ACTA SOCIETATIS
BOTANICORUM POLONIAE
Vol. XLII — nr 2
1973

The radioecology of *Pogonatum urnigerum* (L.) Pal. Beauv.

J. SAROSIEK, W. KOŁA and A. ORDA

Department of Plant Ecology, Institute of Botany Wrocław University

(Received: December 11, 1972)

Abstract

Within the area of the radiation anomaly near Kowary (Sudetes), the moss *Pogonatum urnigerum* grows on sites with natural gamma radiation of the soil within the limits of 0.05 to 0.91 mR/h. By way of detailed ecological analysis, five stenotopic habitats of *P. urnigerum* were singled out, differing, however, in radiation level. On these microhabitats the intrapopulation variability, radioactivity and ecological properties of the *P. urnigerum* populations were investigated. It was demonstrated that radiation within the above mentioned range is an essential ecological factor conditioning the ecotype differences in *Pogonatum urnigerum,* and among them the developmental anomalies.

INTRODUCTION

Bryophyta forming ecological populations are distinguished from other plants by their high natural radioactivity (Grodziński 1965). Radioecological investigations to date demonstrated that some species of *Bryophyta* reflect the radioactivity of the environment in the structure and function of their populations (McCormick 1963; Sarosiek 1972). They may, therefore, be utilised for bioindication of radioactively contaminated areas in the environment and in ecological expert evidence (Maslov et al. 1970). The necessity of more intensive radioecological investigations on plants occurring in natural conditions of elevated chronic radiation is mentioned by Aleksakhin (1968).

The object of the present studies was *Pogonatum urnigerum,* ecological populations of which show an environmental variability in habitats with a relatively high natural chronic radiation in the area of certain radiation anomalies. The purpose of the study was to establish: 1) within what range of natural radiation *Pogonatum urnigerum* occurs in the radiation anomaly area near Kowary (Sudetes); 2) whether there is some relation between the variability of essential morphological characters in this species and the variability of properties of its natural populations with the radiation level of the substrate and 3) what is the influence of chronic low-level radiation on the development of this species in natural conditions.

METHODS

In the anomalous area four sites were chosen with *Pogonatum urnigerum* and one beyond the anomaly in its immediate vicinity. The choice of these five sites, stenotopic as regards edaphic and microclimatic conditions, was made on the basis of a detailed analysis of 12 microhabitats, by elimination for further studies of extreme sites. The sites chosen differed as regards the substrate radiation level.

Gamma radiation of the soil surface on the sites with *P. urnigerum* was measured in the vegetation period of 1971 (May 8, July 10 and Oct. 17) in a universal type UR-4M radiometer with SST-8 scaler with range from 0.005 to 10 mR/h.

Analysis of the chemical properties of the soil characteristic for the given site was performed by the routine method used in soil and ecological studies (Kowaliński et al., 1959; Koter, 1954; Peterburgski, 1947; Maksimov, 1954). In order to reveal the intrapopulational variability of *P. urnigerum* plants on sites with various radiation levels, 12 morphological traits of this species were biometrically analysed (see Table 3). The density of all the investigated populations was also analysed, as, according to Odum (1963), their most prominent characteristic. In view of the large number of *P. urnigerum* individuals in the ecological populations falling to 1 cm^2, samples were collected from a 36 cm^2 surface area. Each of the populations from the selected sites was represented in the analysis by three random samples in which all plants were counted.

The results of biometric measurements were elaborated by mathematical-statistical methods. The method of parallel analyses with one result (Barbacki, 1951) was applied. Some of the traits analysed expressed as per cent were converted to beta angles, according to the Bliss formula (beta = arc sin p) given by Elandt (1957).

The analysed traits of *P. urnigerum* were supplemented by observations on the sex distribution in the particular populations.

The total beta-radioactivity of the plants was measured by the scintillation method in the Isotope Laboratory (IUNG), Laskowice Oławskie.

