (Tabelele 1—4) se desprinde concluzia că acesta ilustrează existența ultimei faze silvestre, faza molidului-fagului-bradului. Desfășurată în climatul mai rece și umed al Subatlanticului, ea a favorizat dezvoltarea fagului (*Fagus*), fără însă ca maximul acestuia (10% raportat la suma A.P., respectiv 8,82% raportat la suma A.P. + suma N.A.P.) să-l ajungă pe cel al molidului (*Picea*) (89, respectiv 77,72%). Molidul se menține în întregul profil cu valori foarte mari (min. 75,33, respectiv 60,62%). Aceasta se explică prin faptul că regiunea respectivă este populată cu păduri de molid. Procentajele celorlalte esențe lemnoase sunt destul de slab reprezentate: pinul, cu valori cuprinse între 0 și 4%, respectiv 0 și 3,24%; carpenul cu valori între 0 și 4,66%, respectiv 0 și 4,29%; arinul: 0—3,33%, respectiv 0—2,77%; stejarul: 0—4%, respectiv 0—3,33%. Cu valori mai ridicate apare bradul (max. 10,66, respectiv 9,35%). Teiul, ulmul, salcia și alunul sunt foarte slab reprezentați. Mesteacănul apare și el, dar cu valori mici (max. 1,33, respectiv 1,08%).

Însumând procentajele stejarului, teiului, ulmului, am obținut valorile stejărișului amestecat (*Quercetum mixtum*), cuprinse între 0,66 și 5,33%, respectiv 0,48 și 4,43%, care atestă absența acestor elemente de la această altitudine, polenul lor fiind adus de curenții aerieni ascendenți de la altitudini mai scăzute.

În concluzie, pe baza datelor certe pe care le avem se pare că stratificarea turbei din perimetrul mlaștinii Poiana Boilor a început relativ recent, în Subatlantic, perioadă în care ne găsim și astăzi; avem rezerve asupra perioadei exacte, urmând ca studii ulterioare să clarifice această problemă (Fig. 2).

În ceea ce privește mlaștina de turbă Răchitiș, ea ilustrează existența fazelor silvestre: *a molidului cu stejăriș amestecat și alun* și *a mo-*

Tabel 1

Reprezentarea procentuală a polenului de arbori din mlaștina de turbă Poiana Boilor (Munții Călimani), raportat la Σ A.P.

Adâncimea (cm)	Pinus	Picea	Abies	Fagus	Carpinus	Betula	Alnus	Quercus	Tilia	Ulmus	Q.M.	Salix	Corylus
20	4,00	78,06	1,33	8,66	2,00	1,33	2,66	1,33	—	0,66	2,00	—	1,33
27	2,00	82,66	2,00	10,00	1,33	0,66	—	1,33	—	—	1,33	—	0,66
34	0,66	76,66	10,66	10,00	0,66	—	0,66	0,66	—	—	0,66	—	—
40	3,33	76,66	8,00	8,00	1,33	0,66	1,33	0,66	—	—	0,66	—	—
47	0,66	77,33	10,00	5,33	2,00	0,66	1,33	2,00	0,66	—	2,66	—	0,66
54	1,33	75,33	6,66	6,66	4,66	—	2,66	2,66	—	—	2,66	—	—
60	3,33	78,00	4,66	5,33	4,66	—	0,66	2,66	0,66	—	3,33	—	—
67	—	85,33	2,00	4,66	2,66	1,33	0,66	2,66	—	0,66	3,33	—	2,00
74	1,33	88,00	0,66	5,33	2,66	—	0,66	—	0,66	—	0,66	0,66	1,33
80	2,00	87,00	1,50	4,00	1,50	0,50	1,00	1,50	—	0,50	2,00	1,00	0,50
87	2,66	85,33	2,66	7,33	1,33	—	—	0,66	—	—	0,66	—	—
94	0,50	89,00	1,00	5,50	2,50	—	—	1,00	—	—	1,00	—	—
100	3,33	80,00	0,66	8,00	4,66	—	0,66	0,66	—	2,00	2,66	—	—
107	0,66	86,66	2,00	6,66	0,66	—	1,33	2,00	—	—	2,00	—	—
114	0,66	84,00	0,66	9,33	2,00	—	—	2,66	0,66	—	3,33	—	0,66
118	2,66	84,66	—	4,00	—	0,66	3,33	4,00	0,66	0,66	5,35	—	—

Tabel 2

Reprezentarea procentuală a polenului de arbori din mlaștina de turbă Poiana Boilor (Munții Călimani). raportat la Σ A.P. + Σ N.A.P.

Adâncimea (cm)	Pinus	Picea	Abies	Fagus	Carpinus	Betula	Alnus	Quercus	Tilia	Ulmus	Q.M.	Salix	Corylus
20	3,24	63,24	1,08	7,02	1,62	1,08	2,16	1,08	—	0,54	1,62	—	1,08
27	1,76	72,94	1,76	8,82	1,17	0,58	—	1,17	—	—	1,17	—	0,58
34	0,50	67,25	9,35	8,77	0,58	—	0,58	0,58	—	—	0,58	—	—
40	2,85	65,71	6,85	6,85	1,14	0,57	1,14	0,57	—	—	0,57	—	—
47	0,53	62,36	8,06	4,30	1,61	0,53	1,07	1,61	0,53	—	2,14	—	0,53
54	1,12	63,84	5,64	5,64	3,95	—	2,25	2,25	—	—	2,25	—	—
60	3,06	67,48	4,29	4,88	4,29	—	0,61	2,45	0,61	—	3,06	—	—
67	—	69,18	1,62	3,78	2,16	1,08	0,54	2,16	—	0,54	2,70	—	1,62
74	0,96	63,46	0,48	3,84	1,92	—	0,48	—	0,48	—	0,48	0,48	0,96
80	1,39	60,62	1,04	2,78	1,04	0,34	0,69	1,04	—	0,34	1,38	0,69	0,34
87	2,19	70,32	2,19	6,04	1,09	—	—	0,54	—	—	0,54	—	—
94	0,43	77,72	0,87	4,80	2,18	—	—	0,87	—	—	0,87	—	—
100	2,57	61,85	0,51	6,18	3,60	—	0,51	0,51	—	1,54	2,05	—	—
107	0,54	70,27	1,62	5,40	0,54	—	1,08	1,62	—	—	1,62	—	—
114	0,53	67,37	0,53	7,48	1,60	—	—	2,13	0,53	—	2,66	—	0,53
118	2,22	70,55	—	3,33	—	0,55	2,77	3,33	0,55	0,55	4,43	—	—

Tabel 3

Reprezentarea procentuală a polenului de ierboase și a sporilor din mlaștina de turbă Poiana Boilor (Munții Călimani), raportat la Σ A.P.

Adâncimea (cm)	Poaceae	Cyperaceae	Apiaceae	Asteraceae	Chenopodiaceae	Ericaceae	Filices	Sphagnum	N.A.P
20	2,00	10,00	—	0,66	—	—	2,00	4,00	3,33
27	6,66	—	—	—	0,66	—	—	3,33	2,00
34	3,33	6,66	—	0,66	—	—	3,33	—	—
40	3,33	6,66	—	3,33	—	—	3,33	—	—
47	3,33	9,33	1,33	2,00	—	0,66	6,66	—	—
54	6,66	10,66	—	0,66	—	—	—	—	—
60	3,33	5,33	—	—	—	—	—	—	—
67	4,00	6,66	0,66	—	—	—	10,00	—	—
74	4,00	10,66	6,66	2,66	—	—	7,33	—	—
80	7,50	20,00	1,00	2,00	—	—	12,50	—	—
87	1,33	4,00	0,66	1,33	—	—	12,66	—	1,33
94	2,00	7,00	0,50	1,50	—	—	2,50	—	1,00
100	7,33	13,33	—	1,33	—	—	6,66	—	0,66
107	3,33	16,66	—	—	—	—	2,00	—	1,33
114	4,00	12,00	—	0,66	—	—	5,33	—	2,00
118	1,33	8,00	—	4,00	0,66	1,33	4,66	—	—

Tabel 4

Reprezentarea procentuală a polenului de ierboase și a sporilor din mlaștina de turbă Poiana Boilor (Munții Călimani), raportat la Σ A.P. + Σ N.A.P.

Adâncimea (cm)	Poaceae	Cyperaceae	Apiaceae	Asteraceae	Chenopodiaceae	Ericaceae	Filices	Sphagnum	N.A.P
20	1,62	8,10	—	0,54	—	—	1,62	3,24	2,70
27	5,88	—	—	—	0,58	—	—	2,94	1,76
34	2,92	5,84	—	0,58	—	—	5,84	—	—
40	2,85	5,71	—	2,85	—	—	2,85	—	—
47	2,68	7,52	1,07	1,61	—	0,53	5,37	—	—
54	5,64	9,03	—	0,56	—	—	—	—	—
60	3,06	4,90	—	—	—	—	—	—	—
67	3,24	5,40	0,54	—	—	—	8,10	—	—
74	2,88	12,01	4,80	1,92	—	—	5,28	—	—
80	5,22	13,93	0,69	1,39	—	—	8,71	—	—
87	1,09	3,29	0,54	1,09	—	—	10,43	—	1,09
94	1,74	6,11	0,43	1,31	—	—	2,18	—	0,87
100	5,67	10,30	—	1,03	—	—	5,15	—	0,51
107	2,70	13,51	—	—	—	—	1,62	—	1,08
114	3,20	9,62	—	0,53	—	—	4,27	—	1,60
118	1,11	6,66	—	3,33	0,55	1,11	3,88	—	—

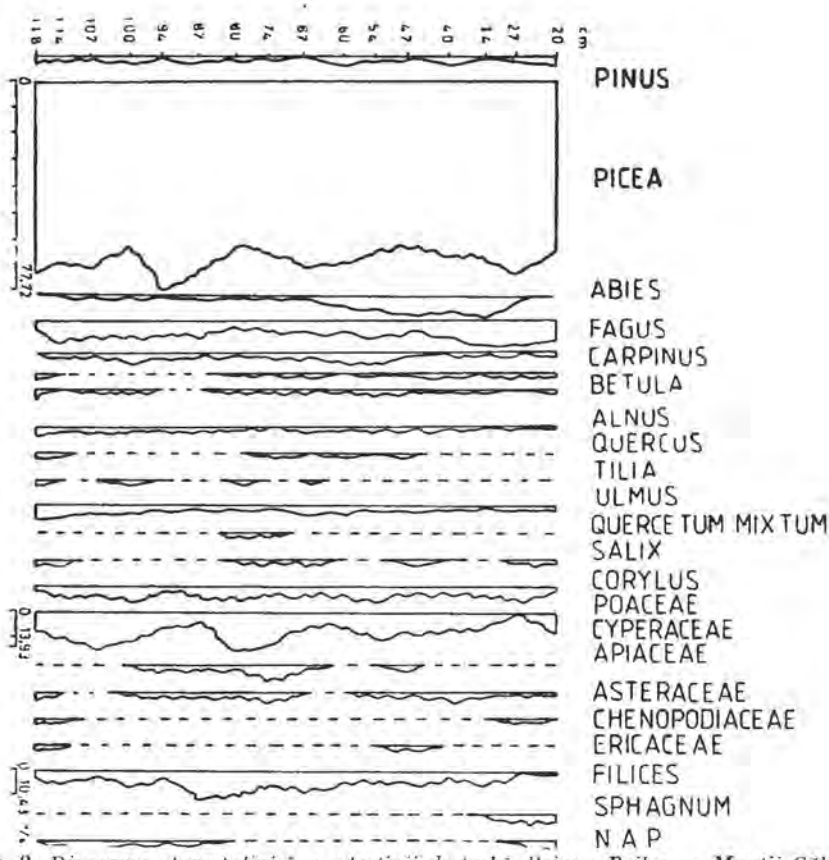


Fig. 2. *Diagrama sporo-polinică a mlaștinii de turbă Poiana Boilor — Munții Călimani.*

lidului—fagului—bradului, fiind deci mai veche decât cea de la Poiana Boilor.

Prima dintre aceste faze, cea a *molidului cu stejăriș amestecat și alun*, s-a stratificat în perioada călduroasă postglaciară, din Atlantic, care a favorizat dezvoltarea stejărișelor, la altitudini mai mici, sub brâul pădurilor de molid. În înmlăștinirea de la Răchitiș am surprins palinologic această fază, parțial, între orizonturile 100—127 cm. Se caracterizează prin procentajele relativ ridicate pentru stejărișul amestecat (între 9,33 și 21,33%, respectiv 6,54 și 9,42%). Stejarul participă cu valori asemănătoare ulmului, teiul cu valori mai scăzute, iar arțarul apare doar sporadic (Tabelele 5—6). Nu am surprins această fază silvestră decât fragmentar, iată de ce nu apar episoadele cu predominarea uneia sau alteia dintre esențele de mai sus.

Caracteristică acestei faze îi este și abundența alunului, care forma pâlcuri compacte, cu largă răspândire în sânul stejărișelor, după cum se poate constata pe baza valorilor procentuale ale polenului său obținute din aceste orizonturi (maximum 46%, raportat la suma AP, res-

pectiv maximum 21,91%, raportat la suma AP + suma NAP). Și în aceste spectre polinice polenul dominant rămâne cel de molid, ca și la Poiana Boilor. Valorile sale oscilează între 58 și 80,66%, respectiv între 29,14 și 63,74% calculat la suma AP + suma NAP.

Pinul este reprezentat continuu, dar cu valori mai degrabă modeste, care-i atestă prezența în regiune la altitudini mai ridicate (Tabelele 5—6).

Bradul și fagul au fost surprinși simultan, la orizontul 107 cm, deci spre sfârșitul fazei, ceea ce atestă apariția acestor arbori doar la sfârșitul Atlanticului sau mai degrabă, dacă luăm în considerare imperfecțiunea metodei de forare, de abia în Subboreal. Valorile lor sunt oricum nesemnificative pentru această fază silvestră. Tot cu valori nesemnificative, dar constante apar carpenul, mesteacănul, aninul și, cu totul sporadic, salcia.

Următoarei faze silvestre din istoria pădurilor noastre, *faza molidului cu carpen*, îi corespunde un hiatus de sedimentare. Ca dovadă stau valorile constant scăzute ale carpenului din tot profilul (maximum 7,33, respectiv 6,14%).

Faza molidului—fagului—bradului este asemănătoare cu cea descrisă la Poiana Boilor. Molidul este la fel dominant pe tot profilul, de la 20 până la 100 cm adâncime. Maxima sa este totuși mai scăzută față de cea găsită la Poiana Boilor (72,66, respectiv 63,74% — Tabelele 1, 2, 5 și 6). Ca o compensare, apar procentaje mai mari pentru fag (18, respectiv 15,69%) și pentru pin (19, respectiv 15,70%). Procentajul maxim găsit pentru brad este identic cu cel de la Poiana Boilor (10,66, respectiv 9,35%). În rest, celelalte esențe lemnoase sunt și aici mai slab reprezentate (Tabelele 5 și 6), reflectând distanța la care se află aceste păduri față de locul cercetat (Fig. 3).

În ceea ce privește polenul plantelor ierboase, contribuția acestora la edificarea ecosistemelor respective este redată de Tabelele 3 și 4, pentru Poiana Boilor, respectiv 7 și 8 pentru Răchitiș. Se observă pentru ambele mlaștini predominarea *Cyperaceae*-lor, urmată de *Poaceae*. Procentajul primelor crește sensibil în timpul *fazei molidului cu stejăriș amestecat și alun* de la Răchitiș, unde atinge valori de 45,33, respectiv 19,42%. Având în vedere valorile nu foarte ridicate ale polenului de *Cyperaceae*, am efectuat calculul incluzând în suma totală și acest polen. Cu valori mult mai scăzute apare polenul de *Apiaceae*, *Ericaceae*, *Asteraceae*. *Chenopodiaceae*-le sunt aproape inexistente, iar *Artemisia* apare într-un singur orizont, la Răchitiș, cu valori subunitare. Dintre spori i-am pus în evidență pe cei de *Filices*, cu valori mai ridicate, corespunzând valorilor mai mari ale *Cyperaceae*-lor (maximum 30, respectiv 14,22% — la Răchitiș) și doar sporadic pe cei de *Sphagnum* și *Lycopodium*.

În prezenta lucrare am redat și ponderea polenului de arbori (%) de la cele două mlaștini prezentate (Tabelele 9 și 10). Această metodă de abordare permite vizualizarea rapidă a tipului de vegetație ce intra

Tabel 5

Reprezentarea procentuală a polenului de arbori din mlaștina de turbă Răchitiș (Munții Călimani), raportat la Σ A.P.

Adâncimea (cm)	Pinus	Picea	Abies	Fagus	Carpinus	Betula	Alnus	Quercus	Tilia	Ulmus	Acer	Q.M.	Salix	Corylus
20	19,00	65,00	4,00	7,00	1,00	1,00	1,00	1,00	—	—	1,00	2,00	—	—
34	4,00	72,66	10,66	6,66	0,66	0,66	1,33	1,33	0,66	0,66	0,66	3,33	—	0,66
47	13,33	58,00	9,33	12,00	1,33	0,66	0,66	2,00	0,66	1,33	0,66	4,66	—	1,33
60	10,66	70,66	8,00	6,66	0,66	0,66	1,33	0,66	—	—	0,66	1,33	—	0,66
74	5,33	68,00	6,00	10,66	2,00	2,00	3,33	1,33	0,66	0,66	—	2,66	0,66	0,66
80	4,00	58,00	6,00	12,66	7,33	1,33	3,33	4,00	1,33	0,66	1,33	7,33	—	0,66
87	4,00	68,33	3,33	16,00	2,00	—	2,00	2,66	—	0,66	0,66	4,00	—	—
94	4,66	60,00	4,66	18,00	4,66	—	2,00	3,33	0,66	0,66	1,33	6,00	—	2,00
100	3,33	80,00	0,66	4,00	0,66	1,33	—	4,00	2,66	2,00	0,66	9,33	0,66	8,00
107	2,00	77,33	0,66	0,66	4,00	2,00	0,66	6,00	0,66	3,33	1,33	11,33	1,33	9,33
114	2,66	80,66	—	—	—	0,66	2,66	2,00	4,00	6,66	0,66	13,33	—	18,00
120	2,00	67,33	—	—	0,66	2,00	5,33	8,00	4,66	9,33	—	21,33	—	46,00
127	13,33	65,66	—	—	1,33	—	3,33	8,00	0,66	7,33	—	16,00	—	42,66

Tabel 6

Reprezentarea procentuală a polenului de arbori din mlaștina de turbă Răchitiș (Munții Călimani), raportat la Σ A.P. + Σ N.A.P.

Adâncimea (cm)	Pinus	Picea	Abies	Fagus	Carpinus	Betula	Alnus	Quercus	Tilia	Ulmus	Acer	Q.M.	Salix	Corylus
20	15,70	53,71	3,30	5,78	0,82	0,82	0,82	0,82	—	—	0,82	1,64	—	—
34	3,50	63,74	9,35	5,84	0,58	0,58	1,16	1,16	0,58	0,58	0,58	2,90	—	0,58
47	11,23	48,87	7,86	10,11	1,12	0,56	0,56	1,68	0,56	1,12	0,56	3,92	—	1,12
60	9,46	62,72	7,10	5,91	0,59	0,59	1,18	0,59	—	—	0,59	1,18	—	0,59
74	3,93	57,30	5,05	8,98	1,68	1,68	2,80	1,12	0,56	0,56	—	2,24	0,56	0,56
80	3,35	48,60	5,02	10,61	6,14	1,11	2,79	3,35	1,11	0,55	1,11	6,12	—	0,55
87	3,26	58,69	2,71	13,04	1,63	—	1,63	2,17	—	0,54	0,54	3,25	—	—
94	4,06	52,32	4,06	15,69	4,06	—	1,74	2,90	0,58	0,58	1,16	5,22	—	1,74
100	2,34	53,99	0,46	2,81	0,46	0,93	—	2,81	1,87	1,40	0,46	6,54	0,46	5,63
107	1,44	55,76	0,48	0,48	2,88	1,44	0,48	4,32	0,48	2,40	0,96	8,16	0,96	6,73
114	1,83	55,50	—	—	—	0,45	1,83	1,37	2,75	4,58	0,45	9,15	—	12,38
120	0,85	29,14	—	—	0,28	0,85	2,28	3,42	2,00	4,00	—	9,42	—	19,71
127	6,84	33,90	—	—	0,68	—	1,71	4,10	0,34	3,76	—	8,20	—	21,91

Tabel 7

Reprezentarea procentuală a polenului de ierboase și a sporilor din mlaștina de turbă Răchitiș (Munții Călimani), raportat la Σ A.P.

Adâncimea (cm)	Poaceae	Cyperaceae	Apiaceae	Ericaceae	Asteraceae	Artemisia	Chenopodiaceae	Filices	Lycopodium	N.A.P
20	5,00	3,00	2,00	—	—	—	—	—	—	11,00
34	2,00	3,33	0,66	0,66	—	—	—	—	—	6,66
47	3,33	2,00	1,33	1,33	—	—	—	—	—	9,33
60	1,33	1,33	—	1,33	1,33	—	—	—	—	6,66
74	3,33	2,66	0,66	0,66	—	—	—	—	—	10,66
80	2,00	2,00	0,66	0,66	—	0,66	—	1,33	—	10,66
87	3,33	3,33	—	—	—	—	—	2,00	—	14,00
94	2,00	4,00	—	—	—	—	—	3,33	—	3,33
100	6,66	12,00	—	1,33	—	—	—	7,33	—	6,66
107	3,33	9,33	—	1,33	2,00	—	—	4,00	0,66	9,33
114	8,66	22,00	—	0,66	4,66	—	—	20,66	—	4,00
120	4,00	45,33	—	—	2,00	—	0,66	30,00	0,66	5,33
127	2,00	24,00	0,66	—	2,00	—	—	20,66	—	2,66

Tabel 8

Reprezentarea procentuală a polenului de ierboase și a sporilor din mlaștina de turbă Răchitiș (Munții Călimani), raportat la Σ A.P. + Σ N.A.P.

Adâncimea (cm)	Poaceae	Cyperaceae	Apiaceae	Ericaceae	Asteraceae	Artemisia	Chenopodiaceae	Filices	Lycopodium	N.A.P
20	4,13	2,47	1,65	—	—	—	—	—	—	9,09
34	1,75	2,92	0,58	0,58	—	—	—	—	—	5,84
47	2,80	1,68	1,12	1,12	—	—	—	—	—	7,86
60	1,18	1,18	—	1,18	1,18	—	—	—	—	5,91
74	2,80	2,24	0,56	0,56	—	—	—	—	—	8,98
80	1,67	1,67	0,55	0,55	—	0,55	—	1,11	—	8,93
87	2,71	2,71	—	—	—	—	—	1,63	—	11,41
94	1,74	3,48	—	—	—	—	—	2,90	—	2,90
100	4,69	8,45	—	0,93	—	—	—	5,16	—	4,69
107	2,40	6,73	—	0,96	1,44	—	—	2,88	0,48	6,73
114	5,96	15,13	—	0,45	3,21	—	—	14,22	—	2,75
120	1,71	19,42	—	—	0,85	—	0,28	12,85	0,28	2,28
127	1,02	12,32	0,34	—	1,02	—	—	10,61	—	1,36

Tabel 9

Poiana Boilor (Munții Călimani) — ponderea polenului de arbori

Adâncimea (cm)	ΣA.P.	ΣN.A.P.	ΣA.P. + + ΣN.A.P.	ΣA.P. raportată la ΣA.P. + ΣN.A.P. (%)
20	150	35	185	81,08
27	150	20	170	88,23
34	150	21	171	87,71
40	150	25	175	85,71
47	150	36	186	80,64
54	150	27	177	84,74
60	150	13	163	92,02
67	150	35	185	81,08
74	150	58	208	72,11
80	200	87	287	69,68
87	150	32	182	82,41
94	200	29	229	87,33
100	150	44	194	77,31
107	150	35	185	81,08
114	150	37	187	80,21
118	150	30	180	83,33

Tabel 10

Răchitiș (Munții Călimani) — ponderea polenului de arbori

Adâncimea (cm)	ΣA.P.	ΣN.A.P.	ΣA.P. + + ΣN.A.P.	ΣA.P. raportată la ΣA.P. + + ΣN.A.P. (%)
20	100	21	121	82,64
34	150	21	171	87,71
47	150	28	178	84,26
60	150	19	169	88,75
74	150	28	178	84,26
80	150	29	179	83,79
87	150	34	184	81,52
94	150	22	172	87,20
100	150	63	213	70,42
107	150	58	208	72,11
114	150	68	218	68,80
120	150	200	350	42,85
127	150	142	292	51,36

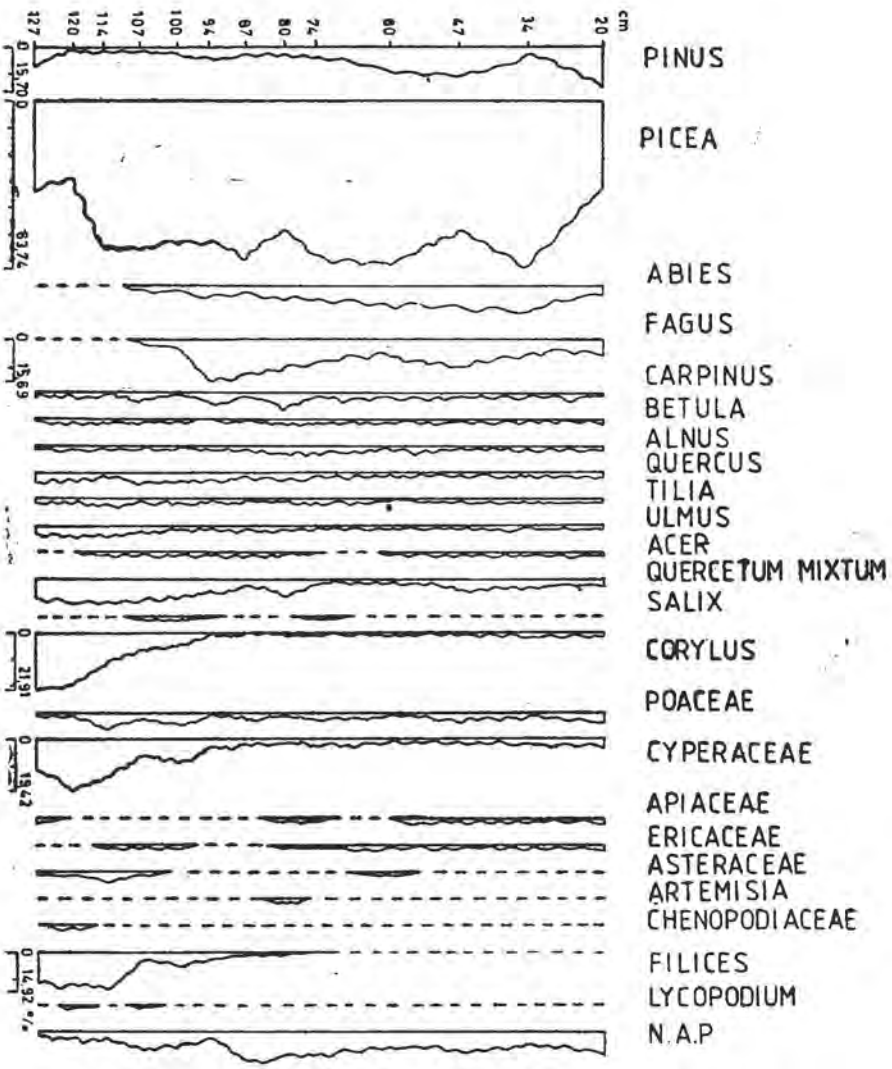


Fig. 3. *Diagrama sporo-polinică a mlaștinii de turbă Răchitiș — Munții Călimani.*

în alcătuirea ecosistemului respectiv la un moment dat (corespunzând *de facto* unei anumite adâncimi), adică dacă era lemnoasă sau ierboasă. Bineînțeles, trebuie să se țină cont de modificările pe care le poate induce prezența masivă a sporilor de briofite și pteridofite în spectrele polinice, precum și de suprareprezentarea locală a unor ierboase, cum sunt *Cyperaceae*-le.

