Response of *Marchantia polymorpha* L. to chronic gamma radiation under natural conditions

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The subject of the present study are natural ecological populations of *Marchantia polymorpha* L. developed within a large radiometrical anomaly in Sudety Mountains. These populations are exposed to action of chronic radiation whose intensity being relatively low is, however, different for each of the investigated populations.

The purpose of the investigation was: 1) to determine the value of gamma radiation, considered as a natural ecological factor, 2) to define the effect of radiation on the development of *Marchantia polymorpha* L.; 3) to find out whether this radiation has any effect on the formation of synousia of *Marchantia polymorpha* L. with other species of *Bryophyta*.

So far, in the domain of radiation ecology only few investigations on the effect of natural radiation on the development of plants have been conducted (Schultz and Klement 1963). Natural radioactivity of granite outcrops in Georgia State (USA) has been studied by Mc Cormick and Cotter (1964). The above authors have stated that the investigated natural radioactivity causes biological effects if it ranges within 0,05 to 0,4 mr/h. Mc Cormick and Platt (1963) have shown ecotypical differences in the endemic species *Diamorpha cymosa* Nutt. caused by radioactivity of granite bed, and Cotter (1963) the changes in photoperiodicity in *Portulaca smalii*.

Mc Cormick and Platt (1962) have conducted an ecological analysis of the selected plant communities from radioactive granite bed and found their spreading and composition of species to depend on the intensity of chronic gamma radiation. De Selm and Shanks (1963) have shown that the fresh weight in *Salix* sp. increases remarkably within natural radiometrical anomaly, no such a reaction being observed in *Pinus silvestris* L.

The present investigations on *Marchantia polymorpha* L. conducted in the vegetative period of 1964 have been completed in the vegetative season of 1965.

This work is a part of investigations conducted by the Department of Ecology and Geography of Plants of the Wrocław University.

The authors are greatly indebted to the Management of the Industrial Establishments at Kowary for being given a technical assistance in the course of their work. The authors express also their thanks to Mrs K. Stankiewicz for the graphs drawn by her.

RESEARCH METHODS

1) Selection of environments. 11 ecological environments of *Marchantia polymorpha* L. have been selected within a relatively great radiometrical anomaly which had been delimited by means of radioactivity measurements. The selected environments differed from one another in the intensity of radiation, and according to a detailed ecological analysis (Sarosiek 1964) they were stenotopic with respect to edaphic and microclimatic factors. By means of much detailed ecological analysis all ecologically extreme environments, even those which showed slight edaphic and microclimatic (lighting in particular) differences with the selected 11 environments have been removed.

Table 1
Levels of radactivity (mr/h) in investigated micro-habitats

No. Micro- habi- tats	Soil surface				Above the plants			
	Spring	Summer	Autumn	average	Spring	Summer	Autumn	average
1	0.20	0.06	0.12	0.13	0.18	0.04	0.11	0.11
2	0.24	0.07	0.16	0.16	0.20	0.05	0.15	0.13
3	0.25	0.08	0.19	0.18	0.24	0.06	0.18	0.16
4	0.22	0.06	0.16	0.15	0.19	0.05	0.14	0.13
5	0.42	0.17	0.25	0.28	0.40	0.14	0.22	0.25
6	0.45	0.19	0.34	0.33	0.42	0.15	0.32	0.28
7	0.24	0.06	0.14	0.15	0.22	0.05	0.12	0.13
8	0.86	0.24	0.63	0.57	0.80	0.19	0.60	0.53
9	1.48	0.28	0.96	0.91	1.42	0.26	0.92	0.87
10	1.11	0.34	0.84	0.76	1.07	0.30	0.80	0.72
11	0.49	0.11	0.36	0.32	0.47	0.10	0.34	0.30
Ave- rage	0.54	0.15	0.38	0.36	0.51	0.13	0.35	0.33

2) Radiometrical measurements. The measurements of the intensity of gamma radiation were measured three times in the course of vegetation, namely in spring (15.V.1964), in summer (10.VII.1964) and in autumn (15.IX.1964). The measurements were taken by means of universal UR-4M radiometer with STS-8 counter whose scales permitted readings from 0.005 to 10 mr/h.