RESULTS

Characteristic of sites

Bryophyte synusiae with the participation of *P. urnigerum* occupy on the investigated area open sites. They grow on brown acidic mountain soil, on granite outcrops with pegmatite veins. The chosen microhabitats lying at a close distance from one another have the same microclimate. The chemical properties of the soil are given in Table 1. These sandy clayey soils are rich in nitrogen and potassium, and have a moderate phosphorus and manganese content, but are poor in calcium. As regards essential nutrient components *P. urnigerum* has on these sites optimal conditions for development. According to Sarosiek (1972) these soils are characterised by an increased uranium content (from 7×10^{-3} to 71×10^{-3} per cent uranium in soil). On the sites within the anomalous area, radiation of the substrate higher than background is associated with the primary halo of uranium dispersion extending above the uraniferous pegmatite vein in granites (Adamski, 1960).

Gamma radiation of the soil surface on the microhabitats investigated is shown in Table 2 (sites arranged in the order of increasing radiation). The moss *P. urnigerum* on the sites within the radiation anomaly occurs

Table 1

Chemical properties of soil from the microhabitats of *Pogonatum urnigerum*

No.	Properties	Range of values from 12 microhabitats in Kowary	Range of values from 5 selected microhabitats
1	Organic substance contents (%)	19.90—27.52	23.47—25.08
2	pH	4.3	4.3
3	Hydrolytic acidity	3.25—14.5	7.1 — 8.3
4	Total exchangeable acidity	9.07—12.8	10.55—11.8
5	Sum of exchangeable cations	5.62—18.4	12.8—15.5
6	Nitrogen contents (%)	0.27— 0.39	0.33— 0.37
7	P_2O_5 mg/100g	3.11— 6.94	3.90— 4.52
8	K_2O mg/100g	14.7 —30.3	24.8 —26.5
9	Ca mg/100g	16.4 —23.4	19.7 —21.1
10	Mg mg/100g	15.7 —20.7	15.7 —20.6
11	Mn mg/kg	29.80—82.57	36.28—43.9

Table 2

Radioactivity levels (mR/h) of soil surface in microhabitats of *Pogonatum urnigerum*

Microhabitats	Spring	Summer	Autumn
1	0.06—0.16	0.05—0.11	0.06—0.15
2	0.34—0.42	0.26—0.39	0.30—0.40
3	0.55—0.64	0.50—0.58	0.52—0.61
4	0.76—0.91	0.72—0.85	0.72—0.88

within the range of natural chronic low-level radiation 0.05—0.91 mR/h. At higher radiation levels within the anomalous area the moss is not found.

The ecological populations of *P. urnigerum* are accompanied on the particular sites by the following bryophyte species: on I: *Bryum caespiticium* L., *Cephalocia bicuspidata* Dum., *Dicranella* sp. Schimp., *Dicranum* sp., *Lophocolea bidentata* (L.) Dum., *Mniobryum albicans* (Wahlb.) Limpr., *Mnium punctatum* Hedw., *Plagiochilla maior* (L.) Dum., and *Rhytidiadelphus squarrosus* (Hedw.) Warnst., on II: *Bryum caespiticium* L., *Campothecium sericum* Kindb., *Lophocolea bidentata* (L.) Dum., *Mnium cuspidatum* (L., Schreb.), *Mnium pseudopunctatum* Br. et Schimp., *Mnium punctatum* Hedw., *Plagiochilla mair* (L.) Dum., *Rhacomitrium* sp. Brid. and *Rhytidiadelphus squarrosus* (Hedw.) Warnst.; on III: *Lophocolea bidentata* (L.) Dum., *Lophocolea heterophylla* (Schrad.) Dum., *Mnium cuspidatum* (L., Schreb.), *Mnium pseudopunctatum* Br. et Schimp., *Mnium punctatum* Hedw. and *Rhytidiadelphus squarrosus* (Hedw.) Warnst.; on IV: *Lophocolea bidentata* (L.) Dum., *Mniobryum albicans* (Wahlb.) Limpr., *Plagiochilla maior* (L.) Dum. and *Rhitidiadelphus squarrosus* (Hedw.) Warnst.; and on V the components of the synusiae are the same species with the exception of *Mniobryum albicans* (Wahlb.) Limpr. and *Rhacomitrium* sp. Brid. The bryophyte synusiae from the sites with elevated radiation comprise less species.