Corelând datele obținute cu cele din Tabelele 4 și 8, se pot constata câteva aspecte.

La Poiana Boilor și Răchitiș, unde sporii nu sunt excedentari, iar polenul de graminee și rogozuri nu este suprareprezentat, apare o vizualizare clară a ecosistemului forestier, indicată de procentajele foarte ridicate ale polenului de arbori (A.P.) raportat la suma totală. Maximul înregistrat pentru acesta la Poiana Boilor este de 92,02%, minimul fiind de 69,68%, iar valoarea medie, care rămâne cea mai semnificativă este de 82,16%. La Răchitiș, situația este similară: maximul = 88,75%, minimul = 42,85%, iar valoarea medie = 75,82%, cu ceva mai scăzută decât la Poiana Boilor.

Munții Călimani, deși cutreierați, au rămas necercetați din punct de vedere palinologic până acum.

Cercetările prezentate în această lucrare inițiază un studiu palinologic absolut necesar. Ele au un caracter oarecum preliminar, urmând să se analizeze și celelalte mlaștini de turbă din regiune, să se descopere altele noi și să se standardizeze toate aceste cercetări.

Analizele preliminare efectuate în aceste mlaștini de turbă au evidențiat doar o parte din evoluția pădurilor tardi- și postglaciare din acești munți. Considerăm că este necesară reluarea studierii acestor turbării cu ajutorul unui echipament corespunzător. N-ar fi inutilă o comparație a acestor rezultate preliminare cu cele ce vor fi obținute ulterior, sprijinite de datări cu C^{14}, pentru stabilirea vârstelor absolute.

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ANALIZA PALINOLOGICĂ A MLAŞTINII DE TURBĂ CĂLIMAN EXPLOATARE II (MUNŢII CĂLIMAN)

SORINA MITROESCU—FARCAŞ*

SUMMARY. — Palynological Analysis of the Căliman Exploatare II Peat Bog (Căliman Mountains). Some preliminary palynological data revealed in the Căliman Exploatare II peat bog (about 1700 m altitude) are presented. The results obtained show the existence of the last two forest phases: the spruce—hornbeam phase and the spruce—beech—fir phase.

În prezenta lucrare sunt redate rezultatele analizei palinologice preliminare efectuate în mlaştina de turbă Căliman Exploatare, profilul II. Această mlaştină se găseşte pe versantul nordic al Munţilor Căliman, sub Vârful Răchitiş şi deasupra „Exploatării de sulf", la cca 1 700 m altitudine. Grosimea stratului de turbă nu depăşeşte 150 cm. Au fost extrase un număr de 16 probe, cu ajutorul unei sonde Hiller.

Prelucrarea probelor în laborator s-a făcut după metoda Erdtman.

Pe baza preparatelor microscopice au fost determinaţi polenul şi sporii, la nivel de familie, gen sau specie. Calculul procentual s-a efectuat în două moduri: prin raportarea polenului, respectiv a sporilor la ΣA.P. (suma polenului de arbori); prin raportarea la ΣA.P. + ΣN.A.P. (suma polenului de arbori + suma polenului de ierboase şi a sporilor, deci suma totală). Rezultatele obţinute sunt redate în Tabelele 1—4. În Tabelul 5 este prezentată ponderea procentuală a polenului de arbori raportat la suma totală.

Prin reprezentarea grafică a rezultatelor din Tabelele 2 şi 4 s-a obţinut diagrama sporo-polinică de la Căliman Exploatare II (Fig. 1).

Rezultate şi concluzii. Mlaştina de turbă de la Căliman Exploatare II pare să fie intermediară ca vechime între cea de la Răchitiş (mai veche) şi cea de la Poiana Boilor (mai tânără), mlaştini prezentate în lucrarea anterioară.

S-au evidenţiat astfel două faze silvestre: *faza molidului cu carpen* (fragmentar) şi *faza molidului—fagului—bradului* [3—5].

Prima dintre acestea se caracterizează prin prezenţa polenului de carpen cu valori mai ridicate, expresivitatea lor fiind totuşi mascată de prezenţa în continuare în spectrele polinice a polenului de *Quercetum mixtum* (stejăriş amestecat), cu valori ridicate, aspect destul de inedit aici.

Astfel, maximul atins de carpen este de 10,66, respectiv 5,44 % (raportat la ΣA.P., respectiv ΣA.P. + ΣN.A.P.), în timp ce stejărişul amestecat atinge chiar 13,33, respectiv 4,25 %, valorile sale nescăzând sub

* *Institutul de Cercetări Biologice, 3400 Cluj-Napoca, România*

Tabel 1

Reprezentarea procentuală a polenului de arbori din mlaştina de turbă Călimani Exploatare II (Munţii Călimani), raportat la Σ A.P.

Adâncimea (cm)	Pinus	Picea	Abies	Fagus	Carpinus	Betula	Alnus	Quercus	Tilia	Ulmus	Acer	Q.M.	Salix	Corylus
10	7,33	46,66	14,00	22,66	0,66	2,00	4,00	1,33	—	0,66	—	2,00	0,66	0,66
20	7,33	56,00	11,33	16,00	0,66	1,33	5,33	2,00	—	—	—	2,00	—	0,66
30	6,00	41,33	9,33	20,00	5,33	1,33	5,33	8,00	—	0,66	2,66	11,33	—	0,66
40	5,33	36,00	8,00	19,33	6,00	6,00	10,00	5,33	0,66	—	3,33	9,33	—	0,66
50	2,66	31,33	4,00	34,66	11,33	2,66	6,66	4,00	—	2,00	1,33	7,33	—	1,33
60	0,66	40,00	4,00	28,66	3,33	2,00	10,00	3,33	—	4,00	3,33	10,66	0,66	4,66
70	4,66	37,33	1,33	24,00	4,66	0,66	20,00	4,00	—	2,66	0,66	7,33	—	2,00
80	2,00	38,00	2,66	24,00	4,66	4,66	14,00	6,00	0,66	2,00	1,33	10,00	—	—
90	2,00	52,00	2,66	22,00	3,33	0,66	10,66	3,33	1,33	0,66	1,33	6,66	—	—
100	2,00	51,33	—	8,00	7,33	2,66	21,66	4,00	0,66	0,66	2,00	7,33	—	2,00
110	2,00	41,33	—	6,00	9,33	4,00	26,66	4,66	1,33	0,66	0,66	7,33	3,33	5,33
120	2,00	24,66	—	5,33	8,66	3,33	35,33	6,00	1,33	1,33	1,33	10,00	10,66	4,00
130	1,33	41,33	—	2,66	5,33	—	36,00	7,33	2,00	2,00	2,00	13,33	—	3,33
140	2,00	34,00	—	2,00	8,66	2,00	42,66	3,33	2,00	2,66	—	8,00	0,33	10,00
145	3,33	23,33	—	0,66	10,66	1,33	52,00	3,33	1,33	2,00	0,66	7,33	1,33	10,66
150	1,50	30,00	—	—	4,00	1,00	54,50	3,50	1,50	2,00	1,00	8,00	1,00	6,50

Tabel 2

Reprezentarea procentuală a polenului de arbori din mlaştina de turbă Călimani Exploatare II (Munţii Călimani), raportat la Σ A.P. + Σ N.A.P.

Adâncimea (cm)	Pinus	Picea	Abies	Fagus	Carpinus	Betula	Alnus	Quercus	Tilia	Ulmus	Acer	Q.M.	Salix	Corylus
10	4,56	29,04	8,71	14,10	0,41	1,24	2,48	0,82	—	0,41	—	1,23	0,41	0,41
20	4,70	35,89	7,26	10,25	0,66	0,85	3,41	1,28	—	—	—	1,28	—	0,42
30	3,07	21,16	4,77	10,23	2,73	0,68	2,73	4,09	—	0,34	1,36	5,79	—	0,34
40	3,40	22,97	5,10	12,34	3,82	3,82	6,38	3,40	0,42	—	2,12	5,94	—	0,42
50	1,06	12,53	1,60	13,86	4,53	1,06	2,40	1,60	—	0,80	0,53	2,93	—	0,53
60	0,32	19,60	1,96	14,05	1,63	0,98	4,90	1,63	—	1,96	1,63	5,22	0,32	2,28
70	2,01	16,09	0,57	10,34	2,01	0,28	8,62	1,72	—	1,14	0,28	3,14	—	0,86
80	1,15	21,92	1,53	13,84	2,69	2,69	8,07	3,46	0,38	1,15	0,76	5,75	—	—
90	1,19	31,07	1,59	13,14	1,99	0,39	6,37	1,99	0,79	0,39	0,79	3,96	—	—
100	0,98	25,32	—	3,94	3,61	1,31	10,52	1,97	0,32	0,32	0,98	3,59	—	0,98
110	1,16	24,12	—	3,50	5,44	2,33	15,56	2,72	0,77	0,38	0,38	4,25	1,94	3,11
120	0,64	7,93	—	1,71	2,78	1,07	11,37	1,93	0,42	0,42	0,42	3,19	3,43	1,28
130	0,30	9,43	—	0,60	1,21	—	8,21	1,67	0,45	0,45	0,45	3,02	—	0,76
140	0,47	8,06	—	0,47	2,05	0,47	10,12	0,79	0,47	0,63	—	1,89	0,15	2,37
145	0,98	6,91	—	0,19	3,16	0,39	15,41	0,98	0,39	0,59	0,19	2,15	0,39	3,16
150	0,58	11,67	—	—	1,55	0,38	21,20	1,36	0,58	0,77	0,38	3,09	0,38	2,52

Tabel 4

Reprezentarea procentuală a polenului de ierboase şi a sporilor din mlaştina de turbă Călimani Exploata e II (Munţii Călimani), raportat la ΣA.P. + ΣN.A.P.

Adâncimea (cm)	Poaceae	Cyperaceae	Apiaceae	Ericaceae	Asteraceae	Artemisia	Chenopodiaceae	Filices	Sphagnum	N.A.P.
10	14,52	19,08	0,41	0,41	—	0,82	0,41	0,82	0,82	—
20	6,41	23,50	0,42	0,42	—	—	—	4,27	0,42	—
30	11,26	24,23	1,02	3,07	—	—	—	0,34	8,53	—
40	10,63	14,89	—	—	0,42	1,70	—	4,25	3,82	—
50	21,60	20,00	—	—	0,26	1,60	—	12,00	4,00	—
60	16,33	24,50	0,98	—	0,98	—	0,32	1,96	3,59	—
70	34,48	17,24	0,57	—	0,86	—	—	2,87	—	—
80	19,61	14,61	0,76	—	1,15	—	—	6,15	—	—
90	19,53	13,54	1,19	—	0,79	—	—	3,98	0,39	0,79
100	18,09	21,38	2,30	—	2,63	0,98	—	4,27	—	—
110	10,50	16,34	0,38	—	1,16	—	—	10,11	—	—
120	24,67	34,33	0,42	—	1,50	—	—	5,36	—	0,21
130	26,63	31,20	0,76	—	0,60	—	0,15	16,74	—	0,30
140	11,86	35,60	0,94	—	0,15	—	—	24,52	—	0,79
145	5,33	43,47	0,59	—	1,38	—	0,19	13,24	—	2,96
150	9,72	20,81	0,19	—	0,97	—	—	23,34	—	3,50

Tabel 3

Reprezentarea procentuală a polenului de ierboase și a sporilor din mlaștina de turbă Călimau Exploatare II (Munții Călimani), raportat la ΣA.P.

Adâncimea (cm)	Poaceae	Cyperaceae	Apiaceae	Ericaceae	Asteraceae	Artemisia	Chenopodiaceae	Filices	Sphagnum	N.A.P.
10	23,33	30,66	0,66	0,66	—	1,33	1,33	1,33	1,33	—
20	10,00	35,33	0,66	0,66	—	—	—	6,66	0,66	—
30	22,66	47,33	2,00	0,66	—	—	—	0,66	16,66	—
40	16,66	23,33	—	—	0,66	2,66	—	6,66	6,00	—
50	54,00	50,00	—	—	0,66	4,00	—	30,66	10,00	—
60	33,33	53,33	2,00	—	2,00	—	0,66	4,00	7,33	—
70	80,00	40,00	1,33	—	2,00	—	—	6,66	—	—
80	34,00	24,66	1,33	—	2,00	—	—	10,66	—	—
90	36,00	24,00	2,00	—	1,33	—	—	6,66	0,66	1,33
100	36,66	43,33	4,66	—	5,33	2,00	—	8,66	—	—
110	18,00	28,00	0,66	—	2,00	—	—	17,33	—	—
120	76,66	106,66	1,33	—	5,33	—	—	16,66	—	0,66
130	116,66	136,66	3,33	—	2,66	—	0,66	73,33	—	1,33
140	50,00	150,00	4,00	—	0,66	—	—	103,33	—	3,33
145	18,00	146,66	2,00	—	4,66	—	0,66	44,66	—	10,00
150	25,00	53,50	0,50	—	2,50	—	—	60.00	—	9,00

Tabel 5

Căliman Exploatare II (Munții Căliman) — ponderea polenului de arbori

Adâncimea (cm)	ΣA.P.	ΣN.A.P.	ΣA.P.+ ΣN.A.P.	ΣA.P. raportată la ΣA.P.+ ΣN.A.P. (%
10	150	91	241	62,24
20	150	84	234	64,10
30	150	143	293	51,19
40	150	85	235	63,82
50	150	225	375	40,00
60	150	156	306	49,01
70	150	198	348	43,10
80	150	110	260	57,69
90	150	101	251	59,76
100	150	154	304	49,34
110	150	107	257	58,36
120	150	316	466	32,18
130	150	507	657	22,83
140	150	482	632	23,73
145	150	356	506	29,64
150	200	314	514	38,91

7,33, respectiv 2,15%. În cadrul acestor stejărișe mixte polenul de stejar este cel mai bine reprezentat (maxim = 7,33 sau 7,22%), în timp ce ulmul și teiul sunt prezente cu valori modeste (2,66—0,77%; 2—0,77%). Alunul se menține și el în această fază silvestră cu valori cuprinse între 2% (0,76%) și 10,66% (3,16%).

Esența dominantă a acestei faze silvestre rămâne însă tot molidul. Valorile sale oscilează între 24,66 și 51,33% (respectiv 6,91 și 25,32%), fiind mai mici însă decât cele pe care le va înregistra în ultima fază silvestră.

Pinul, mesteacănul și arțarul se constituie în prezențe constante, dar cu valori modeste în spectrele polinice. Maximele lor nu depășesc 4% (respectiv 2,33%).

Arinul se arată a fi favorizat de factori edafici locali. Valorile sale se înscriu viguros în spectrele polinice, necoborând în această fază sub 21,66% (8,21%), în timp ce maximul său atinge 54,50% (21,20%), valoare foarte mare, datorată unei suprareprezentări locale, ce estompează astfel valorile celorlalți arbori prezenți aici.

Dacă luăm în considerare ipoteza, după care fagul ar fi apărut doar în Subboreal, înseamnă fie că am surprins această fază în întregime și atunci maximul absolut al carpenului găsit aici este foarte mic, fie că această fază este reprezentată lacunar din diverse motive și valoarea absolută a carpenului ar fi mai mare, la fel întâmplându-se și dacă luăm în considerare ipoteza, după care fagul ar fi apărut încă în spectrele polinice ale Atlanticului și, deci, faza cu carpen nu a fost în întregime surprinsă.

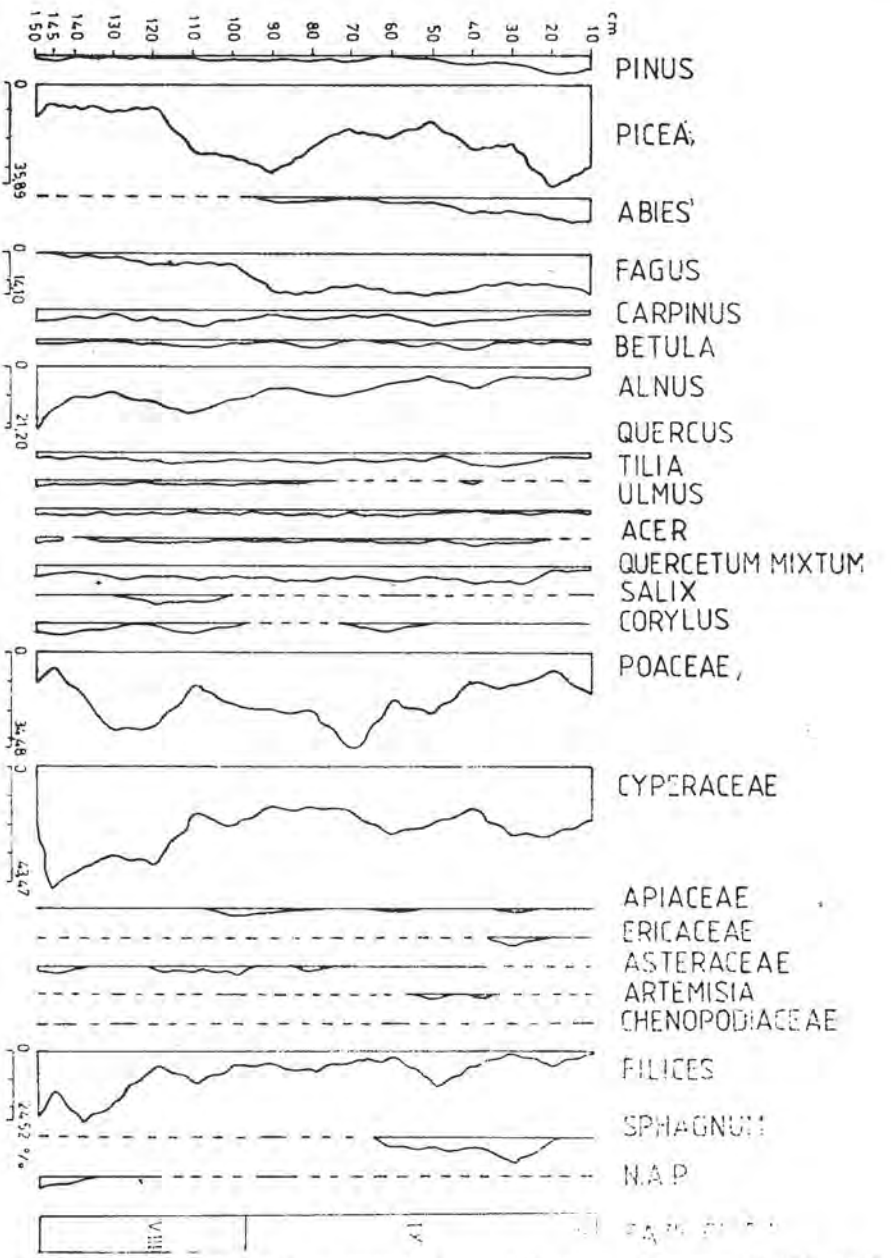

Fig. 1. *Diagrama sporo-polinică a mlaștinii de turbă Călimani Exploatare II (Munții Călimani).*

Pe de altă parte, este foarte probabil ca faza molidului cu carpen să fi fost evidențiată doar pe o grosime mică, de abia 50 cm, având în vedere că și ultima fază silvestră a fost găsită în toate aceste mlaștini doar pe grosimi mici, de 100 — 120 cm. În general, pasul de sedimentare a turbei în Subatlantic este foarte mare, turba având grosimi considerabile și fiind în general edificată de *Sphagnum*. Aici însă, probabil sub influența unor factori locali, atât această fază cât și cele anterioare sunt reprezentate doar pe grosimi reduse, făcând mai puțin probabilă ipoteza existenței unor lacune de sedimentare în fiecare fază silvestră.

Revenind la această *fază a molidului cu carpen*, semnalăm și prezența fagului, precum și absența bradului. Deoarece fagul înregistrează valori destul de scăzute (0—8%, respectiv 0—3,94%) până la sfârșitul fazei (orizontul 90 cm), unde valoarea sa crește brusc la 22% (13,14%), moment ce coincide și cu apariția bradului (2,66, respectiv 1,59%), considerăm totuși că nu a fost surprins momentul începerii ultimei faze silvestre, a *molidului—fagului—bradului*, din cauza unei lacune de sedimentare.

Faza molid—fag—brad este găsită pe o grosime mică, de abia 90 cm. Aici apar maximele absolute ale fagului și bradului (34,66, respectiv 14,10% pentru fag și 14, respectiv 8,71% pentru brad).

Comparativ cu valoarea înregistrată de aceste esențe lemnoase în celelalte două mlaștini prezentate, constatăm că atât maximul fagului cât și cel al bradului de aici le depășesc pe cele înregistrate la Poiana Boilor și Răchitiș. În schimb, polenul de molid este mult mai bine reprezentat în aceste două mlaștini decât la Căliman Exploatare II, unde atinge valoarea maximă de 56% (respectiv 35,89% raportat la ΣA.P. + ΣN.A.P.).

Arinul își menține la începutul acestei faze valori încă ridicate (20—8,62%), scăzând spre suprafață (4—2,48% la 10 cm adâncime). Pinul înregistrează în schimb o ușoară creștere spre suprafață (de la 2% în orizontul 90 cm = baza fazei, la 7,33% la 10 cm, respectiv de la 1,19 la 4,56%).

Carpenul înregistrează o ultimă zvâcnire procentuală (11,33, respectiv 4,53% la orizontul 50 cm), pentru ca spre suprafață valoarea sa să devină subunitară. Și mesteacănul (6—3,82%), stejarul (8—4,09%) și ulmul (4—1,96%) marchează în această fază valoarea lor maximă din întregul profil. În schimb, teiul și salcia dispar aproape în întregime din spectrele polinice. Arinul și alunul scad, de asemenea, spre suprafață foarte mult, la fel și arțarul, care în ultimele două orizonturi nu mai este semnalat în acest profil. Stejărișul mixt înregistrează în schimb o oscilație sinusoidală, valorile sale fiind determinate de dinamica speciilor componente. În ultimele două orizonturi este și el foarte slab reprezentat (2—1,28%).

În ceea ce privește polenul plantelor ierboase, semnalăm și aici, ca și în cele două mlaștini anterior prezentate, existența cu valori mari a polenului de *Poaceae* și *Cyperaceae*, ambele atingându-și valoarea maximă în *faza molidului cu carpen:* 116,66% (26,63%) pentru graminee

și 150% (43,47%) pentru rogozuri, cărora le corespunde și maximul de spori de *Filices* (103,33, respectiv 24,52%). Aceste valori foarte mari sunt un indiciu al climei calde și uscate din Subboreal, care le-a favorizat dezvoltarea, respectiv sporularea ferigilor.

Celelalte plante ierboase, inclusiv *Artemisia*, înregistrează valori nesemnificative. Spre suprafață dispar *Asteraceae*-le, orizont la care apar în schimb *Ericaceae*-le, dar cu valori subunitare. Și sporii de *Sphagnum* apar mai numeroși în Subatlantic, fără ca maximul lor să depășească însă 16,66%.

În lucrare am redat și ponderea polenului de arbori de la Căliman Exploatare II (Tabelul 5). Corelând rezultatele obținute cu cele din Tabelul 4 se constată o situație deosebită față de Poiana Boilor și Răchitiș. Astfel, pentru polenul de arbori avem doar 64,10% valoarea maximă și 22,83% valoarea minimă. Media este, de asemenea, scăzută, reprezentând doar 46,61%. Situația este cauzată de factorii de influență arătați anterior: prezența cu valori foarte mari în unele orizonturi a sporilor, precum și suprareprezentarea locală a gramineelor și, în special, a rogozurilor, deci o reprezentare corectă a ecosistemului ar trebui să excludă acești factori.

În concluzie, stratificarea mlaștinii de turbă de la Căliman Exploatare II pare să fi început în Subboreal [1, 2], fapt atestat de procentajele carpenului și de apariția fagului aproape din baza profilului, cu valori în creștere. Tranziției de la faza molidului cu carpen la faza molidului—fagului—bradului îi corespunde probabil o ușoară lacună de sedimentare, evidențiată de saltul valorilor fagului, de la 8% la 100 cm adâncime, la 22% la 90 cm adâncime, moment ce coincide și cu apariția bruscă a bradului (2,66%). De asemenea, faza molidului—fagului—bradului nu este în întregime surprinsă, fapt atestat de procentajul bradului din orizontul terminal (14% la 10 cm adâncime), ce nu reflectă repartiția actuală a bradului în Căliman.

De aceea, va fi necesară continuarea studiului palinologic al acestei turbării prin analizarea unor alte profile.

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ECOLOGY OF THE POPULATIONS OF TERRESTRIAL ISOPODS (*CRUSTACEA: ISOPODA*) ÎN CHEILE TURZII

NICOLAE TOMESCU*, SHARON ACCOLA* and CRISTINA PAŞCA*

SUMMARY. — Twelve species of terrestrial isopods live in the Cheile Turzii National Reservation: *Ligidium hypnorum, Hyloniscus riparius, Anaroniscus roseus transsylvanicus, Cylisticus convexus, Protracheoniscus politus, Porcellium collicolum, Porcellio spinicornis, Trachelipus difficilis rotundatus, Trachelipus nodulosus, Armadillidium vulgare, Armadillidium carniolense,* and *Armadillidium versicolor quinqueseriatum*. They are distributed in different ecosystems within the perimeter of the canyon: on a plateau (station I): *T. nodulosus;* in a steppe-type grassland (station II): *T. nodulosus, A. versicolor quinqueseriatum, P. spinicornis;* in a wood with a southern aspect (station III): *P. politus, A. vulgare, A. carniolense;* in a wood with a northern aspect (station IV): *P. politus, T. difficilis rotundatus, A. carniolense;* in a coppice along the Hăşdate Brook (station V): *L. hypnorum, H. riparius, A. roseus, C. convexus, P. politus, P. collicolum, T. difficilis rotundatus, A. vulgare* and *A. carniolense*. The species in the steppe-type grassland (station II), the wood with the northern aspect (IV), and the coppice (station V) form specific stable communities. In these locations the terrestrial isopod populations have high frequency and abundance values, an indication that the ecological conditions in these ecosystems are within the optimum limits for these species. The populations of the three species in the wood on the slope with a southern aspect have decreased frequency and abundance values, a proof that the fluctuations of ecological factors exceed optimum limits. The mortality rate is greater and the populations have a reduced population effective. In the coppice (station V), the stenotopic species (*L. hypnorum, H. riparius, A. roseus, P. collicolum,* and *C. convexus*) have a limited distribution and are found only in microhabitats in the immediate vicinity of the brook, which have a high humidity. *T. difficilis rotundatus* and *A. vulgare* have a wide distribution in the entire perimeter of the coppice. The greatest abundance was recorded for *T. difficilis rotundatus*. The period of biological activity varies from 4—5 months for *L. hypnorum* and *P. collicolum* to 7—8 months for *P. politus, T. nodulosus, T. difficilis rotundatus,* and *A. vulgare*. The size class structures of the populations indicate an inter- and intraspecific variability. The intraspecific varability is related to sex, age, and longevity. In the period of annual biological activity, numerical modifications, which are determined by natality and mortality rates, take place in the isopod populations. Notable numerical variations were recorded for *L. hypnorum, C. convexus, P. collicolum,* and *A. carniolense*.