3) Biometrical and mathematical analysis. In order to find out differences in the vegetative development of the thallus of *Marchantia polymorpha* L. in 11 environments differing from one another by the intensity of radiation, the biometrical analysis of the selected morphological characteristics of the investigated species has been carried out. The following characteristics have been assumed as representative: 1. the length of the I-st order ramification of the thallus lobe, 2. the length of the II-nd order ramification of the thallus lobe, 3. the width of the lobe of the It-s

order, 4. the width of the lobe of the II-nd order, 5. the number of ramifications, 6. the width of the ramification of the III-rd order (if it occur), 7. the area of thallus. The area of thallus has been measured by planimeter. The arithmetical means have been calculated for all measurements (Table 3).

The whole material has been classified by the dendrite or Wrocław Taxonomy method (Florek and all. 1952). This method is used if multivariate objects are to be classified and their mutual resemblance shown. In order to obtain identical effect of separate characteristics on the distances between the individual objects, all characteristics were standardized (the arithmetical mean and disperion being equal to 0, and 1, respectively), (Perkal 1953 and 1958). Two dendrites have been made, one for morphological characteristics and one for the analysis of fresh and dry weights and of ashes. In both dendrites the distances mean the avarage distances, i.e. the total distances among objects divided by the number of standarized characters (Table 5).

Table 2

Difference of radioactivity ($\mu\text{r/h}$) between soil surface and above the plants in investigated micro-habitats

No. micro- habitats	Spring	Summer	Autumn	Average
1	28	20	12	20
2	31	22	13	22
3	15	16	14	15
4	30	18	24	27
5	22	38	30	30
6	24	20	20	21
7	15	14	14	14
8	56	45	35	45
9	62	22	40	41
10	38	34	40	37
11	15	12	16	15
Average	31	25	23	24

4) Fresh and dry weights and the percentage of ashes (Table 4) have been computed according to generally applied methods.

DESCRIPTION OF SYNOUSIA WITH *MARCHANTIA POLYMORPHA* L.

Within the investigated radiometrical anomaly *Marchantia polymorpha* occurs either in pure populations or with other spore plants forming in open places of the initial stages of turf smaller or larger synousia. In separate environments the following species are the components of synousia; in 1. *Marchantia polymorpha* L., *Plagiochilla maior* (L.) Dum. and *Mnium pseudopunctatum* Br. Schimp.; in 2: *M.*

Table 3
Absolute (in cm.) and standardized values of morphologic characters of *Marchantia polymorpha* L.

No. Micro-habitats	Absolute values							Standardized values						
	Length of lobe I	Length of lobe II	Width of lobe I	Width of lobe II	Number of lobes	Width of lobe III	Area of thallus in cm ²	Length of lobe I	Length of lobe II	Width of lobe I	Width of lobe II	Number of lobes	Width of lobe III	Area of thallus in cm ²
1	4.27	3.34	1.05	0.85	2.40	0.60	5.78	-0.26	-0.27	-1.01	-0.63	-0.88	-0.55	-0.43
2	3.88	3.11	1.07	0.94	2.50	0.66	5.06	-0.55	-0.46	-0.93	-0.27	-0.63	-0.16	-0.67
3	3.99	2.92	1.30	0.89	2.70	0.72	6.55	-0.47	-0.62	-0.09	-0.47	-0.13	+0.24	-0.17
4	4.07	3.38	1.23	0.91	2.50	0.64	5.62	-0.41	-0.23	-0.35	-0.39	-0.63	-0.29	-0.48
5	3.01	2.49	0.95	0.87	2.50	0.56	5.05	-1.20	-0.98	-1.37	-0.55	-0.63	-0.82	-0.68
6	4.17	2.95	1.38	0.89	2.60	0.62	5.80	-0.34	-0.60	+0.20	-0.47	-0.38	-0.42	-0.42
7	3.60	2.63	1.40	0.80	2.50	0.45	4.98	-0.76	-0.87	+0.27	-0.83	-0.63	-1.55	-0.70
8	6.69	5.22	1.78	1.23	3.70	0.84	10.85	+1.54	+1.92	+1.67	+0.89	+2.38	+1.03	+1.29
9	7.38	6.10	2.01	1.71	3.16	1.06	14.51	+2.06	+2.06	+2.51	+2.81	+1.03	+2.48	+2.53
10	6.01	5.00	1.28	1.09	3.20	0.71	8.50	+1.04	+1.13	-0.16	+0.33	+1.13	+0.17	+0.49
11	3.78	3.09	1.12	0.90	2.50	0.66	4.82	-0.63	-0.48	-0.75	-0.43	-0.63	-0.16	-0.75