Analysis of ecological populations of *Pogonatum urnigerum*

Mathematical-statistical analysis demonstrated significant differences between the *P. urnigerum* plants in respect to morphological traits and their natural populations as far as density on sites with various levels of natural chronic low-level soil radiation is concerned (Table 3).

As regards the percentual contribution of branched plants (trait 1), the populations from within the anomalous area differ significantly from those from outside, thus, from nonradiating natural territory (population V). This population is characterised by only 1 per cent of nonbranched plants. The populations from the anomalous area (I—IV) also differ in respect to this trait from one another. They are characterised by a high per cent of branched plants (mean 22.7), the higher the more intensive is the radiation on the site. As regards the percentage of dichotomously branched plants (trait 2), the populations differ significantly from one another as in the case of trait 1. Populations I and II, and III and IV, respectively, are close in this respect (Photo 1). Plants from the population beyond the anomalous area exhibit only branchings of the type of dichotomy. Populations from the anomalous radiation area differ significantly from one another as regards the percentual contribu-

Table 3

Mean values of morphological and populational characters of *Pogonatum urnigerum*

Populations	Plants with branches, %	Plants with dichotomous branches, %	Plants with undichotomous branches, %	Height of plants, cm	Number of branches	Number of I order branches	Number of II order branches	Number of III order branches	Total length of branches, cm	Lentgh of I order branches, cm	Length of II order branches, cm	Length of III order branches, cm	Population density
	1	2	3	4	5	6	7	8	9	10	11	12	13
I	13.1	10.5	2.5	3.8	53.3	95.9	4.06	0.0	32.3	30.06	0.81	0.0	15.7
II	19.6	13.6	5.9	4.8	40.0	88.2	11.40	0.25	88.1	77.4	10.40	0.2	27.5
III	34.0	20.1	15.8	6.2	89.3	82.6	17.2	0.16	218.2	180.9	22.45	0.25	27.1
IV	36.2	25.3	8.6	7.03	135.6	68.7	28.7	2.33	181.24	273.28	83.80	5.71	49.4
V	1.0	1.0	0.0	3.93	4.39	100.0	0.0	0.0	10.3	10.3	0.0	0.0	51.3
Dt	1.7	1.3	0.58	1.1	32.27	4.1	3.8	0.2	81.6	59.4	30.12	3.2	1.4
F emp.	9.17	7.14	11.9	5.9	1.6	3.9	3.9	6.5	3.9	11.1	15.6	1.8	6.7
F tab.	3.48	3.48	3.48	3.48	3.48	3.48	3.48	3.48	3.48	3.48	3.48	3.48	3.48

tion of nondichotomously branched plants (trait 3). In this trait population I and II, and II and IV are similar (Photo 2). *P. urnigerum* plants from sites with elevated radiation differ significantly from the nonirradiated natural population and from one another in height (trait 4). The plants are the higher the more intensive is the radiation on the site. As regards the total number of gametophyte branches (trait 5), wide differences were found between the populations from the anomalous area, and the population from outside it. Populations I and II do not differ significantly in this respect, on the other hand, populations III and IV have a particularly large number of branches (Photo 3). In the plants of the natural nonirradiated population there only occur I order branches (trait 6). Population I shows 95.9 per cent of I order branches and 4.06 per cent of II order one (trait 7) and no III order branches (trait 8). With increasing radiation in the microhabitat, the per cent of II and III order branches increases. As regards these traits, the populations from the area of anomalous radiation differ significantly from one another. In the total length of branches (trait 9) populations I and II do not differ, but differ from the remaining populations. The length of branches of I, II and III order (traits 10, 11, 12) increases with increasing radiation of the microhabitat. As regards length of I order branches, the populations did not differ, but they do as far as the length of branches of the II and III order is concerned. The length of branches of the II and III order is by far the longest in population IV from the microhabitat with highest radiation.

The highest density (trait 13, Table 3) is characteristic for population V from beyond the anomalous area. Population IV from the microhabitat with highest radiation shows a density similar to population V. Populations II and III do not differ significantly in density from each other. The lowest density was noted in population I from the microhabitat with weakest radiation.