Cheile Turzii represents a northeastern extension of the Trascău Mountains and is located in the hilly zone of northwestern Romania. The maximum altitude, 794 m, is found on the right side of the Hăşdate Brook, which flows through the canyon. The canyon, which is

* *Babeş-Bolyai University, Department of Zoology, 3400 Cluj, Romania*

composed of Jurassic limestone with abrupt walls, has an extremely varied micro- and mesorelief and the ecological conditions are very diversified. The variety of the ecological conditions determined a great biodiversity of flora and fauna. In our research we studied the ecology of terrestrial isopods in the principal ecosystems that exist in the canyon area.

Description of the stations. According to the vegetational associations and ecological conditions, we defined 5 stations.

The plateau on the left slope (station I) has an altitude of 760 m and an inclination of approximately 4—8°. The layer of soil is thin, perforated here and there by protrusions of segments of bedrock. Insolation of the soil surface is intense, reaching temperatures exceeding 30°C in summer and with a marked diminution of humidity. The vegetation is formed of shrubs and bushes, predominantly *Prunus spinosa*, *Rosa canina*, and *Crataegus monogyna*. In the herbaceous layer, *Festuca rupicola*, *Fragaria vesca*, *Agrostis tenuis*, *Thymus comosus*, and *Carex tomentosa* predominate.

The steppe-type grassland (station II), situated at the base of the plateau, on a slope with an inclination of approximately 45°, has o southern aspect. The insolation of the soil is extremely powerful and temperature and humidity conditions are similar to those of the plateau. The ligneous vegetation is composed of rare shrubs of *Cornus mas* and *Prunus tenella*. The herbaceous layer, which is richer than on the plateau, is formed of xerophilous species, predominantly: *Stipa pulcherrima*, *Botriochloa ischaemum*, and *Brachypodium pinnatum*.

The oak and hornbeam (Quercus petraea, Carpinus betulus) wood (station III) is also situated on the slope with a southern aspect, below the steppe-type grassland. The wood is made up of young trees, with a height of 10—12 m and a diameter of 5—15 cm. The depth of the litter layer is variable and, in some areas, discontinuous, where herbaceous xerophilous species grow, such as: *Dictamnus albus*, *Medicago lupulica*, etc. Here also, in the summer, the temperature is elevated and the soil becomes dessicated to a depth of more than 2 cm. There exist, however, microhabitats, in which a certain degree of humidity is maintained (under rocks, small spaces which are formed between the soil and the base of the tree trunks, etc.) and to which animals which live under leaf litter can withdraw.

The oak and hornbeam wood (station IV), which is located on the right side of the Hăşdate Brook, has a northern aspect and an inclination of approximately 20°. The height of the trees is 15—20 m and their diameter 15—30 cm, with a dense tree-top covering (0.8), producing a decreased insolation of the soil surface. The herbaceous layer is weakly developed. The boulders and rocks are covered with rich layer of moss, which maintains a high humidity and moderate temperatures in summer. The leaf litter layer is relatively thick and uniform, offering optimum conditions for the epigeous animals which live in the patoma.

The coppice on the margin of the Hăşdate Brook (station V) occupies a narrow band of level terrain with alluvial soil on both sides of the brook. The ligneous vegetation is made up of: *Salix alba*, *Salix fragilis*, *Populus tremula*, *Acer campestre*, *Fraxinus excelsior*, *Robinia pseudacacia*, *Cornus sanguinea*, and *Corylus avellana*. The herbaceous vegetation, which is very rich and varied, is made up of hygrophilous and skiophilous species. The surface of the soil has a rich layer of humus, composed of decaying vegetable matter and is covered by a herbaceous layer and leaf litter. Close to the brook's banks the soil humidity remains elevated all year and the temperature does not exceed 25°C in summer and in some microhabitats is even lower. There is a great diversity of microhabitats in this station, which is reflected by the biodiversity of epigeous species.

Materials and methods. For studying the qualitative and quantitative aspects of the ecology of isopods we used pitfall traps, a method which is based on the capturing of animals as they move about on the soil surface. The results of the collections are influenced by the degree of mobility, which varies from species.

to species, or even within the same species, in relation to their age or physiological condition (the females of some species have a lesser degree of mobility in their reproductive period). Even so, the pitfall trap method is the most suitable for terrestrial isopods, which have a very pronounced aggregative distribution, as it can be used in all types of ecosystems [1, 2, 7]. However, with this method very young individuals cannot be collected and, therefore, it is impossible to calculate the age classes of the populations. Likewise, one cannot collect endogeous species, nor those of a very small size, which have a reduced mobility. In the 5 stations, we placed a total of 27 traps, 4 traps in each of stations I, II, and III, 6 traps in station IV, and 9 in station V. The captured animals were collected at two-week intervals in 1991 and 1992. The species were identified, the adult individuals were counted and classed according to sex, measured, and the number of gravid females and the eggs or embryos in the marsupial pouch were counted. On the basis of the material collected, we could establish the distribution, community structure, frequency, constancy, dominance, abundace, age classes, and the population dynamics of the species we studied.

Results and discussions. During the period of the two years of research in Cheile Turzii, we collected 16,092 individuals of terrestrial isopods, belonging to 9 species (Table 1). In our investigations we ascertained the existence of three additional species: *Hyloniscus riparius, Androniscus roseus transsylvanicus* (in the coppice — V) and *Porcellio spinicornis* (in the steppe-type grassland — II). These species could not be collected with pitfall traps and, therefore, they do not appear in the data presented in this paper.

The distribution of terrestrial isopods in ecosystems. The distribution of the species of isopods in the ecosystems which we studied varies (Table 1), being determined by ecological factors and specific physiological characteristics [3, 4]. Only one species lives on the xeric sunny plateau (I), *Trachelipus nodulosus*, a typical xerothermous species. In the xeric steppe-type grassland (II), where the conditions are similar to those on the plateau but with more heterogeneous microhabitats, three species, all xerothermous, live: *T. nodulosus, Armadillidium versicolor quinqueseriatum*, and *Porcellio spinicornis*. The first two species were captured in the same traps and form an ecological community here (Table 1). *P. spinicornis* is limited to the detritus at the base of the rock wall in the upper part of the slope, where we could not put pitfall traps. Even though it lives in the same ecosystem as the first two species, one cannot say that they form an ecological community. In the wood on the slope with the southern aspect (III), three species live: *Protracheoniscus politus, Armadillidium carniolense* (a sylvan species), and *A. vulgare* (a eurytopic species). Accidentally, we found several individuals of *T. nodulosus*, which had migrated from the steppe-type grassland which is situated on the same slope, in continuation of the wood. In the wood on the slope with a northern aspect (IV), there are also three species: *Protracheoniscus politus, Armadillidium carniolense*, present also in station III, and *Trachelipus difficilis rotundatus*, which is absent from the wood on the southern slope. In station IV, the isopod populations are more numerous, which implies that the ecological factors of this wood are within the optimum limits for sylvan species.

Table 1

Total number of isopods captured per trap, per species, and per station

Station	Trap	SPECIES								
		L. hypnorum	C. convexus	P. politus	P. colicolum	T. nodulosus	T. difficilis	A. vulgare	A. versicolor	A. carniolense
I	C1					64				
	C2					70				
	C3					47				
	C4 = 261					80 = 261				
II	C5					43			38	
	C6					74			7	
	C7					484			84	
	C8 = 1415					191 = 792			494 = 623	
III	C9			5				79		6
	C10			14				10		12
	C11			16				70		14
	C12 = 297			10 = 45				57 = 216		4 = 36
IV	C13			75	1		2420			5
	C14			67			1543	2		51
	C15			28			403			112
	C16			39			245			97
	C17			207	1		303		1	201
	C18 = 6506			94 = 510	= 2		594 = 5508	1 = 3	= 1	16 = 482
V	C19	278	11	22			510	47	2	
	C20	3	2	5	1		618	45		4
	C21	1	1	10			847	71		15
	C22	410	13	64	2		756	56	1	2
	C23	1	1				540		2	
	C24	6	6	1			365			
	C25	184	15	11	15		196	148	2	3
	C26	15	14	4	130		555	95	1	
	C27 = 6695	6 = 904	6 = 69	5 = 122	62 = 210		413 = 4800	95 = 557	1 = 9	= 24

TOTAL = 15,174

In the coppice (V), where there is a great ecological diversity (microhabitats with varying conditions), the biodiversity of the isopod fauna is much greater, compared with that of the other ecosystems. Nine species, with differing ecophysiological characteristics live here: *Androniscus roseus transylvanicus* and *Cylisticus convexus* (which are humicolous species but are also found under rocks in very humid places), *Ligidium hypnorum, Hyloniscus riparius* (paludicolous species), *P. politus, Porcellium collicolum, T. difficilis rotundatus* and *A. carniolense* (sylvan species), and *A. vulgare* (eurytopic species). One can also observe the ecological diversity of the coppice by the varying number of individuals captured in each trap (Table 1), especially the stenotopic species are present in only one ecosystems (*L. hypnorum, C. convexus, xus*). These species were captured in large numbers only in the traps that were in the immediate vicinity of the brook. A similar situation also exists in station IV, where an extremely large number of individuals of *T. difficilis rotundatus* were captured in traps 13 and 14 (Table 1), which were placed at the base of some moss-covered rocks. The species' preference for certain ecosystems is rendered in Fig. 1. Several species are present in only one ecosystem (*L. hypnorum, C. convexus, P. collicolum* — along the brook, and *A. versicolor quinqueseriatum* — in the steppe-type grassland). They are stenotopic species. *H. riparius* and *A. roseus transsylvanicus* also enter in this category. Other species live in two or three ecosystems, such as *P. politus* and *A. carniolense*, but they manifest an evident preference for mesohygrophilous woods with a northern aspect.

Specific structure of isopod communities. Communities of terrestrial isopods are generally made up of a restricted number of species, often

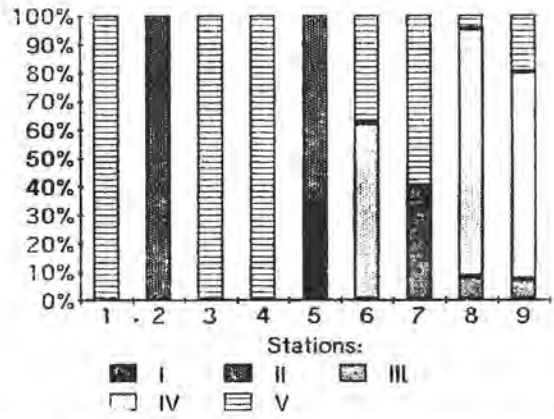

Fig. 1. *Distribution of species of terrestrial isopods in the stations located in Cheile Turzii.* 1 — Ligidium hypnorum. 2 — Armadillidium versicolor. 3 — Cylisticus convexus. 4 — Porcellium collicolum. 5 — Trachelipus nodulosus. 6 — Trachelipus difficilis rotundatus. 7 — Armadillidium vulgare. 8 — Armadillidium carniolense. 9 — Protarcheoniscus politus.

2—3 and rarely 6—7 or more [8, 9, 12]. The isopod fauna in an ecosystem depends on the existing ecological conditions, the magnitude of the circadian and seasonal oscillations, as well and the degree to which the species are stenotopic or eurytopic, namely, their tolerance to these oscillations [4, 5, 14]. Certain species can coexist in a certain biotope and in another biotope they do not live together [9, 12]. The variety of species in an ecosystem also depends on the diversity of the microhabitats within its perimeter [3, 4, 10, 11]. The existence of several types of microhabitats within an ecosystem creates the possibility for a greater biodiversity, as it offers optimum conditions for stenotipic species.

We calculated the coefficient of ecological affinity for the species captured in stations II, III, IV, and V, where two or more species were found. In our calculations, we used the *Jaccard index* (J) and the probability index (p). The two species in the steppe-type grasslands, *T. nodulosus* and *A. versicolor quinqueseriatum* have an ecological affinity ($J = 47\%$) and they form a coenotic community ($p<c$). In the wood with the southern aspect, where in summer the temperature is elevated and humidity is reduced, three species were collected: *P. politus*, *A. carniolense*, and *A. vulgare*. The statistical calculations of the results of the collections show us that under the ecological conditions existing in this wood, *P. politus* forms a community with *A. vulgare* ($p<c$), but not with *A. carniolense* ($p>c$). On the other hand, the value of p indicates affinity between *A. vulgare* and *A. carniolense* (Fig. 2 — S-III). In the wood on the slope with the northern aspect (S-IV), where the humidity is higher and the temperature is moderate, *T. difficilis rotundatus*, *P. politus*, and *A. carniolense* form a community of isopods. Under the conditions in this wood, all three species form a stable community (Fig. 2 — S-IV), the last two being represented by a much larger population than was found in the wood with the southern aspect. Eight species live in the coppice along the Hăşdate Brook (S-IV). *Hyloniscus riparius* and *Androniscus roseus* could not be collected in the pitfall traps and, therefore, only 6 species are considered in our calculations (Fig. 2 — S-V). *A. versicolor quinqueseritaum* and *A. carniolense* were found present accidentally in the material we collected here. The ecological diversity of the coppice indicates a collection of species from different microhabitats, related to the conditions found there and the ecophysioloigcal peculiarities of the isopod populations. *T. difficilis rotundatus* and *A. vulgare* coexist in almost the entire perimeter of the coppice ($J = 53\%$). The other species have a distribution which is limited to certain microhabitats (Table 1) in which, however, the above mentioned species also enter. The value of p shows that those 6 species can cohabitate under certain conditions, especially in ecosystems in which several types of microhabitats exist, therefore offering optimum conditions for stenotopic species (*L. hypnorum*, *H. riparius*, *C. convexus*, and *P. collicolum*). However, the reduced value of the Jaccard index, which shows the distribution of their populations within the perimeter

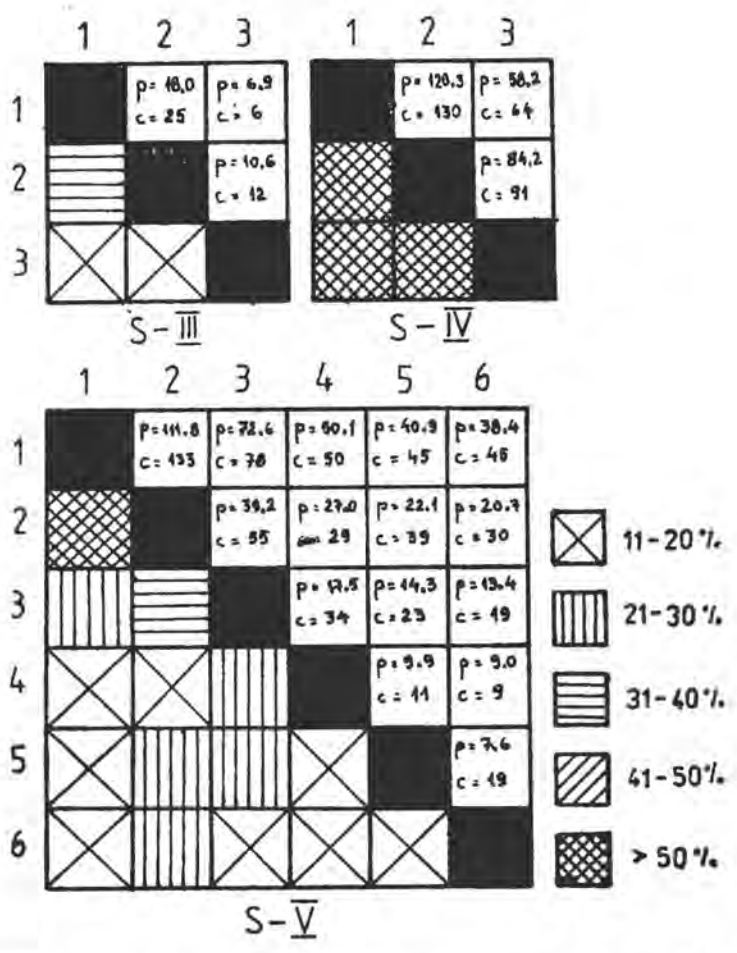

Fig. 2. *Communities and ecological affinity of species of terrestrial isopods in Cheile Turzii.*
S-III (Station III): 1 — P. politus. 2. — A. vulgare. 3 — A. carniolense.
S-IV (Station IV): 1 — P. politus. 2 — A. carniolense. 3 — T. difficilis rotundatus.
S-V (Station V): 1 — T. difficilis rotundatus. 2 — A. vulgare. 3 — L. hypnorum. 4 — P. politus. 5 — P. collicolum. 6 — C. convexus.

of the ecosystem, indicates that they have different habitat preferences (Table 1).

On the basis of our research, one can conclude that not all the species existing in an ecosystem form stable communities, as there do not exist great ecological affinities among them. Eurytopic species, which have a wide distribution in an ecosystem, penetrate into the microhabitats of the stenotopic species and only here form a coenotic community [4, 9, 12, 14]. It is possible that this situation exists in the majority of invertebrate species.

Frequency and constancy. The appearance of a species in the collections that are taken depends on the size of the population and the distribution of individuals in the biotope. The value of the frequency shows the degree to which the ecological conditions in an ecosystem correspond to the physiological requirements of the species [5, 6, 9, 12]. The frequency value indicates the constancy of the species, which varies from one ecosystem to the other.

On the plateau (S-I) *T. nodulosus* has a high frequency, as it is a species which is constant in the epigean layer (Table 2). In the steppe-type grassland (S-II) the frequency values are relatively similar, an indication that the conditions in this ecosystem are optimal for both species. The absence of the species *A. versicolor quinqueseriatum* on the plateau can be considered as an indication that its ecological valences have narrower limits that those of *T. nodulosus* and that these two species do not live together in all ecosystems in which *T. nodulosus* is present. In the oak and hornbeam wood on the slope with a southern aspect (S-III), the frequency values are lower for all the species. According to the results obtained, *P. politus* (a sylvan species) and *A. vulgare* (a eurytopic species) in station III are accessory and *A. carniolense* (also a sylvan species) appears relatively accidentally. They are indicators that certain ecological factors (especially temperature and humidity) in

Table 2

Frequency, constancy, abundance, and dominance of terrestrial isopods in Cheile Turzii

Species/station	Frequency (%)	Constancy	Abundance (x/trap/species)	Dominance (%)
I — *PLATEAU*				
1. T. nodulosus	71.4	constant	3.2	—
II — *STEPPE-TYPE GRASSLAND*				
1. T. nodulosus	60.0	constant	6.3	55.9
2. A. versicolor quinqueseriatum	48.8	accessory	4.9	44.1
III — *SOUTHERN WOOD*				
1. P. politus	28.1	accessory	0.3	15.1
2. A. vulgare	48.4	accessory	1.6	72.7
3. A. carniolense	19.5	accidental	0.2	12.2
IV — *NORTHERN WOOD*				
1. P. politus	69.0	constant	2.6	7.8
2. T. difficilis	94.3	euconstant	28.3	84.8
3. A. carniolense	38.1	accessory	2.4	7.4
V — *COPPICE*				
1. L. hypnorum	62.8	constant	9.3	13.5
2. C. convexus	31.4	accessory	0.5	1.0
3. P. politus	33.0	accessory	0.8	1.8
4. P. collicolum	46.3	accessory	2.1	3.2
5. T. difficilis	89.0	euconstant	17.4	71.7
6. A. vulgare	58.4	constant	2.4	8.4
7. A. carniolense	7.5	accidental	0.1	0.4

certain periods of the year exceed the optimal ecological limits for isopods, thus determining an accentuated increase in the mortality rate, especially in juvenile stages. In the other oak and hornbeam wood (S-IV), which is situated on the slope with a northern aspect, the frequency values of the species of isopods are much greater than in station III. An increased numerical abundance was registered for all the species. It is an indication that in this wood the oscillations of humidity and temperature do not exceed the optimal ecological limits and the survival coefficient of the isopod species is higher. Of the 6 species collected in the coppice (S-V), *T. difficilis rotundatus* has the highest frequency, which indicates that the species is euryconstant. *L. hypnorum* and *A. vulgare* are constant. In this category one can also include *Hyloniscus riparius* and *Androniscus roseus*, which could not be collected with pitfall traps, but frequently appear in the same microhabitats as *L. hypnorum*. *C. convexus*, *P. collicolum*, and *P. politus* are accessory species and *A. carniolense* appears accidentally here.

Numerical dominance was calculated in the stations in which two or more species of isopods live (Table 2; Fig. 3). With several exceptions, the consumption rate of decaying vegetable matter is relatively similar in terrestrial isopod species [6]. In this case a numerical dominance represents an indication regarding the contribution of a certain species to the cycle of material and energy flow, which depends on the size of the animals, the metabolic rate, the consumption rate, and the size of the population [6]. In station II the population of both species is almost equal numerically. In station III *A. vulgare* dominates numerically and in stations IV and V *T. difficilis rotundatus* dominates. Numerical dominance depends on the biotic potential and the survival index of the species. The biotic potential varies from species to species, according to the action of the pressure of ecological factors [12, 13]. For species of isopods which are numerically dominant, the ecological conditions are optimum, thus determining an elevated survival index.

Numerical abundance is the medium number of individuals of a species collected per trap per station. The pitfall trap method does not permit an evaluation of the density per surface unit, especially due to the fact that the majority of species have a very pronounced aggregate distribution. In station II the abundance values of those two species are relatively similar. In station III the abundance of all three species is reduced due to oscillations in temperature and humidity, which in summer exceed optimum limits, contributing to the increased mortality rate, especially of the immature individuals. Compared to station III and station IV, the abundance of the species *P. politus* and *A. carniolense* is more than 8 and 12 times greater, respectively, showing that the conditions in station IV are optimum and the survival index is much higher than in station III. The highest value for abundance was registered for *T. difficilis rotundatus* in stations IV and V. Ecological conditions in these ecosystems are extremely favourable for *T. difficilis*, which is represented in much greater numbers that the other species. The collections from the traps (Table 1) indicate a wide distribution of

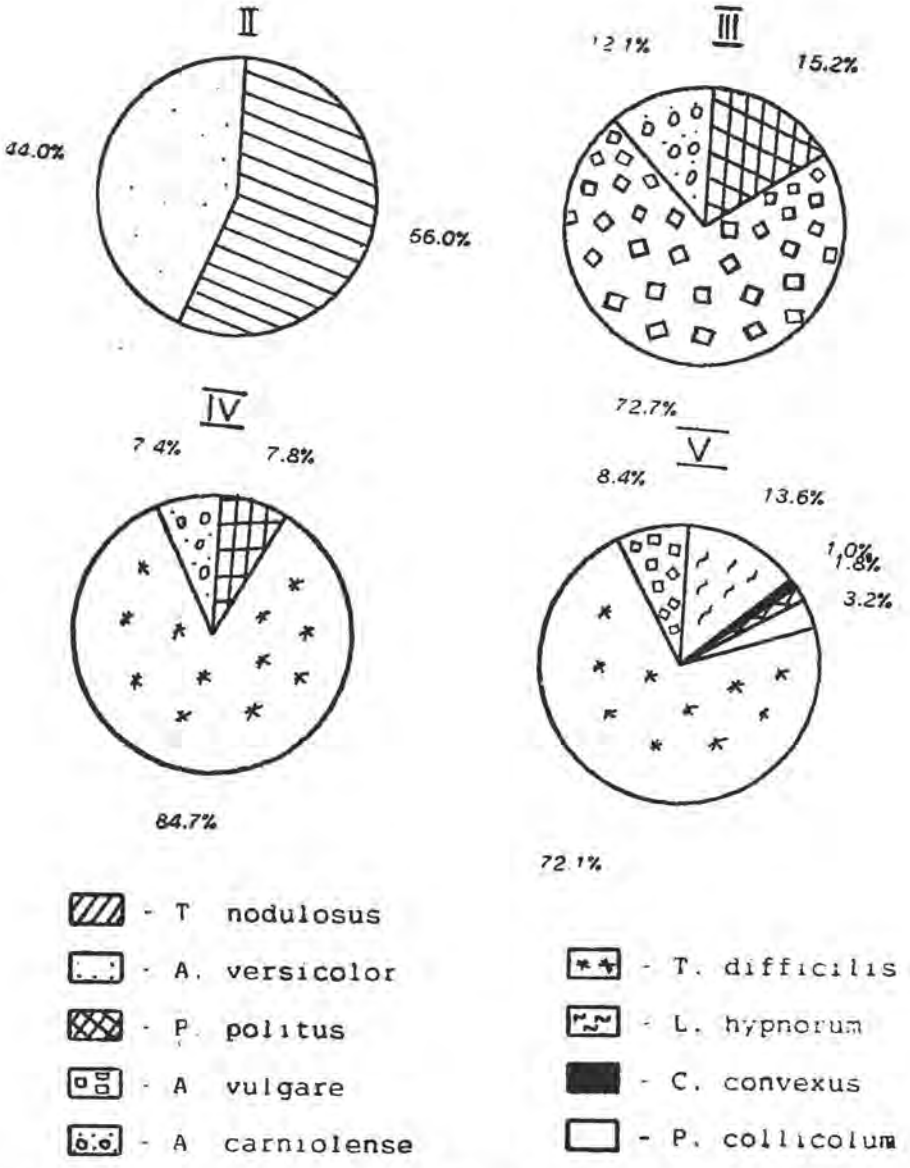

Fig. 3. *Faunistic spectrum of terrestrial isopods in Cheile Turzii for stations II, III, IV, and V.*

the animals in the perimeter of the ecosystems. A high abundance was also registered for *L. hypnorum*; however, its distribution in the perimeter of the coppice is limited to a certain type of microhabitat. The numerical differences in the abundance of the populations of the same

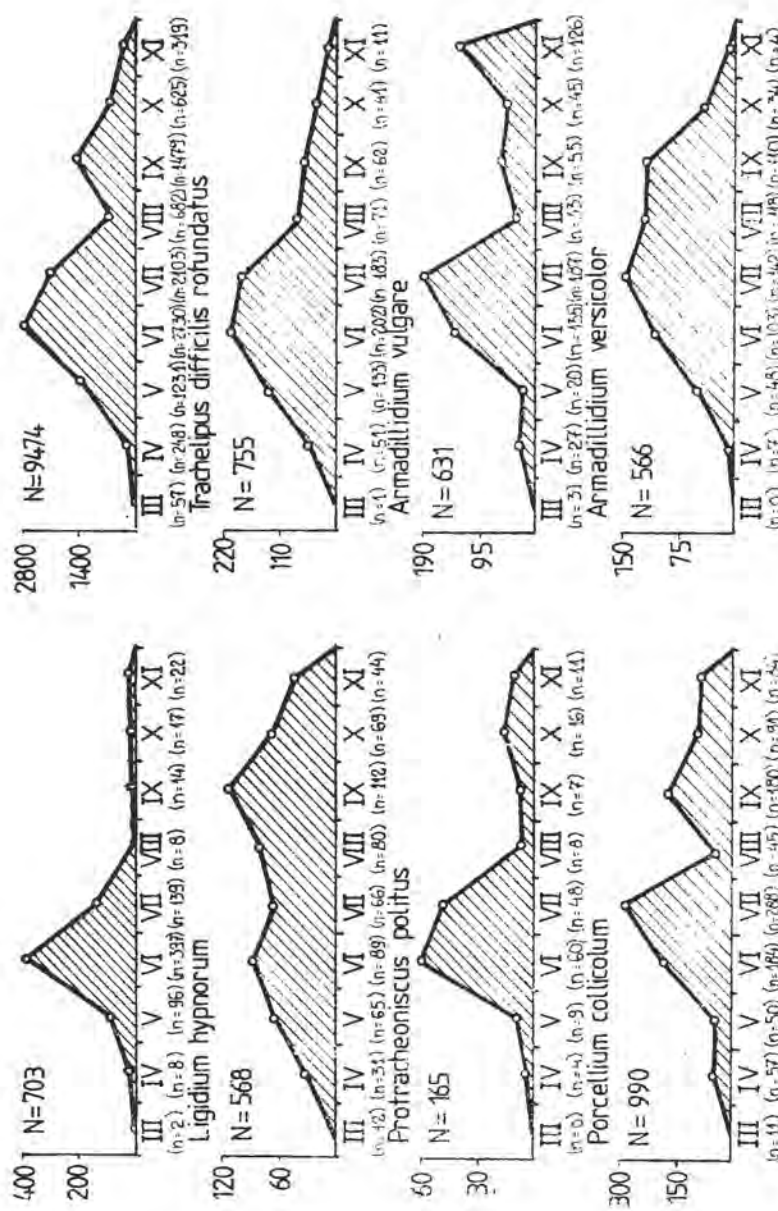

Fig. 4. *Phenogram of biological activity of species of isopods in Cheile Turzii.*

species, existing in the biocoenoses of different ecosystems, reveal the degree to which the ecological conditions are within the optimal limits for each species.