Table 4

Absolute and standardized values of fresh and dry weights and of ashes (in g) of *Marchantia polymorpha* L.

No Micro- habitats	Absolute values			Standardized values		
	Fresh weight	Dry weight	Ashes	Fresh weight	Dry weight	Ashes
1	3.7547	0.3748	0.0383	+0.85	+0.27	-0.18
2	2.7542	0.3488	0.0389	-0.41	-0.03	-0.10
3	2.4860	0.2932	0.0249	-0.75	-0.67	-2.11
4	1.8903	0.2036	0.0397	-1.50	-1.70	+0.02
5	2.2859	0.3252	0.0509	-1.00	-0.42	+1.63
6	3.4430	0.3718	0.0504	+0.46	+0.24	+1.56
7	2.7314	0.4097	0.0486	-0.44	+0.67	+1.30
8	3.9563	0.5489	0.0432	+1.10	+2.27	+0.52
9	4.2843	0.3301	0.0341	+1.52	-0.24	-0.79
10	4.0108	0.4123	0.0381	+1.17	+0.70	-0.21
11	2.2859	0.2561	0.0280	-1.00	-1.09	-1.67

Table 5

The distances of the objects of morphologic characters (right, upper half) and the distances of the objects of fresh and dry weights and of ashes (left, lower half) of *Marchantia polymorpha* L.

No Micro- habitats	1	2	3	4	5	6	7	8	9	10	11
1	×	1.81	3.45	1.65	3.92	2.61	4.51	14.15	19.51	8.16	2.01
2	1.65	×	2.69	1.38	2.60	2.46	3.79	13.80	19.18	8.08	0.52
3	1.47	2.99	×	2.03	4.53	1.62	4.08	11.83	17.16	6.12	1.44
4	1.52	2.87	3.91	×	3.45	1.51	3.52	12.90	18.26	6.93	1.31
5	4.35	2.71	4.25	3.40	×	3.81	3.26	16.35	21.98	10.33	2.57
6	2.17	2.79	5.78	5.43	2.18	×	2.88	12.54	17.90	7.59	2.25
7	3.17	2.13	5.06	4.71	1.98	1.59	×	15.16	20.53	10.07	3.39
8	2.96	4.44	7.43	7.08	5.90	3.72	3.92	×	8.06	5.99	13.44
9	1.79	2.83	4.02	5.28	5.11	3.89	4.96	4.24	×	11.55	19.31
10	0.78	2.43	5.19	5.30	5.13	2.95	3.15	2.38	1.87	×	7.93
11	4.70	3.23	2.13	3.79	3.98	6.02	5.30	7.66	4.25	4.42	×