It was found that on the sites with higher radiation, within the limits of 0.05 to 0.91 mR/h, only female individuals of *P. urnigerum grow*, whereas male ones appear in lower radiation ranges between 0.05 and 0.64 mR/h. It should be stressed that in some dozen or so bryophyte synusiae from the anomalous area, the highest frequency of sporulating, that is producing sporogonia, plants was noted on sites with a radiation range of 0.50 to 0.64 mR/h. On sites with a radiation range exceeding 0.64 mR/h, sporulating plants of the species studied appeared only sporadically. On sites outsides the anomalous radiation area, but similar as regards edaphic and microclimatic conditions, the sporulating plants frequency in natural *P. urnigerum* populations was around 40 per cent. Population III from the site with a relatively high radiation had as much as 82 per cent of sporulating plants. In the ecological populations on sites without elevated radiation the ratio of male to female individuals

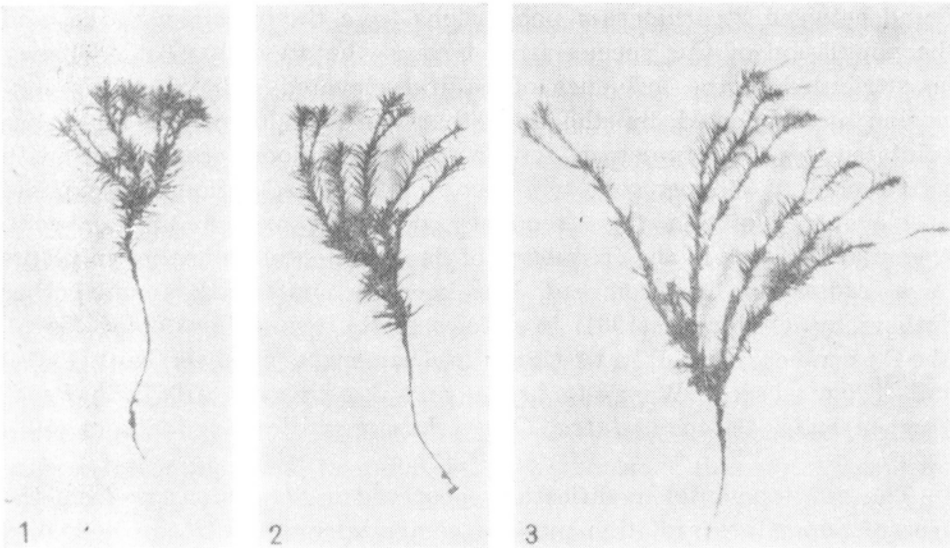

Photo. 1. Dichotomic branchings of *Pogonatum urnigerum*
Photo. 2. Nondichotomic branchings of *Pogonatum urnigerum*
Photo. 3. Profuse branching of *Pogonatum urnigerum* (population IV)

was on the average 2 : 3, whereas the same ratio on sites with continuous low-level gamma radiation was 3 : 7.

Plants from populations on sites with elevated radiation differ significantly from one another and from the plants of populations from sites without elevated radiation in total beta radioactivity, namely the mean total beta activity of plants from the anomalous area was 1060.2 pc/g ash, while the analogical value for plants from beyond this area (population V) was only 68.0 pc/g. The more intensive the radiation of the microhabitat the higher is the total beta-radioactivity of the plants: population I has a total beta activity of 246.4, population II 384.8, population III 398.8 and population IV from the site with highest radiation 2311.0 pc/g ash.