The period of biological activity of the isopod species in Cheile Turzii was established on the basis of monthly pitfall trap captures. The activities of feeding and reproduction are associated with the activity of the animals and thus the rate of their capture in the traps. A shorter period of activity was registered for *L. hypnorum* (Fig. 4) and *P. conspersum*, species which are stenotopic and stenoecic. The longest period of activity, 8 months, was recorded for the species with a wide distribution in the perimeter of the ecosystems: *P. politus*, *T. nodulosus*, *T. difficilis rotundatus*, *A. vulgare*, and *A. versicolor quinqueseriatum*. Although *A. carniolense* is a sylvan species like *P. politus* and *T. difficilis*, its length of activity is only 6 months, from May through October. The length of the period of biological activities is related to the species' tolerance to climatic factors, especially temperature. The species with a greater tolerance resume activities early in the spring, the beginning of April or sometimes the end of March and continue them until the end of November or in some years even the beginning of December. Their threshold of biological activity is lower, probably under 10°C.

Size structure of adults. To appreciate the variability of the size of the individuals of a species, we established size classes for the adults of 6 species of terrestrial isopods which were captured in large numbers. Variability is determined by the age of the adults as well as by genetic factors, because there exists an accentuated difference in the size of individuals of the same age, especially between males and females [12, 13].

In *L. hypnorum*, *P. politus*, and *T. difficilis rotundatus*, the greatest percent of adult males belong to the classes of the smaller size groups. In the larger size groups one finds only females (Fig. 5). This situation could be determined by genetical factors (it is known that the male isopods are smaller than the females of the same age), as well as by a difference of longevity. Isopods moult also in the adult stage and their size is related to their life span. The male adults of *P. politus* die a short time after mating, whereas some of the females may live until the following year [12]. The distribution of the size classes of *T. nodulosus*, *A. versicolor quinqueseriatum*, and *A. vulgare* is more or less similar. One can conclude that in these species the differences in size between those two sexes are not so pronounced and their longevity is quite similar. Female fecundity increases progressively in relation to size [13]. One wonders what factors determined the evolution of species in those two directions, some in which females have a greater longevity than the males and others in which both sexes have a similar life span. In the first category, with the longer living females, one finds only species which live in forest ecosystems, where the oscillations of temperature and humidity are reduced. The second category comprises *T. nodulosus* and *A. versicolor*, thermophilous species, and *A. vulgare*, a eurytopic species, which inhabits xeric biotopes where thermic values are elevated in summer. It is possible that the similar longevity of males and females of the latter species is an advantageous trait and possibly exists in all

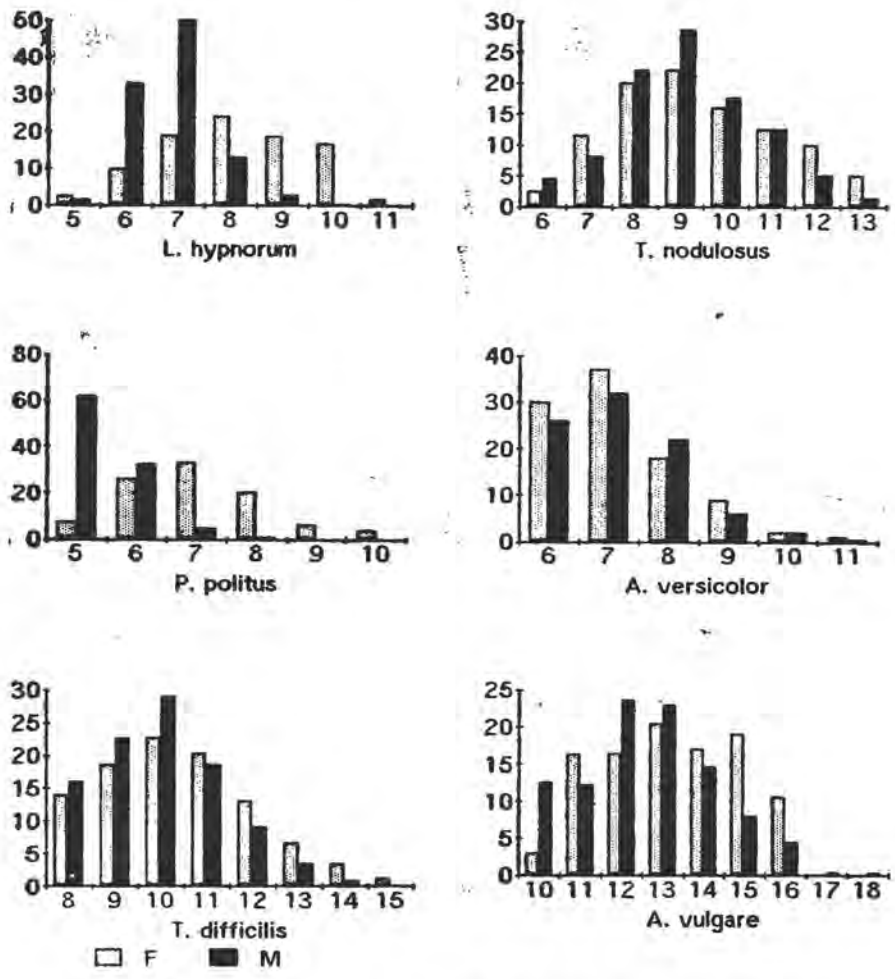

Fig. 5. *Distribution of adult isopods of Cheile Turzii by class size.*
F — Females, M — Males.

species of terrestrial isopods which live in ecosystems with less than optimum conditions.

Population dynamics. Important seasonal and annual fluctuations take place in the population effectives of terrestrial isopods [3, 7, 9, 10, 11]. These modifications are influenced by the natality and mortality rates. The mortality rate, which is influenced by climatic factors, registers seasonal and annual variations [3, 12]. To evaluate the modification in the isopod population effectives in Cheile Turzii, we calculated the

Table 3

Mean number of individuals collected per trap, per species, and per station, in 1991

Station	Species	Sampling date — 1991															
		1.V	16.V	30.V	13.VI	27.VI	10.VII	26.VII	8.VIII	23.VIII	5.IX	18.IX	3.X	18.X	1.XI	15.XI	28.XI
I	T. nodulosus	0.3	1.0	0.5	0	2.0	1.0	0.3	2.3	5.5	5.0	4.2	5.0	3.0	0.2	2.0	0
II	T. nodulosus	0.2	2.2	0	1.5	0.2	3.0	3.2	0.7	3.0	3.5	5.7	3.0	2.0	0.7	3.2	1.5
	A. versicolor	0.7	0.2	0	0	0.5	0	3.0	1.7	1.5	5.9	3.0	1.7	0.5	0.5	5.2	0.2
III	P. politus	1.2	1.0	0	1.0	0	0	1.0	0.5	0.5	0.3	0.7	1.0	0.7	0	0	0
	A. vulgare	0	0.5	0	1.5	2.2	1.7	2.5	2.0	1.5	3.3	0.5	1.2	1.0	0	0.2	0
	A. carniolense	0	0.2	0.3	0.2	0.5	0.2	0.5	1.2	1.7	1.3	0.5	0.2	0	0	0	0
IV	P. politus	1.2	1.0	0	1.0	0	0	1.0	0.5	0.5	0.3	0.7	1.0	0.7	0	0	0
	T. dif. rotundatus	1.7	0.8	26.5	38.8	34.8	30.2	11.3	42.1	42.3	28.8	24.0	88.3	36.0	8.1	13.0	13.0
	A. carniolense	0	3.7	0.3	0.6	4.5	3.0	3.8	4.3	5.0	4.2	3.3	6.3	1.8	0.3	0	0.3
V	L. hypnorum	0	1.3	15.6	52.6	18.3	4.3	0.6	0.3	1.0	1.0	1.6	2.0	1.6	1.0	2.3	1.0
	C. convexus	0	0	0	0.5	0	0.7	0.5	1.0	0.7	1.0	0.2	1.2	1.0	0.7	0.2	0
	P. politus	0	0.2	0.5	0.8	0.3	0.3	0.3	0	0	0.1	1.9	1.8	0.3	0.3	0.3	0.8
	P. collicolum	0.3	1.3	1.3	3.0	2.0	11.0	3.0	0	0.6	1.0	0.3	0.3	0	0.3	1.3	1.0
	T. dif. rotundatus	2.2	14.7	23.8	30.1	32.4	20.8	17.5	31.5	37.4	14.7	14.0	27.4	7.8	1.5	2.8	1.4
	A. vulgare	2.2	5.5	1.8	5.4	5.1	5.1	3.1	2.1	0.8	1.5	1.0	2.3	1.1	0	0.1	0
	A. carniolense	0	0	0	0	0	0.2	0	0.3	0.6	0.5	0.1	0	0	0	0	0
	A. versicolor	0	0	0	0	0	0	0	0	0	0	0.1	0.3	0.1	0	0	0

Table 4

Mean number of individuals collected per trap, per species and per station, in 1992

Station	Species	Sampling date — 1992																	
		13.III	27.III	10.IV	24.IV	8.V	22.V	5.VI	19.VI	3.VII	17.VII	3.VIII	31.VIII	14.IX	25.IX	9.X	23.X	6.XI	20.XI	4.XII
I	T. nodulosus	0	0.3	1.3	1.7	1.3	1.5	0.5	4.3	3.5	2.3	5.8	0	7.0	1.5	1.3	6.3	2.5	1.0	0
II	T. nodulosus	0	0.5	8.3	6.3	1.5	5.3	1.3	8.8	33.3	18.3	38.0	3.0	22.7	1.5	1.3	2.3	6.5	9.5	5.0
	A. versicolor	0	0.5	1.7	3.0	2.3	1.3	2.8	19.3	15.3	13.8	24.5	3.0	4.3	0.5	1.3	1.3	13.0	20.8	1.0
III	P. politus	0	0	0	0	0.3	0.5	0.3	0.2	0.3	1.3	0.5	0.3	0.5	0	0.3	0	0.3	0	0
	A. vulgare	0	0	1.0	0.5	1.3	2.8	1.8	3.5	3.0	7.8	4.5	4.3	1.3	0.8	0.7	1.3	2.0	1.0	0
	A. carniolense	0	0	0	0	0.3	0.8	0.3	0.5	0	0	0	0.2	0	0	1.5	0	0	0	0
IV	P. politus	1.0	0	2.2	0.7	0.3	0.4	1.0	3.5	3.0	1.2	2.5	1.7	3.0	0	2.0	1.7	0.8	2.3	0.8
	T. difficilis rotundatus	1.7	0.4	16.0	7.3	5.8	46.4	27.8	140.2	49.3	67.2	22.8	16.7	21.0	4.7	21.0	7.2	12.0	8.3	2.8
	A. carniolense	0	0	0	0.2	2.3	1.6	1.0	6.2	5.3	10.0	3.2	5.3	3.0	0.7	1.5	0.8	0.7	0	0
V	L. hypnorum	0	0.3	1.0	1.0	0.6	14.3	18.3	33.0	72.3	18.0	6.3	0.3	0	0	0	0.6	2.6	1.3	0.3
	C. convexus	0	0	0	0	0.5	0	0.2	0.7	0.7	0.5	1.0	0.2	0.7	0.5	0.5	0.2	0	0.2	0
	P. politus	0.1	0	0.7	0	4.0	0.7	0.2	0.3	0.8	0	0.4	0.3	1.0	0.1	0	0	0.7	0.1	0.4
	P. collicolum	0	0	0	0.6	0.3	0	0	6.0	6.6	1.6	1.3	1.3	0	0.6	0	4.0	1.0	0.6	0.3
	T. difficilis rotundatus	0.2	0.1	8.5	3.8	8.0	34.8	11.0	34.3	27.7	48.5	49.8	17.0	17.7	6.2	8.3	3.6	2.5	3.7	1.0
	A. vulgare	0	0	0.2	0.3	7.8	2.8	2.4	1.7	4.2	2.3	1.6	0.9	0.8	0.3	0.6	0.9	0.9	0.1	0
	A. carniolense	0	0	0	0	0	0.2	0	0	0	0	0.5	0.4	0.2	0	0	0	0	0	0.1
	A. versicolor	0	0	0.2	0	0	0	0.1	0.1	0.1	0	0	0	0	0	0	0	0	0	0

average number of animals captured with each collection (Tables 3 and 4), considering that the material was collected at regular intervals of time. In all the species there were seasonal and annual fluctuations. The mean number captured was high over a relatively long period of the year for some species (*T. nodulousus, T. difficilis rotundatus, A. vulgare*), which suggests that their populations do not undergo important numerical modifications until late autumn. For some other species, for example *L. hypnorum, P. politus, C. convexus, P. collicolum*, and *A. carniolense*, a numerical increase was recorded for a short period of time and then followed by a marked decrease, probably determined by an increase in the mortality rate of the adult individuals. These species, especially *L. hypnorum, C. convexus*, and *P. collicolum*, have a narrower tolerance to fluctuations of environmental factors and do not tolerate a decreased relative humidity. After the reproductive period, nearly all the males of *P. politus* die, creating a rapid decrease in the population size [12]. Several factors can determine the prolonged elevated population effective in the first three species. *T. difficilis rotundatus*, a sylvan species, lives under leaf litter in stations IV and V, where climatic factors are optimum and adult mortality rate is low. The survival coefficient of this species is very high in this ecosystem, producing a great increase in the population effective. This species has the greatest population effective in the perimeter of Cheile Turzii. On the other hand, the maintenance of a relatively elevated population effective of *T. nodulosus* and *A. vulgare* over a period of time is due to the greater tolerance of these species to fluctuations of ecological factors. The mortality of isopods is related to the amplitude and the limits of the fluctuations of ecological factors in the ecosystems in which they live (if they do not exceed the optimal values for the species). It is also related to their degree of tolerance to these oscillations, a physiological attribute, determined genetically, which is characteristic for each species.

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THE SPERMATOGENETIC CYCLE IN TERRESTRIAL ISOPODS UNDER THE CLIMATIC CONDITIONS OF ROMANIA. II. THE EVOLUTION OF SPERMATOGENETIC PHASES IN ISOPODS MAINTAINED UNDER LABORATORY CONDITIONS DURING THEIR HIBERNAL PERIOD AND THE ESTABLISHMENT OF THE NUMBER OF GENERATIONS HATCHED DURING ONE YEAR

CONSTANTIN CRĂCIUN*

SUMMARY. — Histological studies were performed on the evolution of spermatogenetic phases in isopods maintained under optimal laboratory conditions during their hibernal rest, as compared to isopods collected directly from nature, during the same period. By providing the optimal living conditions, the male individuals from the laboratory resume with intensity their spermatogenetic activity. The female isopods, under laboratory conditions, hatch four generations during one year, as compared to the females found in nature, which have just one hatching per year. These experiments demonstrate both the importance of favourable environmental conditions on the reproduction and development of terrestrial isopods and the ability of these animals to respond quickly to the favourable conditions assured.

This experiment was organized in order to compare the spermatogenetic activity of the isopods collected directly from nature in December — May (activity which is presented in Part I of this study [3]) with that of isopods maintained in terraria at an almost constant temperature (22°C), in the same period, but in which the hibernal rest has been suspended. I mention that there is no report as yet of any similar study, either in isopods or in other crustaceans, except for the one reported by Crăciun [1].

Materials and methods. The terrarium was set up on December 3. It provided normal humidity, light and feeding conditions, as well as a temperature of 22°C. In this terrarium I introduced mature *Porcellio scaber* individuals of both sexes, collected from nature and being, therefore, in the hibernal period.

First of all, I noticed that the isopods resumed their normal activities as early as the next day. On December 24, *i.e.* after exactly 3 weeks, the isopods molted, and on January 17 the females produced the generation of young that they would have normally produced in May-June.

Gonads were excised only from mature male individuals, starting on December 3 and continuing weekly until May 20. After the gonads had been adequately prepared, the serial sections were stained and examined under the light microscope.

Results and discussion. The male reproductive system of terrestrial isopods consists of a pair of gonads, symmetrically placed on both sides of the digestive tract. In its turn, each gonad is made up of 3 testicular follicles which open separately and at different levels in the anterior

* *Babeş-Bolyai University, Department of Biology, 3400 Cluj-Napoca, Romania*

region of vas deferens that functions as a seminal reservoir. The 3 follicles were designated as I, II and III. Also, the gonad from the left of the digestive tract was marked with L, and the one on the right with R (see Fig. 1 in [3]).

In isopods, spermatogenesis occurs in the 6 testicular follicles, from where the mature spermatozoa pass and accumulate in the anterior segment of vas deferens. I examined separately the evolution of the spermatogenetic activity of the testicular follicles nos. I, II and III of the left and right gonads. Alongside of the structural and functional evolution of germinal elements, the degree of functional synchronism and asynchronism of the 6 testicular follicles for the two gonads of all *Porcellio scaber* individuals sacrificed was also studied.

In order to follow the dynamics of all the spermatogenetic processes in their chronologic evolution, I defined, based of my previous studies [1—3], 6 phases which were characteristic of the whole spermatogenetic cycle (see Fig. 2 in [3]). I studied comparatively the evolution of these 6 spermatogenetic phases in all 6 follicles of gonads excised from isopods collected during the hibernation period (December—May), both from laboratory terraria and directly from nature.

Based on these observations, I prepared the monthly tables and the corresponding graphs which present the results of this experiment (Tables 1—6).

Based on the data presented in detail for each month from December till May, I made up a synoptic table of the spermatogenetic information for the isopods kept in terrarium (Table 7). This table contains data which are statistically analyzed and serve to compare the evolution of the spermatogenetic activities of the two groups of isopods studied.

The graphic representation of the data from this synoptic table demonstrates again that the spermatogenetic cycles are unequal in amplitude and evolution in time (Fig. 1). By comparing the graphs of the spermatogenetic activities of the isopods from the terrarium with the ones of the isopods from nature, one notices a very large and significant difference in the evolution and amplitude of the spermatogenetic phases. Phase 1, which in outdoor isopods reaches its maximum in winter, is the least active phase in terrarium isopods where it is present only in December and January. Also, phases 2 and 3 display a rapid evolution and a low amplitude in terrarium isopods. On the contrary, phases 4 and 5, which in outdoor animals were discontinuous and had an evolution of weak intensity, were continuous and moderately intense in terrarium animals. The most significant evolution is presented by phase 6, which decreases steadily from December till May in outdoor isopods, but increases constantly till March and stays at a high level till May in terrarium ones.

Analyzing the evolution of the spermatogenetic phases (Table 8), it can be seen that the terrarium isopods resumed their spermatogenetic activity. In the first part of the analyzed period, phases 1, 2 and 3 are

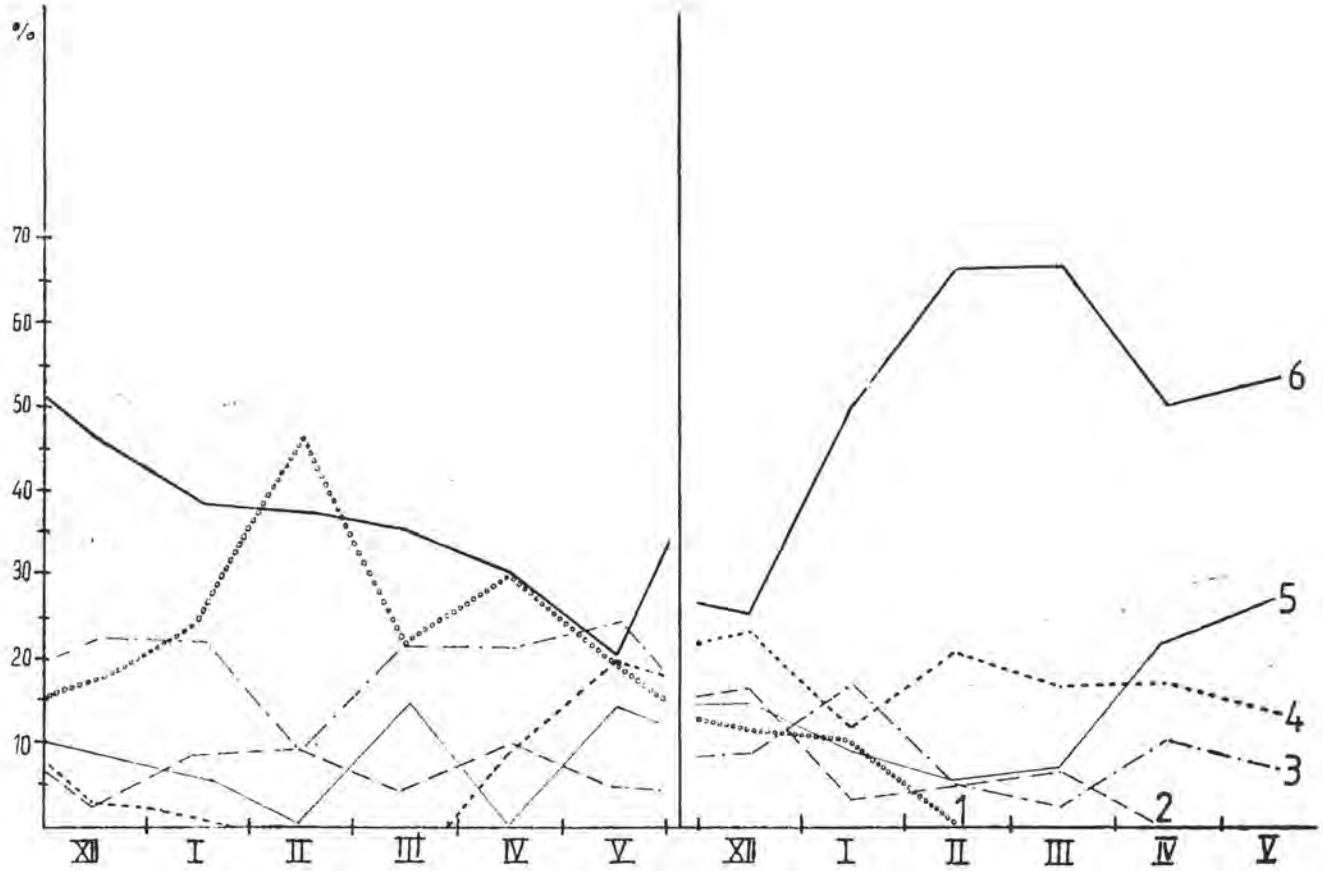

Fig. 1. *The amplitude of the spermatogenetic phases* (1—6) *in* Porcellio scaber *Latr. during the hibernal rest period* (%).
Left — Animals living in nature. Right — Animals living in the terraria.

Table 1

The structural and functional evolution of the testicular follicles in December

Date	Phase of germinal element development in follicles I, II, III						Number of phases in the follicles of a testicle		Phase difference between the two testicles	Degree of synchronism and asynchronism between the phases of the 3 follicles (I–II, I–III, II–III)						Degree of synchronism and asynchronism between the phases of the homologous follicles of the two testicles		
	left			right						left			right					
	I	II	III	I	II	III	left	right								I	II	III
Dec. 3	6	4/5	3	6	4	3	3	3	0–1/II	1–2	3	1–2	2	3	1	0	0–1	0
	2	6	4	2	6	4	3	3	0	2	2	2	2	2	2	0	0	0
Dec. 13	1	5	3	1	5	3	3	3	0	2	2	2	2	2	2	0	0	0
	4/5	2	6/1	4/5	2	6	3	3	0–1/III	2–3	2	1–2	2–3	1–2	2	0	0	0–1
Dec. 20	6	1	4	6	1	4	3	3	0	1	2	3	1	2	3	0	0	0
	1	4	2	1	4	2	3	3	0	3	1	2	3	1	2	0	0	0
Dec. 27	5	4	6	5	4	6	3	3	0	1	1	2	1	1	2	0	0	0
	2	6	4	2	6	4	3	3	0	2	2	2	2	2	2	0	0	0

In December I analyzed 8 gonads with 16 testicles and 48 follicles (24 pairs).

Conclusions :

1. The follicles present all the spermatogenetic phases, having the following distribution :

Phase / Follicles	1	2	3	4	4/5	Total follicles	SPERMIOGENESIS				Total general
							5	6	6/1	Total follicles	
I	4	4	—	—	2	10	2	4	—	16	16
II	2	2	—	5	—	10	2	4	—	6	16
III	—	2	4	6	—	12	—	3	1	4	16
Total follicles	6	8	4	11	3	32	4	11	1	16	48
%	12.5	16.67	8.33	22.92	6.25	66.67	8.33	22.92	2.08	33.33	100%

2. Number of phases presented by the follicles of a testicle: a) no testicle has all the follicles in the same phases; b) all the testicles have follicles in three different phases.
3. Degree of phase synchronism and asynchronism among the follicles of the same testicles (I, II and III):

	left	right
– synchronism	= 0	0
– asynchronism of 1 phase	= 4 folllicles = 16.67%	5 follicles = 20.83%
– asynchronism of 1–1/2 phase	= 3 follicles = 12.50%	1 follicle = 4.17%
– asynchronism of 2 phases	= 13 follicles = 54.16%	14 follicles = 58.33%
– asynchronism of 2–1/2 phases	= 1 follicle = 4.17%	1 follicle = 4.17%
– asynchronism of 3 phases	= 3 follicles = 12.50%	3 follicles = 12.50%
Total	= 24 follicles = 100%	24 follicles = 100%

4. Degree of phase synchronism and asynchronism among the homologous follicles: 22 pairs (91.67%) are synchronous; 2 pairs (8.33%) present asynchronism of 1/2 phase (I/II and I/III).

Table 2

The structural and functional evolution of the testicular follicles in January

Date	Phase of germinal element development in follicles I, II, III						Number of phases in the follicles of a testicle		Phase difference between the two testicles	Degree of synchronism and asynchronism between the phases of the 3 follicles (I—II, I—III, II—III)						Degree of synchronism and asynchronism between the phases of the homologous follicles of the two testicles		
	left			right						left			right					
	I	II	III	I	II	III	left	right								I	II	III
Jan. 8	6	5	3	6	5	3	3	3	0	1	3	2	1	3	2	0	0	0
	6	5	3	6	5	3	3	3	0	1	3	2	1	3	2	0	0	0
Jan. 17	1	2	1	1	2	1	2	2	0	1	0	1	1	0	1	0	0	0
	6	4	6	6	4	6	2	2	0	2	0	2	2	0	1	0	0	0
Jan. 23	6	4	6	6	4	6	2	2	0	2	0	2	2	0	2	0	0	0
	6	4	6	6	4	6	2	2	0	2	0	2	2	0	2	0	0	0
	4/5	6	6	4	6	6	2	2	0—1/I	1—2	1—2	0	2	2	0	0—1	0	0
	5/6	3	6	5/6	3	6	2	2	0	2—3	0—1	3	2—3	0—1	3	0	0	0
	5/6	4	6	5/6	4	6	3	3	0	1—2	0—1	2	1—2	0—1	2	0	0	0
Jan. 30	6/1	1	4	6	1	3	3	3	0—1/I, 1/III	0—1	2—3	3	1	3	2	0—1	0	I
	6	3	6	6	3	6	2	2	0	3	0	3	3	0	3	0	0	0

In January I analyzed 10 gonads with 20 testicles and 60 follicles (30 pairs).