polymorpha L., *Mnium cuspidatum* (L., Schreb.) Leyss, *M. pseudopunctatum* Br Schimp and *Polytrichum commune* L.; in 3: *M. polymorpha* L., *Mnium cuspidatum* (L., Schreb.) Leyss, *M. pseudopunctatum* Br. Schimp. and *Lofocolea bidentata* (L.) Dum.; in 4: *M. polymorpha* L., *Rhytidiadelphus squarrosus* (Hedw.) Warnst., *Bryum caespitium* L. and *Polytrichum commune* L.; in 5: pure population of *M. polymorpha* L.; in 6: *M. polymorpha* L., *Drepanocladus uncinatus* (Hedw.) Warnst and *Campothecium sericeum* Kindb.; in 7: *M. polymorpha* L., *Mnium pseudopunctatum* Br.

Schimp., *Plagiothecium laetum* Br. eur. and *Mniobryum albicans* (Wahlb.) Limpr. sporadically; in 8: *M. polymorpha* L., *Plagiochilla maior* (L.) Dum., *Lofocolea bidentata* (L.) Dum., *Lofocolea heterophylla* (Schr.) Dum. and *Scapania undulata* Dum.; in 9: *M. polymorpha* L. and *Rhytidiadelphus squarrosus* (Hedw.) Warnst. sporadically; in 10: pure population of *M. polymorpha* L.; in 11: *M. polymorpha* L. and *Drepanocladus uncinatus* (Hedw.) Warnst.

RADIATION AS ECOLOGICAL FACTOR

In the investigated environments the radiation is natural, resulting from the dispersed ore particles present in the ground. The radiometric anomaly enclosing the investigated environments of *Marchantia polymorpha* L. has been delimited by measurements of the most penetrating gamma radiations. The results of the measurements of the intensity of gamma radiation are given in Tables 1, 2.

For all investigated environments the annual average value of the intensity of gamma radiation emanated by the soil surface amounts to 0.3 mr/h. Changes in the intensity of gamma radiation emanated by the soil surface of the investigated environments in the course of the vegetative season are presented in Table 1. In all environments the highest radioactivity has been observed in the early spring (0.54 mr/h in the average). The highest radioactivity has been found in soil from the environment 9) in the average 0.90 mr/h in the course of one year), and the lowest one in the soil from the environment 1 (in the average 0.13 mr/h in the course of one year). The intensity of radiation in soils from the environments 8 and 10 is much higher than in the remaining ones. The differences in the level of radioactivity among the separate environments are distinct independently of the season (spring, summer or autumn).

The level of radioactivity over the plants is distinctly lower than that over the soil surface (Table 1). The investigated environments show distinct differences in the intensity of radiation measured immediately above the plants. The average annual value of radiation over the plants for all environments amounts to 0.33 mr/h. The highest value of radiation over the plants has been stated in the spring (0.51 mr/h) and the lowest one in summer (0.13 mr/h). In the autumn the value of radiation over the plants is increasing. The differences in radioactivity measured over the soil surface and over the plants in the investigated environments are given on Table 2. The average annual value of these differences for all environments amounts to 31 μ r/h in spring, 25 μ r/h in summer and 23 μ r/h in autumn. The maximum differences have been observed in the environments 8, 9 and 10, and the minimum ones in the environments 3, 7 and 11. The additional measurements have showed that the radioactivity in the investigated environments increases with the altitude of soil, eg. in the environment 5 the intensity of radiation on the soil surface in spring was 420 μ r/h, 25 cm deep was 480 μ r/h, and 50 cm deep it varied within 586 to 612 μ r/h. Similar increase in the intensity of radiation about 40—60 μ r/h in the average has been noted in autumn immediately after a shower lasting for some days.

ECOLOGICAL ANALYSIS OF THE POPULATIONS
OF *MARCHANTIA POLYMORPHA* L.