DISCUSSION

According to the data of Szafran (1957) concerning the occurrence of *P. urnigerum* on a wide ecological scale, and on the basis of the soil investigations performed (Table 1), the selected microhabitats of this species can be considered as stenotopic. In natural conditions, chronic low-level gamma radiation within the range 0.05 to 0.91 mR/h, at which *P. urnigerum* grows in the environs of Kowary (Table 2), is an essential ecological factor, in agreement with the opinions of McCormick (1963), McCormick and Cotterem (1964) and Sarosiek and Wożakowska-Natkaniec (1967, 1968). The significant differences found between *P. urnigerum* populations from the anomalous area, and the population of this species from beyond the anomaly (Table 3) may be attributed to the influence of natural elevated radiation. This conclusion is supported by the fact that the developmental anomalies exhibited by *P. urnigerum* within the anomalous area occur with a frequency of 36.2 per cent, whereas in natural populations not exposed to elevated radiation this frequency does not exceed 1.5 per cent. A similar increase in the frequency of developmental anomalies in plants in a radioactive environment has been demonstrated among other authors by Osburn (1961) in species of the genus *Penstemon* (56%), McCormick and Platt (1963) in *Diamorpha cymossa* Nutt. (30%) and Kowalski, Worotniska and Lekarev (1967) in *Peganum harmala, Caragana lutea, Orostachys thyrsiflora* and others (10—20%).

The developmental modifications observed in *P. urnigerum* from the area of anomalous radiation may be compared to the already described modifications of plants caused by chronic low-level radiation gamma or X under experimental conditions. A typical reaction of plants to radiation is a limitation of growth (Gunckel, 1965; Gunckel and Sparrow, 1961). *P. urnigerum*, however, shows enhanced growth with the increase of gamma radiation in natural conditions. Thus, chronic radiation within the range of 0.05 to 0.91 mR/h stimulates growth of *P. urnigerum*. The phenomenon of plant growth stimulation by experimental exposure to chronic radiation in small doses was reported by Schneck (Gunckel, 1965) in *Antirrhinum maius* and by Sarosiek and Wożakowska-Natkaniec (1967, 1968) in *Marchantia polymorpha* (also in natural conditions).

P. urnigerum in conditions of elevated radiation forms branchings of the gametophyte of various type, which are not specific to this species (Photos 1 and 2, Table 3). These anomalous branchings of the gametophyte give plant branched forms in a smaller or greater extent. Branching is also one of the plant modifications produced by radiation. Under the conditions of a natural radiation anomaly Woodwell and Oosting (1965) described various degrees of branching in *Erigeron canadensis* depending on the radiation level. Gametophyte branching in *P. urnigerum* is associated with a limitation of apical dominance. In the case of development of a whorl of numerous branches at the apex of the gametophyte, the main axis of the gametophyte is lowered. This is probably due to the inactivation of growth regulators (Skoog, 1935). It is possible that in this case the apical meristems are destroyed under the influence of chronic low-level radiation (Gunckel, 1965).

Anomalous branchings of the type of dichotomy are, according to Gunckel (1965), a typical reaction to radiation, although in seed plants they appear but seldom.

In *P. urnigerum* this anomaly appeared with a high frequency — the higher the more intensive was the radiation. The frequency of dichotomically branched plants of *P. urnigerum* under radioactive environment conditions greatly exceeds the frequency of plants anomalously, sympodially branched. Dichotomy of freesia shoots was induced by low radiation doses from ^{60}Co (Kukułczanka and Sarosiek, 1970).

It has been demonstrated that with the increase of radiation, the density of the *P. urnigerum* population decreases. In each case of radioactivity we deal with a populational effect resulting from the various resistance of the particular individuals in a population to radiation as a limiting factor (Grodziński and Wiktorowa, 1970). It is possible that low-level radiation in the range of 0.05 to 0.91 mR/h eliminates in natural conditions from the *P. urnigerum* population plants with a lower tolerance to radiation. If we consider that with increasing radiation the proportion of anomalously branched plants markedly increases and that these plants require more space, the lower density of the examined populations depending on the radiation level may be explained by a more stringent intraspecific competition.

The contribution of bryophyte species accompanying *P. urnigerum* in the synusiae decreases with increasing radiation. It may be concluded there from that radiation is also in this case a factor discriminating bryophyte species with a lower tolerance. The phenomenon of discrimination of bryophyte species in synusiae from natural anomalous radiation areas has been described by McCormick (1963) and Sarosiek and Wożakowska-Natkaniec (1967).