Conclusions :

1. The follicles are in all the spermatogenetic phases, with the following distribution :

Phase / Follicles	1	2	3	4	4/5	Total follicles	SPERMIOGENESIS 5	5/6	6	6/1	Total follicles	Total general
I	2	—	—	1	1	4	—	4	11	1	16	20
II	2	2	4	6	—	14	4	—	2	—	6	20
III	2	—	6	—	—	8	—	—	12	—	12	20
Total follicles	6	2	10	7	1	26	4	4	25	1	34	60
%	10.00	3.33	16.67	11.67	1.66	43.33	6.67	6.67	41.67	1.66	56.67	100%

2. Number of phases presented by the follicles of a testicle: a) no testicle has all the follicles in the same phase; b) 12 testicles (60%) have follicles in two different phases; c) 8 testicles (40%) have follicles in three different phases.

3. Degree of phase synchronism and asynchronism among the follicles of the same testicles (I, II and III):

	left	right
– synchronism	= 5 follicles = 16.67%	5 follicles = 16.67%
– asynchronism of 1/2 phase	= 3 follicles = 10.00%	2 follicles = 6.67%
– asynchronism of 1 phase	= 4 follicles = 13.33%	5 follicles = 16.67%
– asynchronism of 1–1/2 phase	= 3 follicles = 10.00%	1 follicle = 3.33%
– asynchronism of 2 phases	= 7 follicles = 23.33%	10 follicles = 33.33%
– asynchronism of 2–1/2 phases	= 2 follicles = 6.67%	1 follicle = 3.33%
– asynchronism of 3 phases	= 6 follicles = 20.00%	6 follicles = 20.00%
Total	30 follicles = 100%	30 follicles = 100%

4. Degree of phase synchronism and asynchronism among the homologous follicles: 27 pairs (90%) are synchronous; 3 pairs (10%) present the following asynchronism: 2 cases with 1/2 phase (2/I) and 1 case with 1 phase (1/III).

Table 3

The structural and functional evolution of the testicular follicles in February

Date	Phase of germinal element development in follicles I, II, III						Number of phases in the follicles of a testicle		Phase difference between the two testicles	Degree of synchronism and asynchronism between the phases of the 3 follicles (I–II, I–III, II–III)						Degree of synchronism and asynchronism between the phases of the homologous follicles of the two testicles		
	left			right						left			right					
	I	II	III	I	II	III	left	right								I	II	III
Feb. 7	3 5	6 6/1	5/6 6/1	3 5	6 6/1	5/6 6/1	3 2	3 2	0 0	3 1–2	2–3 1–2	0–1 0	3 1–2	2–3 1–2	0–1 0	0 0	0 0	0 0
Feb. 14	5/6 6	6 5/6	6 4	5/6 6	6 5/6	6 4	2 3	2 3	0 0	0–1 0–1	0–1 2	0 1–2	0–1 0–1	0–1 2	0 1–2	0 0	0 0	0 0
Feb. 20	4 6	6 4	6 2	4 6	6 4	6 2	2 3	2 3	0 0	2 2	2 2	0 2	2 2	2 2	0 2	0 0	0 0	0 0
Feb. 26	5/6 6	4 4	6 6	5/6 6	4 4	6 6	2 2	2 2	0 0	1–2 2	0–1 0	2 2	1–2 2	0–1 0	2 2	0 0	0 0	0 0

In February I analyzed 8 gonads with 16 testicles and 48 follicles (24 pairs).

Conclusions :

1. The follicles are in all the spermatogenetic phases, except phase I, as follows:

Phase / Follicles	2	3	4	Total follicles	SPERMIOGENESIS 5	5/6	6	6/1	Total follicles	Total general
I	—	2	2	4	2	4	6	—	12	16
II	—	—	6	6	—	2	6	2	10	16
III	2	—	2	4	—	2	8	2	12	16
Total follicles	2	2	10	14	2	8	20	4	34	48
%	4.17	4.17	20.83	29.17	4.17	16.67	41.67	8.32	70.83	100%

2. Number of phases presented by the follicles of a testicle: a) no testicle has all the follicles in the same phase; b) 10 testicles (62.50%) have follicles in two different phases; c) 6 testicles (37.50%) have follicles in three different phases.
3. Degree of phase synchronism and asynchronism among the follicles of the same testicles (I, II and III):

	left	right
– synchronism	= 4 follicles = 16.62%	4 follicles = 16.62%
– asynchronism of 1/2 phase	= 5 follicles = 20.82%	5 follicles = 20.82%
– asynchronism of 1–1/2 phase	= 4 follicles = 16.62%	4 follicles = 16.62%
– asynchronism of 2 phases	= 9 follicles = 37.50%	9 follicles = 37.50%
– asynchronism of 2–1/2 phases	= 1 follicle = 4.17%	1 follicle = 4.17%
– asynchronism of 3 phases	= 1 follicle = 4.17%	1 follicle = 4.17%
Total	= 24 follicles = 100%	24 follicles = 100%

4. Degree of phase synchronism and asynchronism among the homologous follicles: there are no phase asynchronism, all the homologous follicles functioning synchronously.

Table 4

The structural and functional evolution of the testicular follicles in March

Date	Phase of germinal element development in follicles I, II, III						Number of phases in the follicles of a testicle		Phase difference between the two testicles	Degree of synchronism and asynchronism between the phases of the 3 follicles (I—II, I—III, II—III)						Degree of synchronism and asynchronism between the phases of the homologous follicles of the two testicles		
	left			right						left			right			I	II	III
	I	II	III	I	II	III	left	right										
Mar. 6	4	6	6	3/4	6	6	2	2	0—1/I	2	2	0	2—3	2—3	0	0—1	0	0
	6	6	2	6	6	6	2	1	2/III	0	2	2	0	0	0	0	0	0
Mar. 12	6	6	6	6	6	6	1	1	0	0	0	0	0	0	0	0	0	0
	6	5	4	6	5	3	3	3	1/III	1	2	1	2	3	2	0	0	1
Mar. 21	6	6	4	6	5/6	4	2	2	0—1/II	0	2	2	0—1	2	1—2	0	0—1	0
	6	4	6	6	4	6	2	2	0	2	0	2	2	0	2	0	0	0
Mar. 26	2	6	5/6	2	6	5	3	3	0—1/III	2	2—3	0—1	2	3	1	0	0	0—1
	4	6	6	4	6	6	2	2	0	2	2	0	2	2	0	0	0	0

In March I analyzed 8 gonads with 16 testicles and 48 follicles (24 pairs).

Conclusions :

1. The follicles are in all the spermatogenetic phases, except phase 1, as follows :

Phase / Follicles	2	3	3/4	4	Total follicles	SPERMIOGENESIS 5	5/6	6	Total follicles	Total general
I	2	—	1	3	6	—	—	10	10	16
I	—	—	—	2	2	2	1	11	14	16
III	1	1	—	3	5	1	1	9	11	16
Total follicles	3	1	1	8	13	3	2	30	35	48
%	6.25	2.08	2.08	16.67	27.08	6.25	4.17	62.50	72.92	100%

2. Number of phases presented by the follicles of a testicle: a) 3 testicles (18.75%) have all follicles in the same phase; b) 9 testicles (56.25%) have follicles in two different phases; c) 4 testicles (25%) have follicles in three different phases.
3. Degree of phase synchronism and asynchronism among the follicles of the same testicles (I, II and III):

	left	right
– synchronism	= 8 follicles = 33.33%	9 follicles = 37.50%
– asynchronism of 1/2 phase	= 1 follicle = 4.17%	1 follicle = 4.17%
– asynchronism of 1 phase	= 2 follicles = 8.33%	1 follicle = 4.17%
– asynchronism of 1–1/2 phase	– –	1 follicle = 4.17%
– asynchronism of 2 phases	= 12 follicles = 50.00%	8 follicles = 33.33%
– asynchronism of 3 phases	= – –	2 follicles = 8.33%
– asynchronism of 2–1/2 phases	1 follicle = 4.17%	2 follicles = 8.33%
Total	= 24 follicles = 100%	24 follicles = 100%

4. Degree of phase synchronism and asynchronism among the homologous follicles: 19 pairs (79.17%) are synchronous; 5 pairs (20.83%) present the following asynchronism: 3 cases with 1/2 phase (1/I, 1/II, 1/III); 1 case with 1 phase (1/III); 1 case with 2 phases (1/III).

Table 5

The structural and functional evolution of the testicular follicles in April

Date	Phase of germinal element development in follicles I, II, III						Number of phases in the follicles of a testicle		Phase difference between the two testicles	Degree of synchronism and asynchronism between the phases of the 3 follicles (I–II, I–III, II–III)						Degree of synchronism and asynchronism between the phases of the homologous follicles of the two testicles		
	left			right						left			right			I	II	III
	I	II	III	I	II	III	left	right										
Apr. 2	6	5	6	6	5	6	2	2	0	1	0	1	1	0	1	0	0	0
	6	4	6	6	4	6	2	2	0	2	0	2	2	0	2	0	0	0
Apr. 10	6	6	6	6	6	6	1	1	0	0	0	0	0	0	0	0	0	0
	3	6	6	3	6	6	2	2	0	3	3	0	3	3	0	0	0	0
Apr. 18	3	5	6	3	5	6	3	3	0	2	3	1	2	3	1	0	0	0
	3	5	6	3	5	6	2	3	0	2	3	1	2	3	1	0	0	0
Apr. 25	5	6	4	5	6	4	3	3	0	1	1	2	1	1	2	0	0	0
	5	6	4	5	6	4	3	3	0	1	1	2	1	1	2	0	0	0
Apr. 29	5	6	4	5	6	4	3	3	0	1	1	2	1	1	2	0	0	0
	6	5	4	6	5	4	3	3	0	1	2	1	1	2	1	0	0	0

In April I analyzed 10 gonads with 20 testicles and 60 follicles (30 pairs).

Conclusions ;

1. The follicles lack phases 1 and 2 germinal elements, having the following distribution :

Phase / Follicles	3	4	Total follicles	SPERMIOGENESIS 5	6	Total follicles	Total general
I	6	—	6	6	8	14	20
II	—	2	2	8	10	18	20
III	—	8	8	—	12	12	20
Total follicles	6	10	16	14	30	44	60
%	10.00	16.67	26.67	23.33	50.00	73.33	100%

2. Number of phases presented by the follicles of a testicle: a) 2 testicles (10%) have all follicles in the same phase (phase 6); 6 testicles (30%) have follicles in two different phases; 12 testicles (60%) have follicles in three different phases.
3. Degree of phase synchronism and asynchronism among the follicles of the same testicles (I, II and III):

	left	right
— synchronism	= 6 follicles = 20,00%	6 follicles = 20.00%
— asynchronism of 1 phase	= 12 follicles = 40.00%	12 follicles = 40.00%
— asynchronism of 2 phases	= 8 follicles = 26.67%	8 follicles = 26.67%
— asynchronism of 3 phases	= 4 follicles = 13.33%	4 follicles = 13.33%
Total	= 30 follicles = 100%	30 follicles = 100%

4. Degree of phase synchronism and asynchronism among the homologous follicles: all follicles are synchronous.

Table 6

The structural and functional evolution of the testicular follicles in May

Date	Phase of germinal element development in follicles I, II, III						Number of phases in the follicles of a testicle		Phase difference between the two testicles	Degree of synchronism and asynchronism between the phases of the 3 follicles (I–II., I–III, II–III)						Degree of synchronism and asynchronism between the pases of the homologous follicles of the two testicles		
	left			right						left			right					
	I	II	III	I	II	III	left	right								I	II	III
May 8	6	5	4	6	5	4	3	3	0	1	2	1	1	2	1	0	0	0
	3	6	5	3	6	5	3	3	0	3	2	1	3	2	1	0	0	0
May 13	5	6	5/6	5	6	5/6	3	3	0	1	0–1	0–1	1	0–1	0–1	0	0	0
	5	6	6	5	6	6	2	2	0	1	1	0	1	1	0	0	0	0
May 20	6	4	6	6	4	6	2	2	0	2	0	2	2	0	2	0	0	0

In May I analyzed 5 gonads with 10 testicles and 30 follicles (15 pairs).

Conclusions :

1. The follicles lack phases 1 and 2 germinal elements, having the following distribution :

Phase / Follicles	3	4	Total follicles	SPERMIOGENESIS 5	5/6	6	Total follicles	Total general
I	2	—	2	4	—	4	8	10
II	—	2	2	2	—	6	8	10
III	—	2	2	2	2	4	8	10
Total follicles	2	4	6	8	2	14	24	30
%	6.67	13.33	20.00	26.67	6.67	46.66	80.00	100%

2. Number of phases presented by the follicles of a testicle: a) no testicle has all the follicles in the same phase; b) 4 testicles (40%) have follicles in two different phases; c) 6 testicles (60%) have follicles in three different phases.
3. Degree of phase synchronism and asynchronism among the follicles of the same testicles(I, II and III):

	left	right
– synchronism	= 2 follicles = 13.33%	2 follicles = 13.33%
– asynchronism of 1/2 phase	= 2 follicles = 13.33%	2 follicles = 13.33%
– asynchronism of 1 phase	= 6 follicles = 40.00%	6 follicles = 40.00%
– asynchronism of 2 phases	= 4 follicles = 26.67%	4 follicles = 26.67%
– asynchronism of 3 phases	= 1 follicle = 6.67%	1 follicle = 6.67%
Total	= 15 follicles = 100%	15 follicles = 100%

4. Degree of phase synchronism and asynchronism among the homologous follicles: all the homologous follicles are synchronous.

Table 8

Evolution of the spermatogenetic phases of follicles I, II and III from animals grown in terraria (Dec.—May) (%)

Phase	1			2			3			4			5			6		
Follicles / Month	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
XII	8.33	4.17	—	8.33	4.17	4.17	—	—	8.33	—	10.42	12.50	8.33	6.25	—	8.33	8.33	8.34
I	3.33	3.33	3.34	—	3.33	—	—	6.67	10.00	1.67	10.00	—	1.66	1.67	—	26.67	3.33	20.00
II	—	—	—	—	—	4.17	4.17	—	—	4.17	12.50	4.16	4.17	—	—	20.83	20.83	25.00
III	—	—	—	4.17	—	2.08	—	—	2.08	8.33	4.17	6.25	—	4.17	2.08	20.84	25.00	20.83
IV	—	—	—	—	—	—	10.00	—	—	—	3.33	13.34	10.00	13.33	—	13.33	16.67	20.00
V	—	—	—	—	—	—	6.67	—	—	—	6.67	6.66	13.33	6.67	6.67	1.333	20.00	20.00
Mean	1.94	1.25	0.56	2.08	1.25	1.74	3.47	1.11	3.40	2.36	7.85	7.15	6.26	6.18	1.46	17.22	15.69	19.03

Table 7

Synoptic table of the spermatogenetic data of animals kept in terraria (Dec.—May) (%)

Month	Gonads studied				Spermatogenetic phases of the follicles										Total follicles in spermiogenesis	Number of phases of the 3 follicles			Degree of phase synchronism or asynchronism among the follicles of the same testicle														Degree of synchronism and asynchronism within the pairs of homologous follicles							Frequency of follicle asynchronism (Total)		
																			left							right															
	Total gonads	Total testicles	Total pairs	Total follicles	1	2	3	3/4	4	4/5	5	5/6	6	6/1		All 3 in the same phase	in 2 phases	in 3 different phases	Synchronism 0	1/2	1	1 1/2	2	2 1/2	3	Synchronism 0	1/2	1	1 1/2	2	2 1/2	3	Synchronism 0	1/2	1	1 1/2	2	2 1/2	3	I	II	III
XII	8	16	24	48	12.50	16.67	8.33	—	22.92	6.25	8.33	—	22.92	2.08	33.33	—	—	100	—	—	16.67	12.50	54.16	4.17	1250	—	—	20.83	4.17	58.33	4.17	12.50	91.67	8.33	—	—	—	—	—	—	1	1
I	10	20	30	60	10.00	33.33	16.67	—	11.67	1.66	6.67	6.67	41.67	1.66	56.67	—	60.00	40.00	16.67	10.00	13.33	10.00	23.33	6.67	20.00	16.67	6.67	16.67	3.33	33.33	3.33	20.00	90.00	7.00	3.00	—	—	—	—	2	—	1
II	8	16	24	48	—	4.17	4.17	—	20.83	—	4.17	16.67	41.67	8.32	70.83	—	62.50	37.50	16.67	20.82	—	16.67	37.50	4.17	4.17	16.67	20.82	—	16.67	37.50	4.17	4.17	100	—	—	—	—	—	—	—	—	—
III	8	16	24	48	—	6.25	2.08	2.08	16.67	—	6.25	4.17	62.50	—	72.92	18.75	56.25	25.00	33.33	4.17	8.33	—	50.00	4.17	—	37.50	4.17	4.17	4.17	33.33	8.33	8.33	79.17	12.50	4.16	—	4.17	—	—	1	1	3
IV	10	20	30	60	—	—	10.00	—	16.67	—	23.33	—	50.00	—	73.33	10.00	30.00	60.00	20.00	—	40.00	—	26.67	—	13.33	20.00	—	40.00	—	26.67	—	13.33	100	—	—	—	—	—	—	—	—	—
V	5	10	15	30	—	—	6.67	—	13.33	—	26.67	6.67	46.66	—	80.00	—	40.00	60.00	13.33	13.33	40.00	—	26.67	—	6.67	13.33	13.33	40.00	—	26.67	—	6.67	100	—	—	—	—	—	—	—	—	—
Total	49	98	147	294	3.74 Mean	5.07	7.99	0.35	17.02	1.32	12.57	5.70	44.24	2.00	64.15	4.79	41.46	53.75	16.67	8.05	19.72	6.52	36.39	3.20	9.45	17.36	7.50	20.28	4.72	35.97	3.34	10.83	93.47	4.64	1.19	—	0.70	—	—	3	2	5

characterized by a low amplitude and a short development in time, due to the quick transformation of their germinal elements during the newly reactivated spermatogenetic cycle. On the contrary, phases 4 and 5 present an intense activity, producing the germinal elements required for the large amount of spermatozoa to be produced in phase 6. The evolution of the spermiogenetic activity (phases 5 and 6) is relevant. It begins in December and increases continuously until May, representing a major percentage of all the monthly spermatogenetic activities: 33, 57, 71, 74 and 80%, respectively (Table 7). The evolution of the curves representing phases 5 and 6 is also very suggestive, since these curves are similar to an image and its reflection in a mirror and thus indicate the transformation of phase 5 into phase 6 (Fig. 1). The percentage of functional synchronism increased significantly, both in the follicles of the same gonad, and in the homologous follicles of the two symmetrical gonads (Table 7). I mention here that the percentage of asynchronism in the spermatogenetic activity of the animals taken directly from nature is higher during their hibernal rest. If hibernation is suspended, as it is the case with the terrarium animals, the functional asynchronism is significantly reduced. Therefore, during the intense spermatogenetic activities, the homologous testicular follicles of the two symmetrical gonads function synchronously (Table 7, a 100% synchronism in April and May). Also, the asynchronisms are minimal and almost all at a difference of half a phase, which again stresses the fact that the functional asynchronism is caused, first of all, by unfavourable environmental conditions (*e.g.* temperature, humidity, feed, light) and suggests that under optimal living conditions, only the anomalies will be expressed.

A comparison of December May spermatogenetic activities of terrarium isopods with May — October activities of outdoor isopods (Fig. 2) shows an almost perfect similarity of the curves representing phases 3, 4, 5 and 6. In terrarium isopods, the favourable temperature suspended the hibernation and determined in December the onset of intense spermatogenetic activities which are kept at high levels until May and are similar to the ones presented by outdoor isopods in May — October, *i.e.* under their favourable living conditions in nature.

This conclusion is supported by the fact that on December 24, the animals from the terrarium molted, and on January 17 the females produced a new generation 6 weeks after being placed under optimal temperature conditions. Comparatively, their outdoor counterparts produced a new generation only in the first part of June, that is with a 5-month delay. This means that if the hibernal diapause is suspended and optimal development conditions are restored, the period of sexual activity can occur 5 months earlier. Furthermore, keeping the isopods of our temperate region under favourable living conditions, their spermatogenetic cycles become shorter, and more such cycles can occur per year, facilitating the couplings and the hatching of several isopod generations during one year.

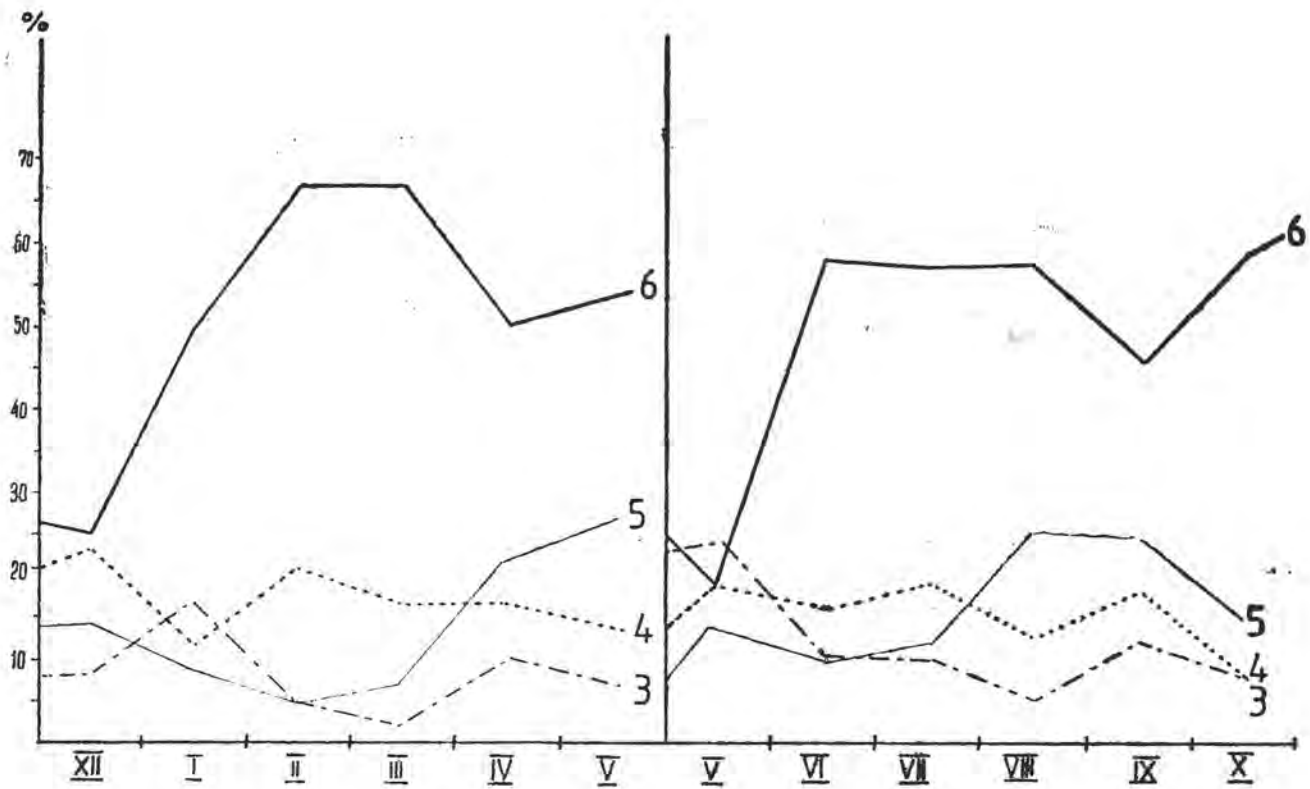

Fig. 2. *Evolution and amplitude of the spermatogenetic phases 3, 4, 5 and 6* (%).
Left — Animals kept in the terraria at 22°C during the hibernal period. Right — Animals collected from nature in spring through autumn.

Thus, as my experiment has shown, the female isopods produce their first hatching when they are 11—12 months old, if kept under natural environmental conditions. The data reported by Tomescu [5] indicate that an adult female of *Trachelypus balticus* lays two series of eggs per year, one at the beginning of June and the other at the end of July—beginning of August. In this species, it was also established that the males fertilize the females only in spring, and that the females use for the second fertilization the spermatozoa deposited in their seminal receptacles during the first mating.

Taking into account these data and the results of my experiment concerning the arrest of the hibernal period, I initiated another experiment in order to establish the number of generations that a *Porcellio scaber* female can produce per year, if kept under optimal living conditions together with mature male individuals.

For this experiment, I collected 12 young isopods of the same age (8 females and 4 males) and placed them in a terrarium. All these individuals had been hatched in the same period, *i.e.* at the beginning of June. The isopods were studied daily and beginning with February 2, when they were 8 months old, the females produced the first generation of young, an event that occurs when they are 11 months old, if kept outdoors. In our laboratory, the second generation was produced around May 6, *i.e.* at 11 months, the third around July 1, at 13 months, and the fourth around August 10, at 14 months.

I mention that 2—3 days before hatching, each female was isolated in a small terrarium, and 4—5 days after hatching, they were put back into a usual terrarium, together with the 4 males, and only the young were left in the small terraria.

The animals were maintained until January 5 of the next year, but they did not produce a fifth generation by that time. Then, they all died in a laboratory accident. Nevertheless, I am sure that on February 2, a year from the date when the first young generation was hatched, the females would have produced a fifth generation. In the period studied, hatching occurred on the average every 2—2.5 months, a rhythm which is also supported by Mocquard and co-workers' [4] experiments made with *Porcellio dilatatus* maintained under favourable conditions of temperature and photoperiodism.

According to the data of my experiment, by the age of 14 months, a *Porcellio scaber* female produces 4 generations of young, all within 6 months, *i.e.* when the female is 8—14 months old, under laboratory conditions. On the other side, the outdoor isopods hatched a single generation.

Conclusions. These experiments demonstrate both the importance of favourable environmental conditions on the reproduction and development of terrestrial isopods and the ability of these animals to respond quickly to these favourable conditions once they occur.

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INFLUENŢA UNOR COMPUŞI ANORGANICI ASUPRA PRODUCŢIEI DE ALCALOIZI LA CULTURILE DE CELULE DE *BERBERIS PARVIFOLIA*

CONSTANTIN DELIU*, CORNELIA MUNTEANU-DELIU şi VICTOR BERCEA***

SUMMARY. — Influence of Some Inorganic Compounds on the Production of Alkaloids in Cell Cultures of Berberis parvifolia. The study of the effects of increased concentrations of Cu or Ni sulphates and chlorides (1, 5, 10, 25 and 50μ M), added to the culture media of the cell suspensions of *Berberis parvifolia*, revealed an inhibition of cell growth and of starch synthesis and a stimulation of the synthesis of proteins and protoberberinic alkaloids. These effects of inhibition and stimulation were more pronounced in the case of copper and sulphate ions.

Cu toate că tehnica obţinerii de metaboliţi secundari prin intermediul culturilor de suspensii celulare rezultate din plante superioare s-a ameliorat mult în ultimul timp şi s-a extins la foarte multe specii, nu toate culturile sintetizează cantităţile dorite din compuşii respectivi. Pentru mărirea productivităţii s-au utilizat o serie de metode printre care se înscrie şi optimizarea mediului nutritiv.

În cazul culturilor celulare realizate din specii ce aparţin unor genuri care sintetizează alcaloizi protoberberinici, aşa cum sunt *Berberis*, *Thalictrum* şi *Coptis*, scăderea concentraţiei de fosfat de potasiu [2] sau creşterea celei de sulfat de cupru [7, 10] au condus, în general, la sporirea cantităţii de berberină acumulată în celule sau excretată în mediul lor de cultură.

În cadrul acestei lucrări am investigat efectul concentraţiilor crescute de Cu şi Ni asupra unor procese metabolice (creştere celulară; sinteza de proteine, amidon şi alcaloizi protoberberinici) ce au loc în culturile de suspensii celulare de *Berberis parvifolia*.