1. Observations. As early as during a direct observations of groups of *Marchantia polymorpha* L. in the synousia of spore plants we could observe, besides the differences in the structure of the very synousia, the differences in formation of thalluses and in their development. Ecological populations of *M. polymorpha* L. from the environments 2, 5, 7, 11 can be distinguished by larger and well ramified thalluses. The populations of *Marchantia polymorpha* L. from the remaining environments show an intermediate size of thalluses. Similar differences among some populations have been observed in the development of cups with gemmulae. The populations of *Marchantia polymorpha* L. from the environments 1, 2, 5, 7 did not produce gemmulae at all, at the same time the populations from the environments 9, 10, 11 produced them in abundance, whereas the populations from the environments 3, 4, 6 developed only very few cups with gemmulae. Only some populations of *Marchantia polymorpha* L. developed the female reproductive organs (from the environments 1, 2, 7, 8). The female organs being particularly well developed in the populations from the environments 7 and 8. The populations from the environment 8 which had produced very numerous female organs differed from the analogical population from the environment 7 by much larger archegoniostates.

2. Biometrical analysis of morphological characteristics. The dendrite (Figure) representing the groups of separate ecological populations of *Marchantia polymorpha* L. differing among one another has been made on the basis of values given in Table 5 (according to the applied method). The dendrite of objects (populations) for morphological characteristics bears a linear character, its lateral branches being rather short. In the above dendrite one can distinguish: a group of objects 6, 4, 1, 2, 3 close to it the objects 5 and 7, and a group of more distant objects 8, 9, 10 which are far off from one another. In the plants belonging to the first group of objects the ramifications of the thallus of the I-st and II-nd order are rather short, the ramifications of the thallus of the I-st, II-nd and III-rd orders are not wide, the number of lobes and the area of thallus being small. Only in the object 3 belonging to this group the number of lobes and their areas have values approaching the average. Therefore this object is a link with more distant objects 10, 8, 9. The objects 5 and 7 are characterized by a small length of the ramifications of the I, II and III orders and by the smallest area. The remote objects 10, 8, 9 are remarkable by a great number of lobes and long ramifications of the I-st and II-nd order. The objects 8 and 9 have distinctly wider ramifications of thallus and a large area. The object 10 is characterized by the intense segmentation of lobes, whence the width of lobes approaches the average value. This characteristic has decided that this object links the remaining objects. In the objects 8, 9, 10 the length of the thallus ramifications of the I and II order is almost two times greater than in remaining objects, their width being only slightly greater. The number of lobes in those objects is 1,2 to 1,5 times greater, and the area is 2 to 3 times greater.

3. Analysis of fresh and dry weights and of ashes. The results of the analysis of fresh and dry weights and of ashes are given in Table 4. In order to group together the obtained values and to find out the relation between this group and the intensity of radiation the absolute values have been computed and standardized according to the demands of the dendrite method (Table 4). On the basis of standardized values the distances between the separate objects (populations) have been calculated — Table 5, which have yielded the dendrite (Figure B) for quantitative values of fresh and dry weights and ashes. The dendrite is ramified and rather well differentiated. Hence, it is difficult to distinguish in it distinct groups of objects. The separate objects differ in fresh and dry weights and ashes contents. The fresh weight is the greatest in the objects 8, 9, 10 and the smallest in the objects 11, 5, 4. The dry weight is the greatest in object 8, and the smallest in objects 11 and 4. The greatest amount of ashes is found in the objects 5, 6, 7 and the smallest one in the objects 9 and 11.

In spite of distinct differentiation in distances of separate objects, both dendrites show a certain resemblance in the arrangement of objects; in both dendrites the objects 8, 9, 10 and 6, 7, 5 are situated on their distant edges. The nearest connections between the pairs of objects are similarly arranged, e.g. the objects 3 and 11 or 4 and 1.

DISCUSSION

The results of measurements of radiometrical anomaly within which the investigated environments have been selected are similar to those obtained from the measurements of natural radiation of granite rocks in Piedmont (Mc Cormick and Cotter 1964).