Within the radiation anomaly the larger proportion of female than of male individuals in the population of *P. urnigerum* which is a dioecious species, and the occurrence in the populations on sites with higher radiation of only female individuals may be explained by their greater tolerance to radiation.

The total beta radioactivity of *P. urnigerum* ash reflects the radioactivity of the substrate. The higher the gamma radiation level of the site the more intensive is the beta-activity of the plants. *P. urnigerum* like *Hylocomium splendens* and *Hypnum cupressiforme* (Grodziński, 1965) fulfils the criteria for indicator species of natural radiation. It may, therefore, be used in bioindication of contamination of the environment.

CONCLUSIONS

1. Within the radiation anomaly area near Kowary, *Pogonatum urnigerum* forms natural populations within the range of chronic radiation from 0.05 to 0.91 mR/. Higher radiation discriminates *P. urnigerum* and some accompanying bryophyte species in the synusiae.

2. Chronic low-level gamma radiation (0.05—0.91 mR/h) significantly affects the development of *P. urnigerum* plants and the dynamics of their ecological populations. It stimulates growth, changes the habitus by inducing branching, limits apical dominance of the main gametophyte and reduces the population density.

3. The developmental anomalies in *P. urnigerum* (modifications of branchings) appear in the elevated radiation area with a high frequency (13.0—36.2%), the greater the higher the radiation level. Anomalous branchings of the gametophyte of dichotomic type are more frequent (1.5—25.3%) than anomalous branchings of the type of sympodium dichasium (2.5—15.8%).

4. Male individuals of *P. urnigerum* within the anomalous area occur only within the gamma radiation range of 0.5—0.64 mR/h, whereas female individuals are found at higher radiation levels reaching, to 0.91 mR/h.

Radiation within this range changes the sex ratio proper to this species in natural populations; the ratio of male to female individuals changes from 2 : 3 to 3 : 7.

5. *P. urnigerum* from the anomalous area is characterised by a high total beta-radioactivity, the more intensive the higher is the radiation level of the substrate. Its mean value is 1060.2 pc/g ash. The high total beta activity of *P. urnigerum* and the observed developmental anomalies in this species due to various levels of gamma radiation of the substrate indicate that this plant may be utilised as a bioindicator of radioactive contamination of the environment.

REFERENCES

Adamski Wł., 1969, Genetyczno-strukturalne typy złóż uranowych w Polsce, Ref. Pol.-Jugosł. Symp. w zakresie geologii i metodyki poszukiwań złóż uranowych, Kowary-Belgrad. 1: 1—9.

Aleksakhin P. M., 1968, Sovriemiennoie sostojaniie i zadaczi radiacionnoi biogeocenologii, Voprosy Radioekologii, 8—31, Atomizdat, Moskva.

Barbacki S., 1951, Doświadczenią kombinowane, PWRiL Warszawa p. 1—36.

Elandt R., 1957, Rocznik Nauk Rolniczych. Vol. 75, ser. A-roślinna (2) PAN wydział NRiL p.: 205—227.

Grodziński D. M., 1965, Estiestviennaya radioaktivnist rastienij i poczv., Izd. Naukova Dumka, Kiev, p. 216.

Grodziński D. M., Viktorova N. V., 1970 Vliyanie gamma — radiacii na kinetiku poulasii rastitielnych kletok w kulturie. Materiali I Wsiesoyuznogo Simpoziuma po radiobologii rastitielnogo organizma, Izd. Naukova Dumka, Kiev, s: 32—33.

Gunckel J. E., 1965, Modyfication of plant growth and development induced by ionizing radiations. Encyclopedia of plant physiology, 15(2):365—367, Springer-Verlag, Berlin - Göttingen - Heildelberg.

Gunckel J. E., and Sparrow A. H., 1961, Encyclopedia of plant physiology, Vol. XVI External factors affecting growth and development, Springer-Verlag, Berlin - Göttingen - Heidelberg, p.: 555—611.

Kowaliński St. (i inni), 1959, Ćwiczenia z gleboznawstwa i podstaw mineralogii z petrografią (Skrypt s. 317). Wyd. W.Sz.R. we Wrocławiu.