Material şi metode. Suspensiile celulare de *B. parvifolia* au fost crescute în vase conice de 200 ml cu 300 ml mediu şi menţinute pe un agitator rotativ (100 rpm) la întuneric şi la 25°C. Mediul de cultură a fost alcătuit din nutrienţi anorganici, după Gamborg şi colab. [5], la care s-a mai adăugat şi 0,025 mg/l $NiSO_4$. Nutrienţii organici au constat din: zaharoză (30 g/l), *myo*-inozitol (100 mg/l), tiamină (5 mg/l), piridoxină (1 mg/l), acid nicotinic (1 mg/l), acid 1-naftilacetic (1,5 mg/l) şi 6-benzilaminopurină (0,3 mg/l). În acest mediu de bază s-au introdus înainte de autoclavare: $CuSO_4 \cdot 5H_2O$; $CuCl_2 \cdot 2H_2O$; $NiSO_4 \cdot 7H_2O$ şi $NiCl_2$ (1, 5, 10, 25 şi 50 μ M). pH-ul tuturor variantelor s-a ajustat la 5,5, tot înainte de autoclavare. La transfer (efectuat la 14 zile de cultură), pentru evitarea heterogenităţii, suspensiile celulare din mai multe vase au fost colectate într-unul singur, din care s-au prelevat inocului. Raportul volumetric dintre inocul şi mediul proaspăt a fost de 1:4.

* *Institutul de Cercetări Biologice, 3400 Cluj-Napoca, România*
** *Universitatea Babeş-Bolyai, Catedra de biologie vegetală, 3400 Cluj-Napoca, România*

Creşterea s-a determinat prin colectarea (prin filtrare) la 14 zile a biomasei celulare (din 4—5 vase/variantă) care a fost apoi supusă uscării la 50°C timp de 24 ore şi cântărită.

Analizele biochimice s-au realizat din biomasa uscată. Astfel, alcaloizii protoberberinici au fost determinaţi, după exctracţia lor cu alcool metilic, spectrofotometric [13].

Amidonul s-a determinat fotoclorimetric după metoda lui Somogyi [12] şi Nelson [11]. Proteinele totale au fost dozate spectrofotometric [9].

Rezultate şi discuţii. Ionii metalelor grele sunt consideraţi de unii autori ca având un efect similar cu cel al elicitorilor, atunci când sunt introduşi în culturile celulare vegetale [3], astfel că ei au fost denumiţi elicitori abiotici Pentru a studia influenţa ionilor de Cu şi Ni asupra culturilor de suspensii celulare de *Berberis parvifolia*, s-au utilizat două săruri ale celor două metale grele, şi anume sulfaţi şi cloruri. Deoarece în compoziţia originală a mediului Gamborg nu intră şi nichelul, în mediu s-a introdus o cantitate de $NiSO_4$ similară cu cea în care se găseşte sulfatul de cupru (0,1 μM). În acest mediu au fost cultivate toate variantele de suspensii celulare, inclusiv pe cele luate ca martor.

Efectul $CuSO_4$, $CuCl_2$, $NiSO_4$ şi $NiCl_2$ asupra creşterii celulare (Fig. 1) este inhibitor, în toate variantele, în care concentraţia celor doi ioni trece de 10 μM. Inhibiţia este întotdeauna mai mare în cazul Cu^{2+}. De asemenea, se remarcă un fenomen interesant şi anume că sulfaţii au o acţiune inhibitoare mai puternică faţă de cloruri, indiferent de cationul ce există în alcătuirea lor. Dacă reducerea creşterii celulare poate fi explicată prin rigidizarea peretelui celular [6] şi/sau scăderea activităţii mitotice [4], este greu de înţeles de ce efectul toxic al celor doi ioni metalici este mai mare atunci când sunt introduşi în mediu sub formă de sulfaţi. Kim şi colab. [7] au efectuat şi ei experimente cu sulfat de cupru pe care l-au introdus în mediul culturilor celulare de *Thalictrum rugosum*. Cu toate că în acest caz efectul toxic al Cu se remarcă la peste 1 mM, la culturile celulare de *B. parvifolia* o cantitate de $CuSO_4$ mai mare de 1,25 mg/l a produs liza a peste 75% din totalul celulelor.

Se cunoaşte că nivelele crescute de metale grele produc, prin mărirea activităţii catalazei, AIA-oxidazei şi a peroxidazelor, o serie de perturbări ale activităţii metabolice a celulelor vegetale [8]. Probabil că datorită acestui fapt are loc scăderea cantităţii de amidon ce se acumulează în celulele de *B. parvifolia* aflate în contact cu sărurile celor două metale. Se poate observa că efectul inhibitor este mai puternic în cazul cuprului, şi că el depinde, ca şi la creşterea celulară, atât de cationi cât şi de anioni (Fig. 2).

Sinteza proteinelor este şi ea afectată de concentraţiile sporite de Cu^{2+} şi Ni^{2+} (Fig. 3). Astfel, în varianta cu 50 μM de $CuSO_4$ se constată aproape o dublare a cantităţii de proteine acumulată în celule. De asemenea, se poate observa că sulfaţii au un efect stimulativ asupra producerii de proteine totale mult mai intens decât clorurile. Probabil că aceste proteine, sintetizate în plus, nu sunt altceva decât enzime care, aşa cum arătau Chongpraditnun şi colab. [1], se pot produce

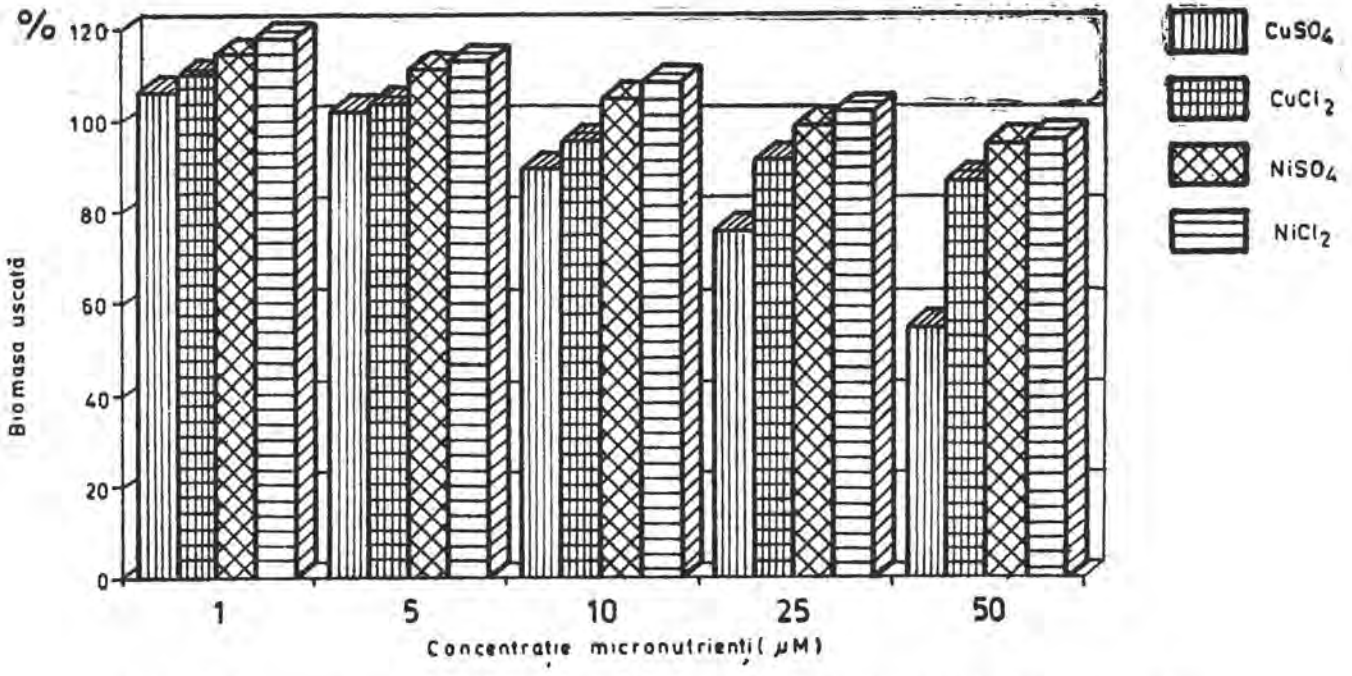

Fig. 1. *Creșterea culturilor celulare de* B. parvifolia *în medii cu concentrații diferite de micronutrienți.*

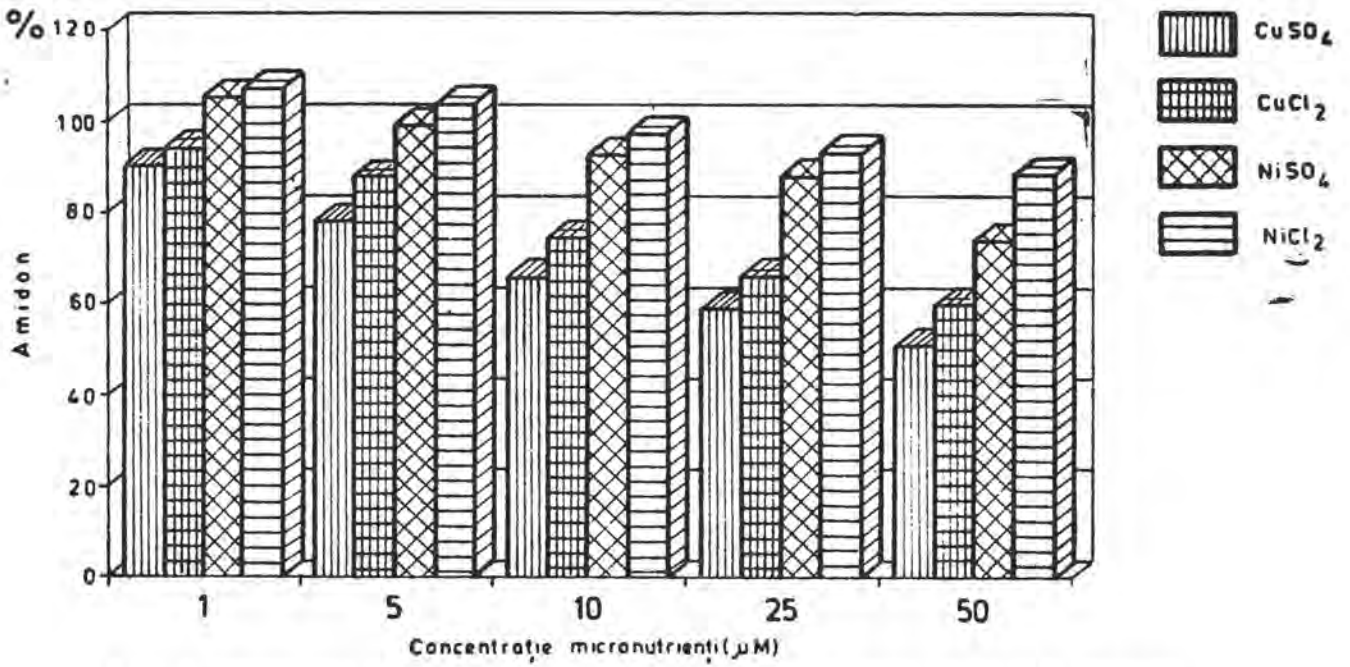

Fig. 2. *Influența unor micronutrienți asupra acumulării de amidon în culturi celulare de* B. parvifolia.

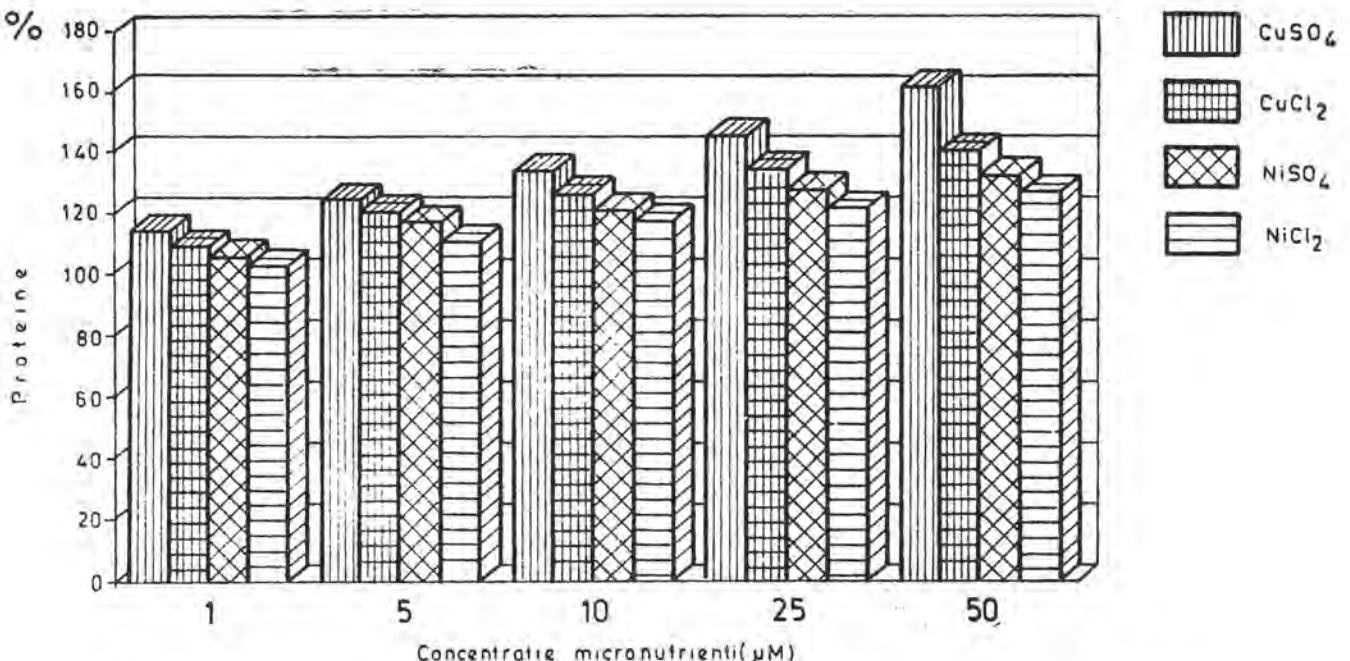

Fig. 3. *Efectul unor micronutrienți asupra sintezei proteinelor totale în culturi celulare de* B. parvifolia.

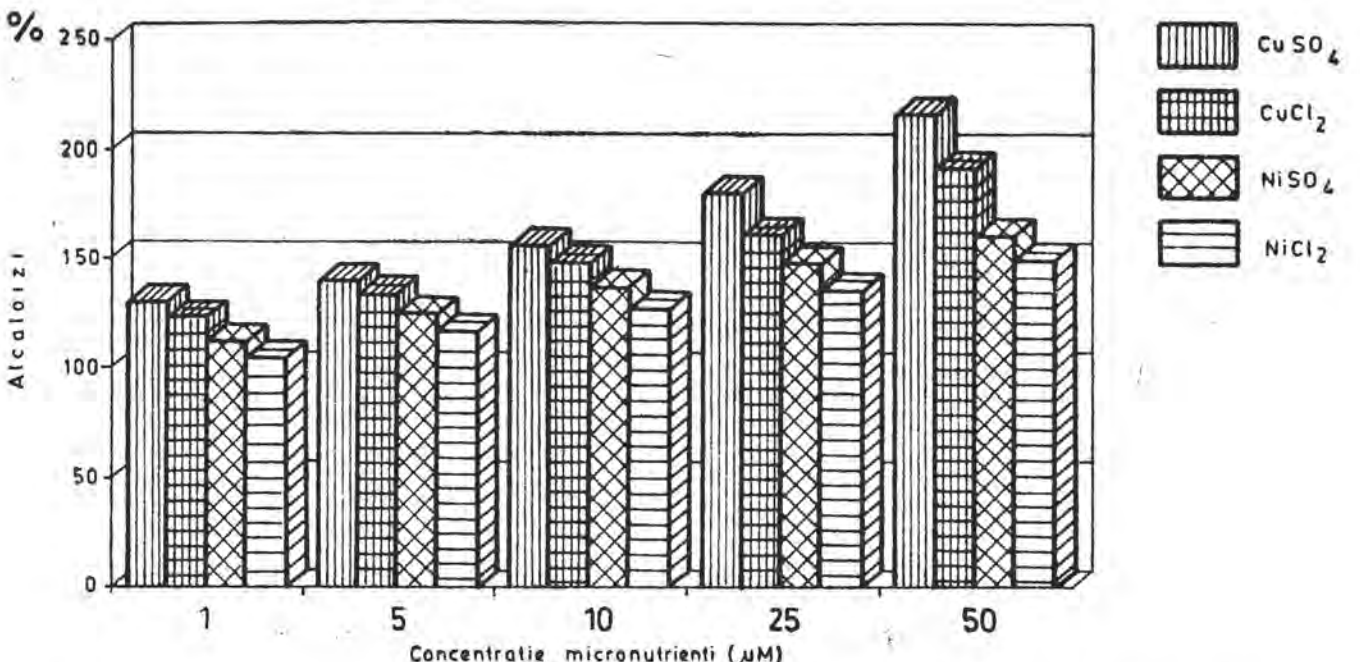

Fig. 4. *Influența unor micronutrienți asupra sintezei alcaloizilor protoberberinici în culturi celulare de* B. parvifolia.

în cantități sporite pentru revenirea din dereglarea metabolică provocată de toxicitatea metalelor. De asemenea, este posibil ca printre ele să existe cantități sporite și de enzime ce fac parte din calea de biosinteză a alcaloizilor protoberberinici.

Sinteza ca și acumularea alcaloizilor protoberberinici a fost în general stimulată de concentrațiile crescute ale sulfaților și clorurilor de Cu sau de Ni (Fig. 4). Acumularea cea mai importantă se remarcă la celulele cultivate pe mediu cu sulfat de cupru în concentrația de 50 μM. În această variantă, cantitatea de alcaloizi (% din substanța uscată) este aproape dublă față de martor. Totuși, datorită toxicității excesive pe care o exercită $CuSO_4$ asupra creșterii celulare, productivitatea suspensiilor (mg alcaloizi/l) este mică. În schimb, la aceeași concentrație, $CuCl_2$ are ca efect o sporire a producției de la 0,615 mg alcaloizi (martor) până la peste 1,0 g/l. Rezultatele noastre sunt în concordanță cu cele obținute la culturile celulare de *Coptis japonica* [10] sau de *Thalictrum rugosum* [7]. Cu toate acestea, trebuie să menționăm că autorii respectivi au utilizat numai $CuSO_4$ în experimentele lor. Toți acești autori dau explicații diferite asupra stimulării sintezei berberinei datorită influenței ionului de Cu. Astfel, Morimoto și colab. [10] arătau că efectul cuprului asupra producerii metaboliților secundari se bazează pe participarea lui la stabilizarea sistemului de transport al electronilor la nivel mitocondrial. În schimb, Kim și colab. [7] cred că această stimulare se datorează capacității cuprului de a produce anumite dereglări ale metabolismului celular, similare celor produse în cazul elicitărilor.

Desigur, este greu în prezent să dăm o explicație precisă, dar noi considerăm că în cazul suspensiilor celulare de *Berberis parvifolia* este posibil ca sporirea sintezei alcaloizilor protoberberinici, ce are loc în urma contactului celulelor cu sărurile de cupru sau nichel, să aibă loc ca urmare a unei intensificări a sintezei de enzime din calea de biogeneză a acestor compuși secundari și/sau a stimulării activității lor.

Concluzii. 1. Introducerea unor concentrații mărite de sulfați sau cloruri de cupru și nichel în mediul de cultură al suspensiilor celulare de *Berberis parvifolia* a avut ca efect stimularea puternică a sintezei alcaloizilor protoberberinici și a proteinelor, precum și inhibarea creșterii celulare și a sintezei de amidon.

2. Acțiunea stimulatoare sau inhibitoare a ionilor celor două metale grele (Cu^{2+} și Ni^{2+}) este potențată într-o măsură mult mai mare de anionul sulfat în comparație cu anionul clor.

3. Datorită efectului său slab inhibitor asupra creșterii celulare, clorura de nichel utilizată într-o concentrație de 50 μM a condus la creșterea producției de alcaloizi (g/l) cu peste 60%.

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STUDIA UNIV. BABEŞ-BOLYAI, BIOLOGIA, XL, 1—2, 1995

INFLUENŢA UNOR COMPUŞI ORGANICI ASUPRA BIOSINTEZEI STEROIZILOR ÎN CULTURI CELULARE DE *DIOSCOREA CAUCASICA*

CONSTANITN DELIU*, CORNELIA MUNTEANU-DELIU şi VICTOR BERCEA***

SUMMARY. — Influence of Some Organic Compounds on Steroid Biosynthesis by Dioscorea caucasica Cell Cultures. The addition of various levels of compounds such as cholesterol, yeast extract, L-leucine, L-serine and choline to *Dioscorea caucasica* Lipsky cell suspension cultures had different effects on their productivity. Thus, cholesterol (the precursor of diosgenin) had a negative influence on cell growth, but did not affect the diosgenin accumulation. The yeast extract produced a strong inhibiton of the cell growth and also of the diosgenin synthesis. Leucine stimulated only phytostero' synthesis. Otherwise, serine and choline, in low concentration (50 mg/l), stimulated the accumulation of diosgenin per gram dry weight, its quantity being higher than 200%.

Diosgenina este utilizată de mult timp ca şi matetrial de start pentru sinteza hormonilor corticosteroizi. În general ea se extrage din rizomii sau tuberculii plantelor ce aparţin genului *Dioscorea*. Culturile celulare realizate din specii vegetale ce sintetizează diosgenină pot deveni o alternativă de obţinere a compuşilor steroidici. Totuşi, dacă în cazul altor plante s-au obţinut rezultate notabile în încercările de a se mări sinteza metaboliţilor secundari, până în prezent productivitatea suspensiilor celulare de *Dioscorea* este destul de redusă. Pentru creşterea producţiei de diosgenină în culturi de celule, s-au întrebuinţat o serie de metode. Ele au constat în: selecţia de linii celulare [4, 6], optimizarea mediului nutritiv [5, 7, 11], elicitare [11] etc. Cu toate străduinţile depuse, rezultatele obţinute până în prezent nu permit cultivarea pe scară industrială a acestor suspensii celulare.

În acest studiu am investigat influenţa pe care o au anumite substanţe organice, respectiv colesterolul, extractul de drojdie, L-leucina, L-serina şi colina asupra productivităţii suspensiilor celulare de *Dioscorea caucasica* Lipsky.

Material şi metodă. Culturile de suspensii celulare de *Dioscorea caucasica* au fost cultivate în mediul Murashige-Skoog [9] cu acid 2,4-diclorfenoxiacetic (0,5 mg/l) în vase Erlenmeyer de 300 ml cu 40 ml mediu. pH a fost reglat înainte de autoclavare la 5,5. Culturile au fost menţinute pe un agitator rotativ (98 rpm) la întuneric şi la o temperatură de 25 ± 1°C. Subcultivările s-au efectuat la un interval de 14 zile, iar raportul dintre inocul: mediu a fost de 1:4. Liniile celulare 1 şi 11 au fost izolate prin selecţie clonală [4].

Creşterea celulară şi sinteza de steroizi s-au urmărit prin recoltarea, la anumite intervale de timp, de biomasă celulară (5 vase per variantă), care a fost apoi uscată la 50°C timp de 24 ore. Compuşii organici testaţi: L-leucina, L-serina, colina

* *Institutul de Cercetări Biologice, 3400 Cluj-Napoca, România*
** *Universitatea Babeş-Bolyai, Catedra de biologie vegetală, 3400 Cluj-Napoca, România*

și extractul de drojdie s-au adăugat ca atare în mediul nutritiv al culturilor celulare înainte de autoclavare. Pentru experiențele cu colesterol, s-a preparat o soluție stoc prin dizolvarea acestuia în alcool etilic fierbinte, după metoda dată de K a u l și colab. [7]. Din soluția respectivă s-au adăugat la mediul nutritiv, înainte de autoclavare, cantitățile necesare pentru a ajunge la concentrațiile finale de 0,01 0,05 și 0,1%.

Extracția diosgeninei și a fitosterolilor s-a realizat din biomasa celulară uscată, cu hexan, după hidroliza cu H_2SO_4 2N în izopropanol 70% [5]. Determinarea cantitativă a steroizilor s-a efectuat din extractele hexanice cu ajutorul unui gaz-cromatograf [4]. Proteinele totale au fost determinate din biomasa celulară uscată, spectrofotometric, după metoda lui L o w r y și colab. [8].

Rezultate și discuții. Culturile de suspensii celulare de *Dioscorea caucasica* Lipsky sintetizează în general cantități mai mici de diosgenină [3, 4] în comparație cu alte specii de *Dioscorea* [5, 7]. Optimizarea mediului de cultură prin adaosul anumitor compuși, cum sunt colesterolul și extractul de drojdie, la suspensiile celulare de *D. deltoidea* a avut ca efect stimularea sintezei de diosgenină [7]. În cazul culturilor celulare de *D. caucasica*, introducerea în mediul nutritiv a colesterolului, extractului de drojdie, leucinei, serinei și colinei a avut o influență diferită asupra creșterii celulare și a sintezei de diosgenină și fitosteroli (Tabel 1). Astfel, colesterolul și extractul de drojdie au inhibat puternic creșterea celulară. Ceilalți compuși, cu excepția leucinei, nu produc scăderi sau măriri semnificative ale biomasei celulare după 14 zile de cultivare a celulelor. Referitor la sinteza steroizilor, se observă că în prezența colesterolului culturile celulare de *D. caucasica* acumulează cantități mult mai mari de fitosteroli față de celelalte variante experimentale, dar nu și de diosgenină. Extractul de drojdie a avut o influență negativă, in-

Tabel 1

Influența unor compuși organici asupra creșterii celulare și acumulării de steroizi la culturile de suspensii celulare de D i o s c o r e a c a u c a s i c a

Compus	Conc. (mg/l)	Creștere (g/l)	Diosgenină (mg/g s.u.)	Steroli (mg/g s.u.)
Control	0	12,81	0,90	1,90
Colesterol	100	9,45	1,00	19,43
	500	7,50	1,11	27,37
	1000	4,30	1,13	36,42
Extract de drojdie	100	8,52	0,62	2,01
	500	6,14	0,32	2,36
	1000	2,40	0,26	2,43
L-Leucină	10	12,95	0,91	3,11
	50	11,43	0,85	5,64
	100	9,17	0,79	6,35
L-Serină	10	13,04	1,37	2,18
	50	12,90	1,80	1,98
	100	12,78	1,75	2,32
Colină	10	13,21	1,29	1,97
	50	13,54	1,74	2,08
	100	13,10	1,70	2,04

diferent de concentrație, asupra sintezei de diosgenină. Leucina, care după Overton [10] poate fi înglobată în moleculele unor steroizi, a indus doar creșterea nivelului de steroli. În schimb, atât serina cât și colina au stimulat, în special, acumularea de diosgenină.

În urma rezultatelor obținute, în a doua etapă experimentală am testat efectul colesterolului, a extractului de drojdie, a serinei și colinei (în concentrații moderate) asupra unor procese metabolice la două linii celulare (1 și 11) de *Dioscorea caucasica* izolate prin selecție clonală [4]. Cele două linii se deosebesc între ele prin mărimea agregatelor celulare, creșterea celulară și sinteza de steroizi. Astfel, suspensiile celulare ale liniei 1 sunt alcătuite din agregate cu un diametru de peste 2 mm și etalează o creștere celulară mai redusă, dar un nivel mai mare de diosgenină în comparație cu linia 11, linie la care agregatele celulare au un diametru sub 1 mm. De asemenea, cele două linii se deosebesc și prin proporția în care se acumulează fitosterolii (Fig. 1 și 2).