The arrangement of the investigated ecological populations of *Marchantia polymorpha* L. given in the dendrite (Fig. A) has testified the significance of the effect of low intensity radiation in different ranges of its activity (Table 1) on the development of this species.

The populations where the intensity of the ground was the highest and those where the radioactivity was the lowest, have been grouped separately, in between position being taken by the plants growing on the ground characterized by an intermediate intensity of radiation. The populations of *Marchantia polymorpha* L. exposed to the highest radiation (0.91 mr/h) show a stimulating effect of radiation on the growth and size of thallus. In this range of radiation not only the size of thallus but also a high degree of its plication may be assumed as the environmental modification. Similar effect of radiation obtained from artificial sources of higher intensity (accumulation 1000 r) has been observed in *Quercus alba* L. and *Q. velutina* Lem. leaves by Mericle and Sparrow (1962). Both species have shown, moreover, the inhibition in production of pollen. Within the investigated anomaly the population of *Marchantia polymorpha* L. growing in the environment characterized by the highest intensity of radiation has shown inhibition in the development of reproductory organs, which under the same complex of ecological conditions were developed in other populations of *Marchantia polymorpha* L.

In natural conditions and within the same range of radiation Mc Cormick and Platt (1962) have observed a more intense development of *Hypericum gentianoides* (L.) B.S.P. a more intense blossoming and a prolonged period of flowering. It allows to infer that in *M. polymorpha* L. the tolerance to radiation is much lower than in *Hypericum gentianoides* (L.) B.S.P.

In contrast with the group of ecological populations of *M. polymorpha* L. from the environments characterized by the highest intensity of radiation, the populations from the environments of the lowest radioactivity do not show any stimula-

Fig. 1. The dendrite of morphologic characters (A) and the dendrite of fresh and dry weights and od ashes (B) *Marchantia polymorpha* L.

tion of their growth, their sexual development being passable their vegetative development is rather weak. Thus, in this range of radiation *M. polymorpha* L. does not show any response. The group of ecological populations of *M. polymorpha* L. from the environments where the radiation has been intermediate (0.32–0.57 mr/h) show also an intermediate development. In these plants the growth is more intense and the area of thallus is larger than in plants growing in the environments characterized by the lowest intensity of radiation, but never such as in plants from the ground of the highest radioactivity. Under the conditions of an intermediate radioactivity the effect of radiation on the sexual development of *Marchantia polymorpha* L. is also less pronounced. The vegetative reproduction being passable, the plants produce a relatively great number of archegoniostates.

As it follows from the analysis, in the ecological populations of *M. polymorpha* L. from the environments characterized by the highest intensity of radiation the production of fresh weight increases (Fig. B). Within a region of radiometrical anomaly a remarkably increased fresh weight has been stated in *Salix* sp., in *Pinus silvestris* L. such a reaction has not been observed (de Selm and Shanks 1963).

CONCLUSIONS

1. Radioactivity of the ground within the investigated anomaly ranges within 0.20—1.48 mr/h for gamma radiation. The intensity of gamma radiation varies with the vegetative season of the year. The highest radioactivity for the investigated ground has been stated in the early spring (for all environments 0.54 mr/h in the average), and the lowest one in summer (0.15 mr/h in the average). In autumn the radioactivity increases and amounts to 0.36 mr/h in the average.

2. Relatively pure and compact ecological populations of *Marchantia polymorpha* L. are intercepting a part of ionizing radiation emitted by the ground. Within the investigated radiometrical anomaly the difference in the intensity of gamma radiation measured over the soil surface and over the compact synousia of *Marchantia polymorpha* L. amounts to 24 μ r/h in the average.

3. In the environments where the radioactivity ranges within 0.13—0.18 mr/h *Marchantia polymorpha* L. does not show any response to radiation.