Kowalsky V. V., Worotniskaya I. E. and Lekarew S. V., 1967, Biogeochemical food chains of uranium in aquatic and terraneous organisms, Radioecol. Conc. Processes — Proc. Intern. Symp. Stockholm, 5:329—332.

Koter M., 1954, Gleba jako środowisko wzrostu i rozwoju roślin, PWN, Warszawa — Olsztyn, p. 279.

Kukułczanka K., Sarosiek J., 1970, Modyfikacje wzrostu i rozwoju frezji (*Fressia hybrida* hort.) wywołane promieniami gamma ^{60}Co, Biul. IHAR 1—2, p:93—98.

Maksimow A., 1954, Mikroelementy i ich znaczenie w życiu organizmów, PWRiL, Warszawa, p.420.

Maslov V. I., Gruzdev B. I., Ovczenkov V. J., Panev A. S., 1970, Materiali I Wsiesoyuznogo Simp. po radiobologii rastitielnogo organizma, Izd. Naukova Dumka, Kiev, p:196.

McCormick J. F., 1963, Changes in a herbaceous plant community during a three-year period following exposure to ionizing radiation gradients. Radioecology — Prooceedings of the First National Symp. on Radioecology held at Colorado State University, September 10—15, 1961, Publ. Reinhold Corrpor., Uew York, p:271,276.

McCormick J. F. and Platt R. B., 1963, Ecotypic differentiation in *Diamorpha cymosa* Nutt, ASB Bull. 10/2/:1—33.

McCormick J. F. and Cotter D. J., 1964, Radioactivity on southeastern granite outcrops, The Bull. of the Georgia Acad. of Science 22/1/:1—9.

Odum E. P., 1963, Podstawy ekologii, PWRiL, Warszawa, p.560.

Osburn W., 1961, Variation in clones of *Penstemon* growing in natural areas of differing radioactivity, Science 134 (3475).

Petersburgski A., 1947, Praktikum po agrokhimii, Moskva, p.:274.

Sarosiek J., 1972, Radioekologia *Marchantia poly*morpha L. w Sudetach, Monographiae Botanicae 28:161—203.

Sarosiek J. and Wożakowska-Natkaniec H., 1967, Response of *Marchantia polymorpha* L. to chronic gamma radiation under natural conditions, Acta Soc. Bot. Pol. 36: 187—197.

Sarosiek J. and Wożakowska-Natkaniec H., 1968. The effect of low--level acute gamma radiation on the growth of *Marchantia Polymyrpha* L. originating from various ecological populations, Acta Soc. Bot. Pol. 37: 413—426.

Skoog F., 1935, The effect of X-irradiation on auxin and plant growth, J. Cellurar comp. Physiol. 7: 227—270.

Szafran B., 1957, Mchy (*Musci*), PAN Warszawa, T. II p.:91.

Woodwell G. M. and Oosting J. K., 1965, Effects of chronic gamma irradiation on the development of old plant communities, Radiation Botany 5(3) : 205—222.

Radioekologia Pogonatum urnigerum (L.) Pal. Beauv.

Streszczenie

W obrębie anomalii radiacyjnej koło Kowar (pow. Jelenia Góra) zalegającej nad uranonośną żyłą pegmatytową w granitach, mech *Pogonatum urnigerum* tworzy ekologiczne populacje wśród synuzji mszaków. Na podstawie szczegółowej ana-

lizy ekologicznej wybrano 5 stenotopowych siedlisk rozwoju *Pogonatum urnigerum* różniących się między sobą poziomem ciągłego promieniowania gamma podłoża. (Tabela 1 i 2). Stwierdzono, iż *Pogonatum urnigerum* występuje tu w zakresie promieniowania gamma od 0,05 do 0,91 mR/h. Populacje *Pogonatum urnigerum* z wybranych siedlisk o różnym poziomie promieniowania poddano analizie biometrycznej analizując 12 cech morfologicznych i zagęszczenie populacji (Tabela 3). Analiza statystyczno-matematyczna wykazała istotne różnice między populacjami z terenu anomalii, a populacją nienapromieniowaną w naturze. (spoza tereu anomalii).