Introducerea celor trei compuși în mediul de cultură al liniilor celulare 1 și 11 a avut efecte diferite asupra unor procese metabolice. Astfel, deși colesterolul este unul din precursorii diosgeninei [11, 12], adăugarea lui la suspensiile celulare de *D. caucasica* a influențat foarte puțin sinteza diosgeninei, mărind însă cantitatea de steroli acumulată de

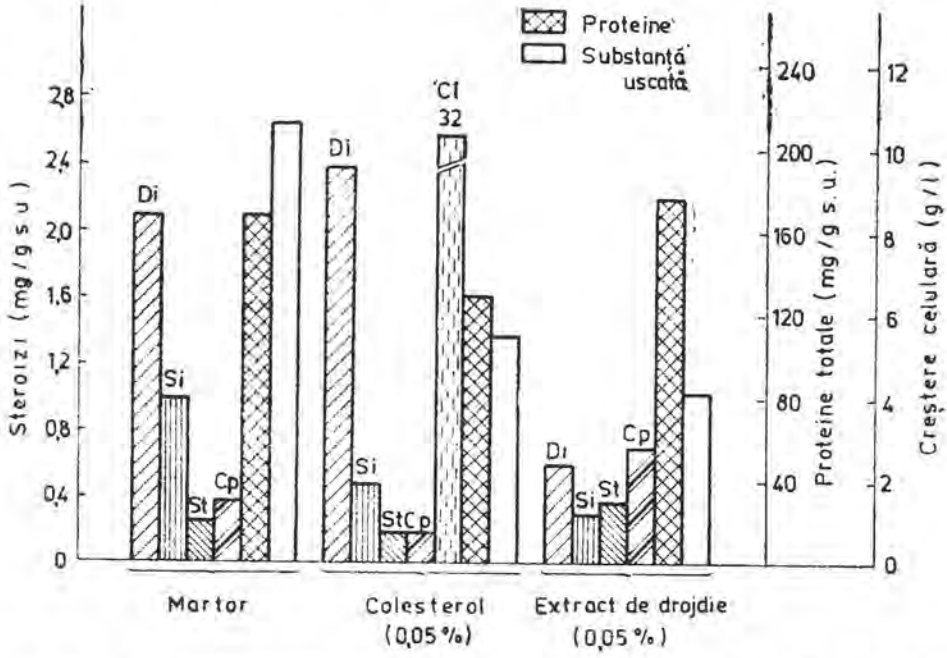

Fig. 1. *Influența colesterolului și a extractului de drojdie asupra creșterii celulare și a sintezei de proteine, diosgenină* (Di), *sitosterol* (Si), *stigmasterol* (St), *campesterol* (Cp) *și colesterol* (Cl), *la linia celulară 1 de* Dioscorea caucasica.

celule. Dar, analizele efectuate asupra biomasei celulare recoltate din cele două linii au scos în evidență că dintre fitosteroli, doar colesterolul se găsește într-o concentrație foarte mare, sinteza celorlalți fiind chiar inhibată (fenomen remarcat și în primele experimente). În celulele cultivate într-un mediu normal (varianta martor), acest compus se acumulează doar în cantități infime. În urma mai multor observații s-a constatat că, prin introducerea soluției alcoolice de colesterol în mediul apos al suspensiilor, se formează o emulsie foarte fină care se poate constitui într-o peliculă ce îmbracă agregatele celulare. Această cantitate în exces, decelată prin analizele gaz-cromatografice ale biomasei celulare, se datorează de fapt colesterolului depus pe agregatele celulare. De asemenea, este de remarcat și faptul că la linia 1 nivelul colesterolului este mult mai mare față de linia 11. O posibilă explicație a fenomenului constă în modul diferit în care se înglobează și se metabolizează colesterolul la cele două linii. Cu cât agregatele celulare au un

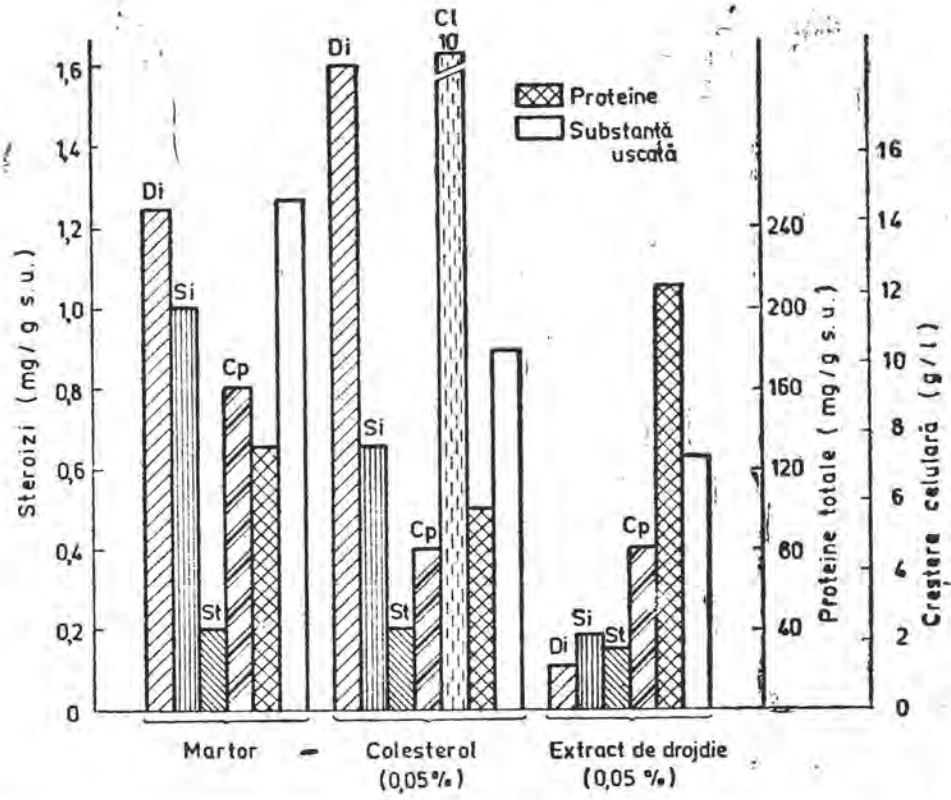

Fig. 2. *Influența colesterolului și a extractului de drojdie asupra creșterii celulare și a sintezei de proteine, diosgeninā* (Di), *sitosterol* (Si), *stigmasterol* (St), *campesterol* (Cp) *și colesterol* (Cl), *la linia celulară 11 de* Dioscorea caucasica.

diametru mai mare, cu atât scade şi numărul de celule care vin în contact direct cu nutrienţii din mediul de cultură. Astfel se poate înţelege şi inhibiţia mult mai puternică a creşterii celulare şi a sintezei de proteine constatată la linia 1, la care numărul de celule din interiorul unui agregat este de peste 500, faţă de cca 150 de celule, câte se găsesc la linia 11. De asemenea, se observă diferenţe între cele două linii şi în ceea ce priveşte acumularea de diosgenină, linia 11 etalând o creştere a nivelului acestui compus cu cca 30% faţă de numai 13% cât se observă la linia 1. Aceasta se poate datora şi faptului că celulele liniei 11 sunt capabile să absoarbă şi să metabolizeze o cantitate mai mare de colesterol, ce poate fi în continuare transformat în diosgenină.

Extractul de drojdie, care stimulează sinteza de diosgenină la suspensiile celulare de *D. deltoidea* ([7], are o influenţă inhibitoare nu numai asupra creşterii celulare, la ambele linii celulare, dar şi asupra acumulărilor de diosgenină şi sitosterol. Mai puţin afectată este sinteza stigmasterolului, iar în cazul campesterolului se constată chiar o stimulare în cazul liniei 1 (Fig. 1 şi 2). Se pare că faţă de cele două linii celulare extractul de drojdie se comportă ca un elicitor, observându-se la ambele linii celulare o creştere semnificativă a sintezei de proteine. Afirmaţia se bazează pe faptul că în majoritatea cazurilor, în urma utilizării unor preparate realizate din diferite ciuperci, culturile de suspensii celulare sintetizează o cantitate sporită de proteine. Ele sunt, după unii autori, enzime care participă la diferite reacţii de apărare ale celulei vegetale, în care este inclus şi metabolismul secundar [1, 2]. Dar, suspensiile celulare de *D. caucasica* nu acumulează nivele sporite de steroizi în urma contactului cu extractul de drojdie. Deci, după părerea noastră, este puţin probabil ca diosgenina să aibă o acţiune antifungică.

Cu toate că până în prezent nu se cunoaşte nici o implicare directă sau indirectă a serinei şi colinei în biogeneza diosgeninei ori a fitosterolilor, rezultatele experimentelor noastre atestă că un asemenea proces poate avea loc. Astfel, cei doi compuşi au stimulat puternic sinteza diosgeninei la ambele linii celulare, cantitatea acumulată de celule fiind de peste două ori mai mare decât cea constatată la suspensiile celulare martor (Fig. 3). Desigur că în acest stadiu al cercetărilor este greu de dat o explicaţie a modului şi a locului în care este implicat aminoacidul (serina) sau vitamina (colina), în calea de biogeneză a steroizilor.

Concluzii. 1. Substanţele organice ca extractul de drojdie, colesterolul, leucina, serina şi colina, folosite în scopul măririi productivităţii culturilor celulare de *Dioscorea caucasica*, au efecte diferite în funcţie de linie celulară utilizată.

2. Colesterolul (precursor al diosgeninei) inhibă puternic creşterea celulară la linia 1 (cu agregate celulare în diametru de peste 2 mm) fără a stimula sinteza de diosgenină. La linia 11 (cu agregate celulare sub 1 mm în diametru), colesterolul produce o inhibiţie mai slabă a

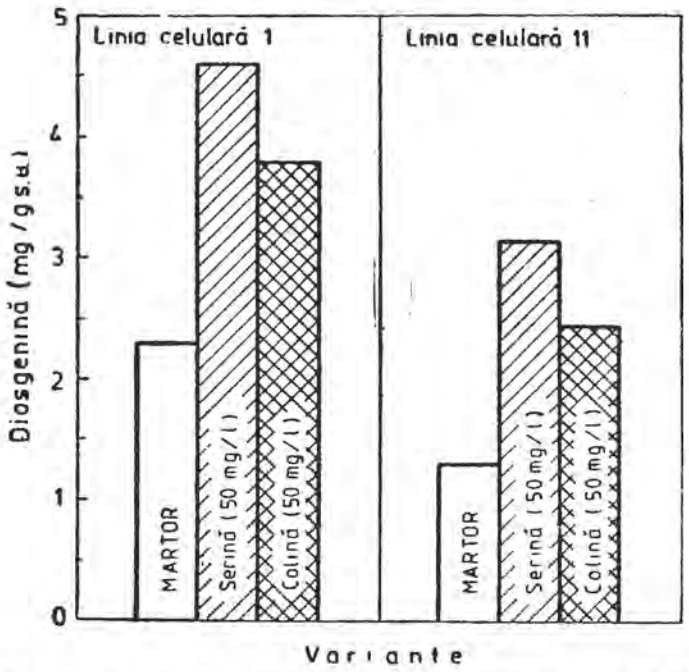

Fig. 3. *Efectul serinei și colinei asupra sintezei de diosgenină la liniile celulare 1 și 11 de* Dioscorea caucasica.

creșterii celulare, în comparație cu linia 1, și o mărire a acumulării de diosgenină cu peste 20%, față de martor.

3. Leucina stimulează acumularea fitosterolilor în aceeași proporție, la ambele linii celulare. Serina și colina au ca efect sporirea sintezei de diosgenină, fără a afecta creșterea celulară, astfel că productivitatea culturilor celulare tratate cu aceste substanțe poate să se mărească de peste două ori.

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MICROBIAL COMMUNITIES IN SOILS OF THE DANUBE DELTA BIOSPHERE RESERVE

MIHAIL DRĂGAN-BULARDA*, ŞTEFAN KISS*, DANIELA PAŞCA, ELENA MANOLACHE*, RADU CRIŞAN**, VASILE MUNTEAN** and GEORGETA MARIN*****

SUMMARY. — Using elective nutrient media, the bacteria belonging to five ecological-physiological groups (aerobic heterotrophs, ammonifiers, nitrate-, sulphate- and iron- reducers) were counted from 20 soil samples taken in the 1991—1994 period in each spring, summer and autumn. The counts of levan-synthesising and levanolytic bacteria and those of actinomycetes and aerobic mesophilic microfungi were also determined in some soil samples.

The aerobic heterotrophic bacteria were found to be always the most numerous group. They were followed by ammonifiers and nitrate- and iron-reducers. The sulphate-reducers were the least numerous group, they were even lacking in some samples

The seasonal variations of microbial counts showed spring or autumn maxima and summer minima.

The microbial counts in the deltaic soils studied could be related to their dehydrogenase activity (TTC-reducing capacity). Both microbial counts and dehydrogenase activity gave the highest values in hillock soils and the lowest ones in poorly vegetated sands.

Danube Delta has a total surface of 2 541 km^2 on the territory of Romania. In general, the Danube Delta soils can be characterised by reduced development of soil profile and weak differentiation of the genetic horizons. These soils are fragile, their physical maturity is reduced and their organic matter is easily degradable; they are affected by more or less intense salinisation and subsidence.

In the last 15 years, significant progress was achieved in the pedological study of soils in the Danube Delta Biosphere Reserve, but their microbial communities and enzymatic activities have not been studied so far. It is well known that the microbial communities and the accumulated enzymes play a key role in the biogeochemical cycles, in functioning and maintaining of soil ecosystems.

Our research was initiated with the aim to obtain data contributing to the characterisation of microbial communities in the Danube Delta soils. We have determined the counts of microorganisms belonging to different ecological-physiological groups. Dehydrogenase activity of these soils was also determined.

Materials and methods. In the springs, summers and autumns of the 1991—1994 period, samples were taken aseptically from three depths of soil plots located in different areas of the Danube Delta. The sampling places, specified in Fig. 1, were

* *Babeş-Bolyai University, 3400 Cluj-Napoca, Romania*
** *Institute of Biological Research, 3400 Cluj-Napoca, Romania*
*** *Danube Delta Research and Design Institute, 8000 Tulcea, Romania*

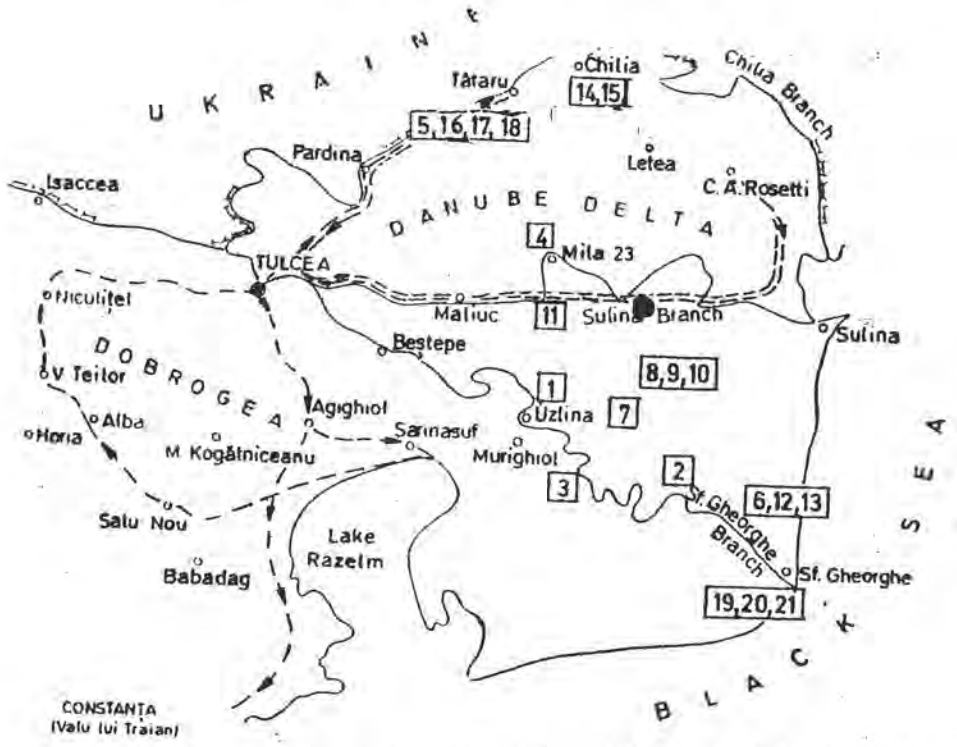

Fig. 1. *The map of the sampling places.* Figures in frames indicate soil numbers.

selected to comprise different soil types and to cover a wide range of soil texture, physical and chemical properties; besides soils under natural vegetation, cultivated soils were also included.

For microbiological and enzymological analyses, the soil samples taken from three depths were mixed in equal proportion. In each soil, most probable numbers of bacteria from 5 ecological-physiological groups (aerobic heterotrophs, ammonifiers, nitrate-, sulphate- and iron-reducers) and actual and potential dehydrogenase activities were determined. In some soils, most probable number of levan-synthesising and levanolytic bacteria as well as colony-forming units of actinomycetes and aerobic mesophilic microfungi were also assessed.

In the microbiological analyses, usual elective nutrient media were used as described in Pochon [6], Allen [1], Pârvu *et al.* [5]. Bacterial numbers and colony-forming units were reported to 1 g soil dried at 105°C for 72 hours. Dehydrogenase activity was measured according to Casida *et al.* [2]. The activity is expressed in mg triphenylformazan/g dried soil/24 hours at 37°C.

Results. Seasonal mean values of the microbial counts and dehydrogenase activities are presented in Tables 1—7.

Aerobic heterotrophic bacteria (Table 1). As expected, such bacteria were cultivable from each soil. Most of the soil samples contained tens or hundreds of millions of bacteria/g dried soil. The greatest number ($\sim 10^9$) was found in the spring sample of soil 7 (an alluvial soil) and

Table 1

Most probable number of aerobic heterotrophic bacteria in deltaic soils

Soil No.	Sampling place	Number of bacteria/g dried soil		
		Spring	Summer	Autumn
1	Uzlina	ND*	2,750,000	ND
2	Ereneiuc	ND	90,000,000	ND
3	Dunavăț	ND	50,412,465	ND
4	Păpădia	ND	32,278,088	ND
5	Plopul — soil cultivated with wheat	ND	10,582,000	ND
6	Grind — solonchak	236,374,150	24,113,475	1,805,536
7	Roşu zone	967,848,710	83,111,702	5,058,130
8	Grind Caraorman	331,625,770	10,223,555	4,343,220
9	Caraorman — interdune area	120,348.760	13,772,587	5,935,678
10	Caraorman — forest	ND	7,924,706	6,258,281
11	Govora zone	ND	47,955,241	1,269,590
12	Sf. Gheorghe — forest	8,410,000	59,150,000	6,840,000
13	Sf. Gheorghe — solonchak	16,760,000	27,970,000	115,700
14	Chilia — pasture	194,700,000	7,430,000	70,000,000
15	Chilia — soil cultivated with wheat	50,960,000	22,600,000	81,560,000
16	Plopul — soil fertilised with natural fertilisers	115,194,000	32,030,000	121,290,000
17	Plopul — unfertilised soil	80,180,600	39,800,000	85,070,000
18	Plopul — soil fertilised with mineral fertilisers	59,850,000	11,870,000	10,770,000
19	Sahalin — *Tamarix*	1,680,000	2,010,000	ND
20	Sahalin — *Scirpus*	21,400,000	ND	ND
21	Sahalin — *Typha*	39,920,000	20,670,000	ND

* ND — Not determined.

the smallest one (~100,000) in the autumn sample of soil 13 (a solonchak). It is worth mentioning that at the sampling place Plopul soil 16 (fertilised with natural fertilisers) and soil 17 (unfertilised) were richer in bacteria than was soil 18 (fertilised with mineral fertilisers). At the sampling place Sahalin, there were more bacteria in soils 20 and 21 under *Scirpus* and *Typha* vegetation, respectively, than in soil 19 under *Tamarix* vegetation. In majority of the soils, bacterial numbers had a spring maximum and an autumn minimum. Summer maxima were recorded in soils 12, 13 and 19, and autumn maxima in soils 15, 16 and 17.

Ammonifying bacteria. Table 2 shows that these bacteria were also present in each soil, but, as expected, their numbers were smaller than those of the all cultivable aerobic heterotrophic bacteria. In most soils, number of ammonifiers ranged from tens of thousands to hundreds of thousands. These bacteria were most numerous in the summer and autumn samples of soil 7 (~500,000 and ~250,000 bacteria/g dried soil, respectively) and least numerous in soils 19, 20 and 21 (194-1,120 bac-

Table 2

Most probable number of ammonifying bacteria in deltaic soils

Soil No.	Sampling place	Number of bacteria/g dried soil		
		Spring	Summer	Autumn
1	Uzlina	ND*	33,000	ND
2	Brenciuc	ND	160,000	ND
3	Dunavăţ	ND	80,201	ND
4	Păpădia	ND	34,761	ND
5	Plopul — soil cultivated with wheat	ND	21,164	ND
6	Grind — solonchak	23,131	226,950	213,989
7	Roşu zone	57,306	531,914	241,582
8	Grind Caraorman	21,569	218,102	169,491
9	Caraorman — interdune area	19,648	176,289	99,297
10	Caraorman — forest	ND	166,736	161,310
11	Gorgova zone	ND	37,298	5,730
12	Sf. Gheorghe — forest	56,800	163,198	1,683
13	Sf. Gheorghe — solonchak	178,870	165,085	1,157
14	Chilia — pasture	249,221	3,967	196,511
15	Chilia — soil cultivated with wheat	31,021	180,872	30,860
16	Plopul — soil fertilised with natural fertilisers	197,652	170,848	178,154
17	Plopul — unfertilised soil	35,925	187,353	10,634
18	Plopul — soil fertilised with mineral fertilisers	191,547	200,000	3,663
19	Sahalin — *Tamarix*	179	1,110	ND
20	Sahalin — *Scirpus*	201	ND	ND
21	Sahalin — *Typha*	289	194	ND

* ND — Not determined.

teria/g dried soil). In some soils, maximum numbers were found in spring and minimum values in autumn, whereas in other soils the maxima appeared in summer and the minima in autumn or spring.

Nitrate-reducing bacteria. One can see from Table 3 that each soil sample contained nitrate-reducing bacteria, but in smaller numbers in comparison with those of the aerobic heterotrophic bacteria. The numbers of nitrate-reducers oscillated between 30/g dried soil (autumn sample of soil 12) and ~250,000/g dried soil (autumn sample of soil 7). In most soils, the bacterial numbers were highest in spring or autumn and lowest in summer.

Sulphate-reducing bacteria (Table 4). These bacteria form the least numerous ecological-physiological group. In some soil samples, the sulphate-reducers were even lacking. Again, soil 7 was found to be the richest soil in bacteria, containing in the summer sample ~3,000 such bacteria g dried soil. The seasonal variations in the numbers of these bacteria were similar to those established for the nitrate-reducers.

Iron-reducing bacteria. It is evident from Table 5 that such bacteria were cultivable from each soil. The amplitude of variations in the

Table 3

Most probable number of nitrate-reducing bacteria in deltaic soils

Soil No.	Sampling place	Number of bacteria/g dried soil		
		Spring	Summer	Autumn
1	Uzlina	ND*	6,481	ND
2	Erenciuc	ND	146,666	ND
3	Dunavăţ	ND	210,815	ND
4	Păpădia	ND	2,607	ND
5	Plopul — soil cultivated with wheat	ND	719	ND
6	Grind — solonchak	23,131	4,680	213,989
7	Roşu zone	12,535	179,521	241,582
8	Grind Caraorman	24,265	125,408	97,457
9	Caraorman — interdune area	4,912	2,203	18,346
10	Caraorman — forest	ND	95,875	161,501
11	Gorgova — zone	ND	3,463	7,485
12	Sf. Gheorghe — forest	45,229	458	56
13	Sf. Gheorghe — solonchak	24,594	2,797	30
14	Chilia — pasture	3,738	2,603	835
15	Chilia — soil cultivated with wheat	177,265	15,826	176,347
16	Plopul — soil fertilised with natural fertilisers	113,650	28,898	38,949
17	Plopul — unfertilised soil	28,226	12,880	20,150
18	Plopul — soil fertilised with mineral fertilisers	191,547	23,375	37,715
19	Sahalin — *Tamarix*	104	929	ND
20	Sahalin — *Scirpus*	1,032	ND	ND
21	Sahalin — *Typha*	2,749	1,702	ND

* ND — Not determined.

numbers of these bacteria was very large ($\sim 10^6$ and ~ 30 bacteria/g dried soil in the summer sample of soil 2 and in the autumn sample of soil 13, respectively). Seasonally, numbers of the iron-reducers varied like those of nitrate- and sulphate-reducers.

One can deduce from Table 6 that *levan-synthesising* and *levanolytic* bacteria, studied in 5 soils, were cultivable, although in small numbers, in 5 and 3 soils, respectively. As expected, each of the 7 soils examined contained *actinomycetes* and *aerobic mesophilic microfungi*. Their colony-forming units ranged from 110,000 to 540,000, and from 10,000 to 120,000/g dried soil, respectively. These findings also indicate the biodiversity of microbial communities in the studied deltaic soils.

Dehydrogenase activity, considered as an indicator of the biological activity in soils (Skujins [7]), was exhibited by overwhelming majority of the soil samples (Table 7). Potential dehydrogenase activity (measured in glucose-amended soil samples) was always higher than actual one (assayed without adding glucose to the soil samples). Comparison of the data in Tables 1—6 with those in Table 7 reveals that,

Table 4

Most probable number of sulphate-reducing bacteria in deltaic soils

Soil No.	Sampling place	Number of bacteria/g dried soil		
		Spring	Summer	Autumn
1	Uzlina	ND*	193	ND
2	Erenciuc	ND	613	ND
3	Dunavăț	ND	389	ND
4	Păpădia	ND	148	ND
5	Plopul — soil cultivated with wheat	ND	23	ND
6	Grind — solonchak	665	1,843	294
7	Roșu zone	939	3,158	30
8	Grind Caraorman	229	24	127
9	Caraorman — interdune area	4,298	102	0
10	Caraorman — forest	ND	125	20
11	Gorgova zone	ND	279	43
12	Sf. Gheorghe — forest	0	0	0
13	Sf. Gheorghe — solonchak	22	46	1
14	Chilia — pasture	28	96	0
15	Chilia — soil cultivated with wheat	512	88	22
16	Plopul — soil fertilised with natural fertilisers	24	48	22
17	Plopul — unfertilised soil	100	0	21
18	Plopul — soil fertilised with mineral fertilisers	0	25	21
19	Sahalin — *Tamarix*	0	0	ND
20	Sahalin — *Scirpus*	151	ND	ND
21	Sahalin — *Typha*	366	0	ND

* ND — Not determined.

in general, high microbial counts were accompanied by high values of dehydrogenase activity, and inversely, the soils poor in microorganisms were, in general, weakly dehydrogenase-active. This was confirmed by calculating the correlation coefficients between bacterial numbers and dehydrogenase activity values. As shown in Table 8, of the 30 correlation coefficients calculated (5 ecological-physiological bacterial groups, 3 seasons and 2 dehydrogenase activities), 12 were positive and significant (at least at $p = 0.5$ level), 12 were positive and unsignificant, and 6 were negative and unsignificant. This means that only 40% of the correlations were significant. Other investigators (*e.g.* Skujins [7], Frankenberger and Dick [4], Engels *et al.* [3]) also found weak or unsignificant correlations between microbial counts and dehydrogenase activities in soils. Of the significant correlations found in the present study, we mention those between most probable numbers of ammonifying and sulphate-reducing bacteria and both dehydrogenase activities in the summer samples.