4. Under natural conditions chronic radiation (the intensity of gamma radiation ranging within 0.76—0.91 mr/h) is a factor stimulating a vegetative development of *Marchantia polymorpha* L. Under the above conditions of radiation the area of thallus in ecological populations of *Marchantia polymorpha* L. is three times larger, the growth and production of gemmulae are more intense, whereas the sexual development is inhibited.

5. Within the investigated radiometric anomaly (ranging from 0.74—0.96 mr/h) the number of components in the investigated synousia decreases with the increasing intensity of radiation. In the environment characterized by the highest intensity of gamma radiation only pure ecological populations of *Marchantia polymorpha* L. have been observed.

6. Since radiation (in a certain range of intensity) is a factor that removes all components but *M. polymorpha* L. from natural synousiacs of Bryophyta, thus such accompanying species as: *Plagiochilla maior* (L.) Dum., *Mnium pseudo-punctatum* Br. Schimp., *M. cuspidatum* (L., Schrab) Leyss., *Polytrichum commune* L., *Lofocolea bidentata* (L.) Dum., *Rhytidiadelphus squarrosus* (Hedw.) Warnst., *Bryum caespitium* L., *Drepanocladus uncinatus* (Hedw.) Warnst., *Campothecium sericeum* Kindb., *Plagiothecium undulatum* Ruthe., *Mniobryum albicans* (Wahlb) Limbr., *Lofocolea heterophylla* (Schrad.) Dum. and *Scapania undulata* (L.) Dum. are less capable of enduring radiation than *Marchantia polymorpha* L.

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Reakcja Marchantia polymorpha L. na ciągłe promieniowanie gamma
w warunkach naturalnych

Streszczenie

Przedmiotem badań są naturalne ekologiczne populacje *Marchantia polymorpha* L. wyrosłe w obrębie dużej anomalii radiometrycznej w Sudetach. Określono zakres i zmienność promieniowania. Radioaktywność podłoża w obrębie badanej anomalii wynosi od 0,20 do 1,48 mr/h dla promieni gamma. W siedliskach o intensywności promieniowania 0,13—0,18 mr/h *Marchantia polymorpha* L. nie wykazuje widocznych reakcji na promieniowanie.

Promieniowanie naturalne w granicach 0,76—0,91 mr/h jest czynnikiem ekologicznym badanych siedlisk w obrębie anomalii stymulującym wegetatywny rozwój *Marchantia polymorpha* L. Stwierdzono, że wraz ze wzrostem natężenia promieniowania w obrębie badanej anomalii radiometrycznej ilość komponentów w synuzjach mszaków maleje. W siedliskach o najwyższym promieniowaniu występują czyste populacje ekologiczne *Marchantia polymorpha* L. Te czyste i w miarę czyste populacje ekologiczne *Marchantia polymorpha* L. zatrzymują część promieniowania jonizującego pochodzącego z podłoża. Różnica w natężeniu promieniowania gamma między powierzchnią gleby a nad zwartą synuzją *Marchantia polymorpha* L. wynosi około 24—26 μ r/h.

Ponieważ promieniowanie naturalne jest czynnikiem stopniowo rugującym poszczególne komponenty z naturalnych synuzji mszaków (zarówno występujące gatunki obficie, jak i sporadycznie), oprócz *Marchantia polymorpha* L. to gatunki te oznaczają się znacznie niższą tolerancją wobec promieniowania niż *M. polymorpha* L. Do takich gatunków, jak stwierdzono należą między innymi *Plagiochilla maior* (L.) Dum., *Mnium pseudopunctatum* Br. Schimp., *M. cuspidatum* Hedw., *Polytrichum commune* Hedw., *Lofocolea bidentata* (L.) Dum., *Rhytidadelphus squarrosus* (Hedw.) Warnst., *Campothecium sericeum* Kindb., *Plagiothecium undulatum* Ruthe., *Mniobryum albicans* (Wahl.) Limbr., *Lofocolea heterophylla* (Schr.) Dum. i *Scapania undulata* (L.) Dum.