Ciągłe, niskopoziomowe promieniowanie gamma w zakresie 0,05—0,91 mR/h jest istotnym czynnikiem ekologicznym, wpływa na rozwój roślin *Pogonatum urnigerum* i na kształtowanie się ich ekologicznych populacji. Promieniowanie to stymuluje wzrost roślin *Pogonatum urnigerum*; im wyższy jest poziom promieniowania w badanych siedliskach w podanych granicach, tym większy jest wzrost roślin. Pod wpływem promieniowania zmienia się pokrój roślin, bowiem indukuje ono rozwój rozgałęzień gametofitu, które nie są typowe dla gatunku. Modyfikacje rozgałęzień gametofitu jako anomalie rozwojowe *Pogonatum urnigerum* w obrębie anomalii radiacyjnej manifestują się dużą frekwencją (od 13,1 do 36,2%), gdy tymczasem w populacjach spoza terenu anomalii udział roślin anomalnie rozwiniętych nie przekracza 1,5%. W naturalnych populacjach udział roślin anomalnie rozgałęzionych, tworzących formy gametofitu w różnym stopniu rozkrzewione, jest tym wyższy im wyższy jest poziom promieniowania w siedlisku. Anomalne rozgałęzienia gametofitu typu dichotomii mają wyższą frekwencję (1,5 — 25,3%) niż anomalne rozgałęzienia typu sympodium dichasium (2,5 — 15,8%). Stwierdzono, iż indukcji rozgałęzień gametofitu towarzyszy ograniczenie apikalnej dominacji osi głównej, tym większe im wyższe jest promieniowanie w siedlisku.

Promieniowanie w podanym zakresie wpływa na strukturę ekologicznych poplacji *Pogonatum urnigerum*, a mianowicie zmienia zagęszczenie populacji i rozkład płci. Ponadto wpływa na skład gatunkowy synuzji mszaków z udziałem badanego gatunku.

Wraz ze wzrostem promieniowania w siedlisku zagęszczenie populacji maleje (Tabela 3). Osobniki męskie *Pogonatum urnigerum* w obrębie anomalii radiacyjnej występują tylko w zakresie promieniowania gamma 0,05—0.64 mR/h, natomiast osobniki żeńskie występują i przy wyższym poziomie promieniowania, do 0,91 mR/h. Promieniowanie w tym zakresie zmienia właściwy temu gatunkowi rozkład płci w naturalnych populacjach; stosunek osobników męskich do żeńskich pod wpływem promieniowania zmienia się z 2 : 3 na 3 : 7.

Wraz ze wzrostem poziomu promieniowania podłoża w siedliskach z terenu anomalii radiacyjnej, udział gatunków towarzyszących *Pogonatum urnigerum* w naturalnych synuzjach mszaków maleje, przy czym przy niskim poziomie ciągłego promieniowania (0,05—0,16 mR/h) tworzy przeciętnie 9 gatunków, natomiast przy poziomie promieniowania (0,72—0,91 mR/h) synuzje tworzą przeciętnie 4 gatunki. W warunkach kowarskiej anomalii radiacyjnej ciągłe niskopoziomowe gamma promieniowanie podłoża, w zakresie 0,72—0,91 mR/h, dyskryminuje w synuzjach udział takich gatunków, jak *Mnium cuspidatum* (L., Schreb.), *Mnium punctatum* Hedw., *Mnium pseudopunctatum* Br. et Schimp., *Campothecium sericeum* Kindb., *Bryum caespiticium* L., *Cephalocia bicuspidata* Dum., *Dicranella* sp. Schimp., *Dicranum* sp., *Rhacomitrium* sp. Brid., *Lophocolea heterophylla* (Schrad.) Dum.

Pogonatum urnigerum z terenu anomalii radiacyjnej charakteryzuje wysoka ogólna beta-radioaktywność, tym wyższa im wyższy jest poziom promieniowania gamma w siedlisku, średnio 1060,2 pc/g popiołu. Populacja tego gatunku z siedliska bez podwyższonego promieniowania wykazuje beta-radioaktywność tylko 68,0 pc/g popiołu.