Table 5

Most probable number of iron-reducing bacteria in deltaic soils

Soil No.	Sampling place	Number of bacteria/g dried soil		
		Spring	Summer	Autumn
1	Uzlina	ND*	38,615	ND
2	Erenciuc	ND	1,066,666	ND
3	Dunavăţ	ND	123,739	ND
4	Păpădia	ND	5,586	ND
5	Plopul — soil cultivated with wheat	ND	235	ND
6	Grind — solonchak	4,337	2,411	1,096
7	Roşu zone	89,541	14,960	4,831
8	Grind Caraorman	8,358	125,408	1,271
9	Caraorman — interdune area	19,648	14,323	12,950
10	Caraorman — forest	ND	2,396	918
11	Gorgova zone	ND	7,193	1,162
12	Sf. Gheorgeh forest	29,541	1,019	136
13	Sf. Gheorghe — solonchak	4,136	1,450	28
14	Chilia — pasture	3,582	2,475	3,438
15	Chilia — soil cultivated with wheat	3,988	6,104	4,408
16	Plopul — soil fertilised with natural fertilisers	113,650	25,627	1,891
17	Plopul — unfertilised soil	26,943	15,222	4,589
18	Plopul — soil fertilised with mineral fertilisers	3,352	2,125	4,310
19	Sahalin — *Tamarix*	224	201	ND
20	Sahalin — *Scirpus*	4,028	ND	ND
21	Sahalin — *Typha*	1,570	2,067	ND

* ND — Not determined.

Table 6

Most probable numbers of levan-synthesising (LS) and levanolytic (LL) bacteria and colony-forming units of actinomycetes and aerobic mesophilic microfungi in deltaic soils

Soil No.	Sampling place	Microbial counts/g dried soil			
		LS bacteria	LL bacteria	Actinomycetes	Microfungi
1	Uzlina	1,103	827	168,000	86,000
2	Erenciuc	133	1,200	300,000	90,000
3	Dunavăţ	2,520	2,520	198,000	49,000
4	Păpădia	486	0	140,000	34,000
5	Plopul — soil cultivated with wheat	818	0	110,000	23,000
14	Chilia — pasture	ND*	ND	540,000	120,000
21	Sahalin — *Typha*	ND	ND	120,000	10,000

* ND — Not determined.

Table 7

Actual and potential dehydrogenase activities in deltaic soils

Soil No.	Sampling place	Dehydrogenase activity (mg triphenylformazan/g dried soil/24 hours at 37°C)					
		Actual	Potential	Actual	Potential	Actual	Potential
		Spring		Summer		Autumn	
1	Uzlina	ND*	ND	0.150	0.467	ND	ND
2	Erenciuc	ND	ND	0.963	12.288	ND	ND
3	Dunavăţ	ND	ND	0	0	ND	ND
4	Păpădia	ND	ND	0.066	1.374	ND	ND
5	Plopul — soil cultivated with wheat	ND	ND	0.135	0.551	ND	ND
6	Grind — solanchak	0.490	3.131	0.990	3.770	1.104	2.933
7	Roşu zone	5.453	22.465	2.430	13.763	0.329	1.098
8	Grind Caraorman	0.130	0.716	0.481	0.598	0.086	0.194
9	Caraorman — interdune area	0.083	0.469	0.022	0.138	0.038	0.209
10	Caraorman — forest	ND	ND	0.343	0.669	0.182	1.053
11	Gorgova zone	ND	ND	0.105	0.812	0.105	0.335
12	Sf. Gheorghe — forest	0.025	0.377	0.042	0.164	0.122	0.320
13	Sf. Gheorghe — solonchak	0.032	0.143	0.086	0.252	0	0.448
14	Chilia — pasture	0.126	0.527	0.196	0.528	0.314	0.897
15	Chilia — soil cultivated with wheat	0.202	0.766	0.114	0.682	0.424	1.118
16	Plopul — soil fertilised with natural fertilisers	0.082	0.186	0.070	0.357	0.208	0.852
17	Plopul — unfertilised soil	0.100	0.183	0.037	0.241	0.092	0.375
18	Plopul — soil fertilised with mineral fertilisers	0.054	0.130	0.109	0.400	0.085	0.344
19	Sahalin — *Tamarix*	0	0.042	0	0.113	ND	ND
20	Sahalin — *Scirpus*	0.035	1.392	0.259	0.264	ND	ND
21	Sahalin — *Typha*	0.492	1.449	0.291	0.649	ND	ND

* ND — Not determined.

Table 8

Correlations between most probable numbers of bacteria from different ecological-physiological groups and actual and potential dehydrogenase activities in deltaic soils
(number of soils analysed: 14 in spring, 21 in summer and 13 in autumn)

Ecological-physiological group	Season	Dehydrogenase activity	Correlation coefficient	Significance
Aerobic heterotrophic bacteria	Spring	Actual	0.6201	$0.02>P>0.01$
		Potential	0.9367	$0.001>P$
	Summer	Actual	0.4267	$0.10>P>0.05$
		Potential	0.4025	$0.10>P>0.05$
	Autumn	Actual	−0.0249	$0.90>P>0.80$
		Potential	−0.0403	$0.90>P>0.80$

Ammonifying bacteria	Spring	Actual	0.6464	$0.02 > P > 0.01$
		Potential	−0.1011	$0.80 > P > 0.70$
	Summer	Actual	0.7276	$0.001 > P$
		Potential	0.9708	$0.001 > P$
	Autumn	Actual	0.4595	$0.20 > P > 0.10$
		Potential	0.1061	$0.80 > P > 0.70$
Nitrate-reducing bacteria	Spring	Actual	0.0399	$0.90 > P > 0.80$
		Potential	−0.0786	$0.80 > P > 0.70$
	Summer	Actual	0.4375	$0.05 > P > 0.02$
		Potential	0.5693	$0.01 > P > 0.002$
	Autumn	Actual	0.5981	$0.05 > P > 0.02$
		Potential	0.1364	$0.70 > P > 0.60$
Sulphate-reducing bacteria	Spring	Actual	0.1140	$0.70 > P > 0.60$
		Potential	0.1194	$0.70 > P > 0.60$
	Summer	Actual	0.9119	$0.0001 > P$
		Potential	0.7893	$0.0001 > P$
	Autumn	Actual	0.7925	$0.02 > P > 0.001$
		Potential	0.1654	$0.60 > P > 0.50$
Iron-reducing bacteria	Spring	Actual	0.5388	$0.05 > P > 0.02$
		Potential	0.5129	$0.10 > P > 0.05$
	Summer	Actual	0.2609	$0.30 > P > 0.25$
		Potential	0.6125	$0.002 > P > 0.001$
	Autumn	Actual	−0.3384	$0.30 > P > 0.25$
		Potential	−0.0416	$0.90 > P > 0.80$

Conclusions. 1. Analytical data were obtained concerning biodiversity of microbial communities living in soils of the Danube Delta. Each of the 21 deltaic soils sampled in the springs, summers and autumns of the 1991—1994 period contained aerobic heterotrophic, ammonifying, nitrate- and iron-reducing bacteria; the sulphate-reducing bacteria were lacking in some samples. In a smaller number of samples analysed, the presence of levan-synthesising and levanolytic bacteria, actinomycetes and aerobic microfungi was also proved.

2. Their numbers decreased in the order: aerobic heterotrophs > ammonifiers > nitrate-reducers > iron-reducers > sulphate-reducers.

3. Seasonal variations of bacterial numbers showed, in general, spring or autumn maxima and summer minima.

4. The correlations between most probable numbers of bacteria from different ecological-physiological groups and dehydrogenase activities were, in most cases, positive and half of the positive correlations were significant at least at $p = 0.05$ level, but the significant correlations were less numerous than the insignificant ones.

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RECENZII

Friedrich Sattler, Eckard v. Wistinghausen, **Ferma biodinamică,** Traducere şi prefaţă de Petre Papacostea, Editura Enciclopedică, Bucureşti, 1994, 366 pagini cu 85 figuri şi 82 tabele în text.

Concepţia care stă la baza agriculturii biodinamice a fost foarte convingător formulată încă în 1976 de traducătorul cărţii, biolog dr. P. Papacostea, fost preşedinte al Comisiei de biologia solului a Societăţii naţionale române pentru ştiinţa solului: „În agricultură, trebuie să fie alese nu cele mai biologice dintre soluţiile economice, ci soluţiile cele mai economice dintre cele biologice". În concordanţă cu această concepţie, cartea apărută iniţial cu titlul „Der landwirtschaftliche Betrieb. Biologisch-Dynamisch" (Ulmer Verlag, Stuttgart, 1985) acordă o atenţie deosebită relaţiilor dintre sol, plante, animale şi om, şi menţinerii echilibrului ecologic în natură.

Cartea descrie bazele biologice ale agriculturii şi constituie, totodată, un manual practic al tehnicilor recomandate pentru diferitele domenii ale agriculturii.

Tematica abordată în carte este comprehensivă, după cum rezultă şi din titlurile capitolelor şi subcapitolelor: Ideea individualităţii agricole; Descrieri de gospodării; Solul, baza agriculturii; Lucrarea solului; Gospodărirea îngrăşămintelor; Mijloace ajutătoare de întreţinere; Acţiuni energetice şi ritmuri; Fitotehnia (Culturi agricole; Plante prăşitoare; Alte culturi; Alte plante furajere; Producerea de material semince de plante furajere); Zootehnia (Vacile de lapte; Mic ghid furajer; Despre lapte; Creşterea cailor; Creşterea porcilor; Oile; Creşterea caprelor; Creşterea păsărilor; Sănătate şi boală în grajdul de animale; Albinăritul; Modul de acţiune şi comportare în caz de poluare radioactivă acută); Îngrijirea peisajului (Amplasarea perdelelor de protecţie; Întreţinerea şi popularea perdelelor de protecţie; Ape şi biotopuri umede; Fâneaţă naturală şi păşune cu flori); Grădina ţărănească; Tehnica în agricultură; Economia muncii şi a gospodăriei; Bilanţuri ale substanţelor minerale (Probleme ale pieţii; Trecerea la modul de gospodărire biodinamică); Aptitudini noi.

Subliniem logica severă, claritatea şi stilul ales al descrierilor. Datorită acestor calităţi, cartea este uşor accesibilă tuturor categoriilor de cititori (agricultori, agronomi, zootehnicieni, medici veterinari, ecologi). Cartea poate servi ca o lucrare de referinţă şi pentru profesorii de biologie care predau discipline agricole.

Suntem convinşi că însuşirea şi aplicarea tehnicilor recomandate în carte vor conduce la îmbunătăţirea calităţii producţiei la fermele agricole şi, implicit, la creşterea nivelului de trai şi a calităţii vieţii celor care lucrează în agricultură.

ŞTEFAN KISS

K. Alef, **Methodenbuch Bodenmikrobiologie: Aktivitäten, Biomasse, Differenzierung** (*Methodological Handbook Soil Microbiology: Activities, Biomass, Differentiation*), Ecomed Verlagsgesellschaft, Landsberg/Lech, Germany, 1991, 284 pages including 35 figures and 7 tables in the text.

The book consists of Preface, 9 chapters, Appendix and Subject index.

In the Preface, Professor Alef emphasises the role played by microorganisms in fertility of soils, in indication of soil contamination and in decomposition of biotic and xenobiotic pollutants. This is why the application of soil microbiological methods is necessary in all environmental investigations related to soils. The book gives the detailed description of a great number of up-to-date soil microbiological and enzymological methods. Each description has the following structure: scientific basis and principle of the method, apparatus and materials, solutions and chemicals, procedure, calculation of results, discussion and references.

Chapter 1 comprises the contents of the book.

Chapter 2 is entitled „General conditions for microbiological work with soil samples". Its 6 subchapters deal with: Sampling, transport and preparation; Soil storage; Comparability of the results; Determination of water-holding capacity; Determination of soil water content and of dry matter; Determination of pH value.

Chapter 3, „Enrichment, isolation and counting of soil microorganisms", is divided into 7 subchapters: Nutrient media; Sterilisation; Preparation of agar plates; Enrichment of selected microbial groups (nitrifiers, denitrifiers, N_2-fixing bacteria — *Azotobacter*, pseudomonads, aerobic cellulose-decomposers, oligotrophic microorganisms) and obtaining of pure cultures; Enrichment of anaerobic microorganisms (anaerobic procedures, solutions of reducing agents and redox indicators, preparation of anaerobic nutrient agar media, enrichment of sulphate-reducers, cellulose-decomposing clostridia, CO_2-reducers); Counting of soil microorganisms (determination of total germ number with the agar plate method, direct microscopic counting procedures, phenol-aniline blue method, acridine orange method, fluorescein isothiocyanate method, agar-film technique); Determination of the most probable number (of ammonium-oxidising bacteria, nitrite-oxidising bacteria, denitrifying bacteria, clostridia).

In the 8 subchapters of Chapter 4, „Determination of microbial activities", methods are described for determination of: Adenosine triphosphate; Adenylate energy charge; Soil respiration; Heat output; Dimethylsulphoxide reduction; Dehydrogenase activity; Nitrogen mineralisation (incubation experiment, percolation method, arginine ammonification, nitrification); Hydrolysis of fluorescein diacetate.

Chapter 5 is devoted to „Anaerobic microbial activities in soil", comprising 4 subchapters: Working with soil samples under anaerobic conditions; Determination of anaerobic ammonification; Determination of iron (Fe^{3+}) reduction; Determination of ATP content and adenylate energy charge in anaerobic soil samples.

Within Chapter 6, „Determination of microbial biomass", the 6 subchapters have the following titles: The fumigation-incubation method; The fumigation-extraction method; The substrate-induced respiration; The respiration-simulation method; ATP content as a parameter for microbial biomass; Direct microscopic counting methods.

„Field methods" are described in the 3 subchapters of Chapter 7: Determination of soil respiration; Determination of N-mineralisation in the field; Litter bag method.

Chapter 8, „Differentiation of microbial populations", consists of two subchapters: Effect of antibiotics on soil respiration; Biomarkers — signature molecules (determination of ergosterol, muramic acid, teichoic acids, lipid A fatty acids, diaminopimelic acid, glucosamine).

In the 9 subchapters of Chapter 9, „Enzyme activities in soil", methods are described for determination of: Protease, Urease; Phosphatase (phosphomono- and phosphodiesterase); Cellulase, β-Glucosidase; Sucrase; Catalase; Arylsulphatase; Amidase activities.

The Appendix is a list specifying technical security and toxicological-labour medicinal data for 84 environmental chemicals.

Profesor Alef's valuable book convincingly reflects the recent methodological development of soil microbiology and enzymology. Application of these methods in more and more laboratories will, undoubtedly, contribute to a better understanding of soil processes, including microbial decontamination of polluted soils.

ŞTEFAN KISS

H.-P. Blume (Herausgeber — Editor). **Handbuch des Bodenschutzes. Bodenökologie und -belastung. Vorbeugende und abwehrende Schutzmassnahmen,** 2. Auflage (*Handbook of Soil Protection. Soil Ecology and Loading, Preventing and Defending Protection Measures,* Second Edition), Ecomed Verlagsgesellschaft, Landsberg/Lech, Germany, 1992, XXIII + 794 pages with 284 figures and 280 tables in the text.

The handbook was elaborated by 24 German scientists under the editorship of Professor Dr. H.-P. Blume (Institute for Plant Nutrition and Soil Science, Christian-Albrechts-Universität, Kiel). This work may be considered an encyclopedia of soil protection in Ger-

many, but general problems of soil protection all over the world are also referred to.

The handbook consists of Foreword, List of authors, Overview and List of contents (pp. V—XXII), Introduction (pp. 1—2), 5 chapters with many subchapters and sections (pp. 5—726), 16 colour plates (pp. 727—757), Lists of abbreviations and units of measure, and Subject index (pp. 759—794). The literature cited is listed in subchapters or sections.

Chapter 1, „Properties and functions of soils" (pp. 5—128), is formed of 10 subchapters dealing with the following topics: Soils as natural bodies; Soil and landscape water regime; Soils as segments of landscape; Soils as life space of organisms; Soils as habitats of plants; Soils as filters, buffers and transformers; Modelling of the behaviour of chemicals in soil and groundwater; Soils as records of earth and landscape history; Soils as suppliers of raw materials; Soils as places for settlement and traffic.

The 9 subchapters of Chapter 2, „Changes and loadings of soils" (pp. 129—494), are entitled: Introduction; Soil transformation and sealing; Cultivation and compaction of soils; Loss of soils; Drainage and irrigation of soils; Fertilisation of soils; Contamination of soils; Deposition of wastes; Anthropogenic soils.

Chapter 3 is dedicated to „Soil inventory as basis of soil protection" (pp. 495—516), comprising 4 subchapters: Introduction; Soil information systems; Technique of soil inventory; Predicting possibilities from soil maps.

Chapter 4 gives a detailed description of the measures for „Protection of soils" (pp. 617—652), in 9 subchapters: Introduction; Legal possibilities of the soil protection; Plannings relevant to soil protection; Plannings relevant to soil protecton in urban-industrial areas; Protection against sealing; Protection against compaction and negative cultivation consequences; Protection against loss and overflow and their consequences; Protection against material loadings and their consequences; Protection through education.

Chapter 5, entitled „Remediation, securing and renaturation of soils" (pp. 653—726), contains 7 subchapters: Introduction; Soil remediation — necessity, possibilities and limits of the law-normative regulations; De-sealing of sealed soils; Cultivation of filled soils; Renaturation of moors and other wetlands; Remediation of compacted soils; Remediation and securing of contaminated soils and substrata.

The handbook, in which the practical aspects of soil protection are especially emphasised, is a useful source of information not only for soil technologists, but also for all experts performing fundamental and/or applied studies on soils.

ȘTEFAN KISS

Antarctic Microbiology, Edited by E. Imre Friedmann, Wiley—Liss, Inc., New York, 1993, X + 634 pages including 210 figures and 43 tables.

The book consists of List and addresses of contributors, Foreword, 16 articles, and Subject index.

The Editor is distinguished professor and director of the Polar Desert Research Center (Department of Biological Science, Florida State University, Tallahassee, Florida). He is well known by microbiologists all over the world for his discovery of endolithic life (*i.e.* life under the surface of rocks) in desert regions.

Most of the 29 contributors are from the USA, but scientists from Australia, Canada, Germany, New Zeland, and Russia also contributed to the book.

In the Foreword, Professor Friedmann poses the question: „Why Antarctic microbiology? Why not African, Australian, or European microbiology?", and gives the answer: „the biology of Antarctica, more than that of any other continent, is dominated by microorganisms. On the continent itself, plants (except microalgae) are scarce. Higher plants are represented by only two species, *Colobanthus crassifolius* (d'Urv.) Hook. f. and *Deschampsia antarctica* Desv., both restricted to the Antarctic Peninsula. Mosses are relatively minor primary producers compared to microalgae and cyanobacteria. Even in the ocean, macroalgae are less significant than in other coastal waters, and the food chain of the rich marine life is based almost entirely on microalgae and

cyanobacteria. The nearly total absence of macroscopic terrestrial animal life further contributes to the unique character of the biology of the Antarctic continent. The role of plant cover on land is taken over by lichens, which grow on the surfaces of rocks and soil in the maritime Antarctic and are hidden under the surface of rocks in the more extreme desert regions".

Of the 16 articles of the book, six deal with marine environments. Their titles and authors are the following: Microbial processes in the southern oceans (D. M. Karl); Phytoplankton (S. Z. El-Sayed and G. A. Fryxell); Protozooplankton (D. L. Garrison and M. M. Gowing); Microorganisms in the Antarctic sea ice (A. C. Palmisano and D. L. Garrison); Nearshore benthic marine sediments (D. C. White, G. A. Smith, J. B. Guckert, and P. D. Nichols); Degradation of particulate organic material in the Antarctic (J. T. Staley and R. P. Herwig).

Seven articles cover topics on terrestrial and freshwater environments: Microorganisms in the Antarctic ice (S. S. Abyzov); The microbiology of Antarctic soils (H. S. Vishniac); Terrestrial lithophytic (rock) communities (J. A. Nienow and E. I. Friedmann); Soils heated by volcanism (P. A. Broady); Lichens in the Antarctic region (L. Kappen); Environmental regulators of microbial activity in continental Antarctic lakes (G. M. Simmons, Jr., J. R. Vestal, and R. A. Wharton, Jr.); Microbial communities and processes in Antarctic flowing waters (W. F. Vincent, C. Howard-Williams, and P. A. Broady).

Three articles deal with other topics: Human infectious diseases (H. G. Muchmore, E. N. Scott, and A. J. Parkinson); Relevance of Antarctic microbial ecosystems to exobiology (C. P. McKay); Protection of Antarctic microbial habitats (S. Draggan).

The book, which comprehensively demonstrates that the microbial communities play significant roles in the ecosystems of the Antarctic continent, is of much interest not only for polar scientists, but also for researchers working in various fields of environmental microbiology.

The publication of „Antarctic Microbiology" is a significant event which will have an impact on modern microbial ecological research.

ŞTEFAN KISS

Guminovye veshchestva v biosfere (*Humic Substances in the Biosphere*), Otvetstvennyi redaktor (Editor): D. S. Orlov, Nauka, Moskva, 1993, 238 pages including 78 tables and 53 figures.

The book is a collection of 29 papers. In the first paper, A. I. Gorovaya and I. I. Yarchuk pay tribute to the late Professor L. A. Khristeva, whose studies on the physiological activity of humic substances remain of fundamental importance.

The other papers are grouped into four sections.

Section 1, „Functions and Structure of Humic Substances", comprises 10 papers dealing with the following topics: Properties and functions of humic substances (D. S. Orlov); Molecular structure of humic acids (T. A. Kukharenko); Molecular structure and reactive capability of humic acids (I. D. Komissarov and L. F. Loginov); Effect of oxidation on the physicochemical properties of humic acids of peat (N. A. Zhmakova *et al.*); Structure of the peat humic acids (N. A. Zhmakova *et al.*); Humic substances in the brown coals from Khandin (Irkutsk region) (T. V. Pokul' *et al.*); Humic substances in marine bottom deposits (E. M. Zaslavskii); Humic acids in recent sediments of the Black Sea (K. Markova *et al.*); Microscopic characterisation of humic acids from Black Sea sediments (S. Vulcheva and K. Markova); Humic acids of peloids (Z. F. Kos'yanova *et al.*).

Section 2, „Humic Substances in the Biosphere", consists of 6 papers having the following titles: Phenolic compounds and humus formation in the plant-soil system (V. I. Kefeli); Humification in the system of molecular mechanisms of biological cycle stagnation in ecosystems (I. E. Leifman); Geochemical role of humic acids in the migration of elements (G. M. Varshal *et al.*); Functional role of complex compounds in the genesis of soils and nutrition of plants (A. I. Karpukhin); Humic preparations and environmental protection (I. L. Lishtvan and A. M.

Abramets); Binding of humic acids to clay minerals (V. M. Dudarchik).

Section 3, „Practical Utilisation of Humic Preparations", also consists of 6 papers: Role of physiologically active humic substances in adaptation of plants to the effect of ionising radiations and pesticides (A. I. Gorovaya); Mechanism of the effect of peat humic preparations on the structural state of membranes and functional activity of yeast cells (V. M. Mazhul' *et al.*); Possibilities for utilisation of oxidised coals and humic substances in the agriculture (N. N. Ulanov); Plant growth stimulants from brown coals (V. V. Rode *et al.*); Utilisation of humic preparations in obtaining mineral fertilisers (G. V. Pirogovskaya); Humic substances of brown coals for reclamation of saline soils (I. V. Aleksandrov *et al.*).

Section 4, „Technological Processes and Properties of Humic Preparations", is also formed of 6 papers: Humic preparations and technological procedures of their obtaining (G. V. Naumova *et al.*); Humic preparations from the high-ash brown coals of the Moscow Basin (D. S. Orlov *et al.*); Comparative characterisation of the humic preparations produced under experimental-industrial conditions (D. S. Orlov *et al.*); Obtaining and applying of humic preparations (D. D. Ruschev *et al.*); Extraction from soil of the humic acids possessing oxidase activity (A. E. Gul'ko); Relative resistance of humic substances as evaluated by electronic and molecular spectra (D. S. Orlov and N. N. Osipova).

The investigations described in the book cover a wide range of fundamental and applied aspects of humus research. The results obtained are valuable contributions to the development of humus science and will, undoubtedly, stimulate further research.

ŞTEFAN KISS

I. K. Khabirov, **Ekologiya i biokhimiya azota v pochvakh Priural'ya** (*Ecology and Biochemistry of Nitrogen in Soils of the Ural Area*), Ufimskii Nauchnyi Tsentr RAN, Institut Biologii, Akademiya Nauk Respubliki Bashkortostan, Ufa, 1993, 224 pages with 76 tables and 24 figures in the text.

Dr. I. K. Khabirov is a member of the soil-biochemical research group of the Biological Institute in Ufa, Bashkiria, Russian Federation. This research group, headed by Professor F. Kh. Khaziev, is well known to soil enzymologists all over the world. The high level of research performed by this group is reflected in a series of books elaborated by F. Kh. Khaziev (Pochvennye fermenty — Soil Enzymes, Moscow, 1972; Fermentativnaya aktivnost' pochv. Metodicheskoe posobie — Enzymatic Activity of Soils. Methodological Textbook, Moscow, 1976; Sistemno-ekologicheskii analiz fermentativnoi aktivnosti pochv — Systemic-Ecological Analysis of the Enzymatic Activity of Soils, Moscow, 1982; Metody pochvennoi enzimologii — Methods of Soil Enzymology, Moscow, 1990), F. Kh. Khaziev and N. S. Naumov (Pochvennyi azot i effektivnost' azotnykh udobrenii — Soil Nitrogen and Efficiency of the Nitrogen Fertilisers, Ufa, 1979), and F. Kh. Khaziev and F. Ya. Bagautdinov (Uglevodnye komponenty organicheskogo veshchestva pochvy — Carbohydrate Components of the Soil Organic Matter. Ufa, 1987).

Dr. I. K. Khabirov's book is also a valuable one. It consists of Preface, 4 chapters, Conclusions and a bibliographical list comprising 460 titles.

As mentioned in the Preface, the book reviews the published and unpublished results of the investigations that the author and his co-workers have carried out on soils in the southern Ural area, on the territory of the Bashkirian Republic, in the 1973—1989 period. The soil samples were submitted to general physical, chemical and agrochemical analyses as well as to other determinations (urease and protease activities; microbial counts; composition of hydrolysable nitrogen compounds;

forms of organic nitrogen compounds; free amino acids; accumulation of amino acids and proteins on cellulosic sheets buried into the soil; cellulose-decomposing capacity; carbohydrate content; O_2 uptake and CO_2 evolution).

Chapter I, entitled „Content, composition and biochemical transformation of nitrogen", includes three subchapters: Humus and nitrogen contents and their reserves; Composition, distribution and forms of nitrogen compounds; Role of enzymes in transformation of nitrogen.

Chapter II („Ecological analysis of the status of soil nitrogen reserve") deals with 4 topics: Physico-geographical factors in the formation of soil nitrogen reserve; Ecological conditions and biodynamics of nitrogen; Nitrogen in natural and anthropogenic ecosystems; Accumulation and migration of nitrogen.

Chapter III, „Kinetics and thermodynamics of the biochemical processes of nitrogen transformation in soils", comprises three subchapters: Kinetics and temperature dependence of nitrification processes and of mineralisation of organic nitrogen compounds; Kinetics and thermodynamics of the enzymatic reaction of urea hydrolysis; Nitrogen-mineralising capacity of soils.

The subchapters of Chapter IV („Regulation of the nitrogen regime of soils") have the following titles: Tillage system; Fertilisation system; Liming of the gray forest soils; Inhibitors of nitrification.

The book brings contributions to a better understanding of the ecology and biochemistry of soil nitrogen. At the same time, it has practical importance, too, especially for increasing efficiency of nitrogen fertilisers and for avoiding their environment-polluting effect.

ȘTEFAN KISS

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