The effect of low-level acute gamma radiation on the growth of *Marchantia polymorpha* L. originating from various ecological populations

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In recent years *Marchantia polymorpha* L. has been the subject of special radiobiological and radioecological studies. Miller, Sparrow and Rogers (1965), who investigated radiosensitivity of the gemmae of *M. polymorpha* L. to acute ^{60}Co irradiation, found that the exposure to 55 kR is lethal, and that gradual inhibition of apical proliferation with simultaneous initiation of non-apical growth of the thallus are observed under exposure to lower radiation doses. Miller and Sparrow (1965) while investigating radiosensitivity of the thallus of *M. polymorpha* L. established that the thallus of the investigated species is approximately 4,3 times more sensitive than the gemmae. Sarosiek and Wożakowska-Natkaniec (1967) who studied the reaction of *M. polymorpha* L. to chronic radiation in natural conditions, observed significant differences between the ecological populations of the investigated species whose natural ecological habitats differed from one another by the intensity of radioactivity.

The purpose of the present work was to find whether ecological populations of *M. polymorpha* L. grown under higher than normal natural radioactivity, of varying intensity would exhibit different reactions to low-level ^{60}Co radiation, i.e. whether the ecological individuality of those populations would be maintained. An other purpose was to study whether the differences in the reaction to low-level chronic radiation observed in natural ecological populations of *M. polymorpha* L. would appear in an early stage of development and under what radiation dose (in the case of different exposures to low-level ^{60}Co radiation).

The ecological populations of *M. polymorpha* L. taken for investigations derived from the same Sudetes radiometric anomaly, on which former radioecological investigations were carried out (Sarosiek and Wożakowska-Natkaniec 1967). The experiments were performed in the Department of Plant Ecology and Geography Wrocław University, ^{60}Co used as the source of radiation was made available to us by the Department of Technology of Metals, Wrocław Technical University.

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MATERIAL AND METHODS

Gemmae of *M. polymorpha* L. from five different populations we used for the experiment. The populations differed in the intensity of natural radioactivity of their habitats (Sarosiek and Wożakowska-Natkaniec 1967).

Population I (control) — non irradiated habitat

Population II — 0.28 mR/h

Population III — 0.45 mR/h

Population IV — 0.57 mR/h all data refer to gamma radiation

Population V — 0.86 mR/h

The gemmae taken from various populations were inoculated on agar agar medium prepared according to Burgeff (1943) method and were incubated in Petri dishes at 13°–18°C. The cultures were kept in a greenhouse on the window sill facing south. In the preliminary experiment (19.X.—27.XI.1965) eight-days-old thalluses derived from populations I and IV were subjected to the following doses of ^{60}Co radiation: 500, 1000, 2000, 3000 and 5000 mR. Strength of dose amounted to 100 mR/h. The growth of thalluses was analysed successively with cumulation of the exposed energy by measuring their length and area in a stereoscopic microscope. The measurements were taken at random in four replications on 3 plants at a time (from two plates and two ranges of vision in each). In the next experiment (24.XI.—15.XII.1965) 3-days-old thalluses of all the investigated populations of *M. polymorpha* L. were exposed to the following gamma irradiation: 500, 1000, 2000, 3000, 4000, 5000, 6000, 8000, 10000 mR, with constant intensity amounting to 1000 mR/h. The growth of thalluses was analysed 2, 6, 10 and 18 days after irradiation, taking the measurements in four replications, like in the preliminary experiment. The frequencies of different kinds of thalluses, namely the frequency of mono-polar, and bi-polar thalluses (the latter included both uniform and non-uniform polar growth of thalluses) and the frequency of thalluses with a greater number of lobes, were computed 2 and 16 days after the day of irradiation. The results from all combinations and replications obtained for separate days of measurements were analysed by the method of combined experiments (Barbacki 1951). The mean error and confidence interval were calculated for each combination, separately.

RESULTS

The preliminary experiment demonstrated a reaction to low-level exposure to gamma radiation (min. 500 mR, max. 5000 mR) in both ecological populations of *M. polymorpha* L. The results are given in Table 1. Because of the long time of irradiation required to obtain the given exposure, the stimulating effect of irradiation, observed under the exposures to 500 mR and 1000 mR was not observed under exposures higher than 2000 mR. In both populations after exposure to 1000 mR measured on 6.XI. the growth was similar to that of the control plants, being weaker

than in plants exposed to 500 mR; 12 days later, however, it was slightly better than in plants exposed to 500 mR and remarkably better than that of control plants. Those differences in growth rate became more distinct in the subsequent day of measurements. The differences between the investigated populations were more distinctly manifested in the surface area of thalluses than in their length. The growth of plants exposed to 2000 mR being at first delayed because of the long time of irradiation, became subsequently quite satisfactory; it could not be, however, compared with the growth of control plants or with plants subjected to lower doses, as their development was much more advanced. The same was observed in plants exposed to 3000 mR and 5000 mR. A certain retardation in the development of plants subjected to higher doses (thus irradiated for a longer period) and their weaker growth can be explained by much worse conditions existing in the irradiation chamber (higher temperature and artificial light) than in the greenhouse where the plants were kept after irradiation.

Table 1

Growth of irradiated thallus of *Marchantia polymorpha* L. from 2 ecological populations

Date	Total accumulated doses of gamma irradiation from cobalt-60 (mr)											
	0		500		1000		2000		3000		5000	
	a	b	a	b	a	b	a	b	a	b	a	b
I Population												
21.X	0.67	0.30										
27.X.	1.47	0.81										
2.XI.	2.20	0.97	2.58	1.22								
6.XI.	3.45	1.38	3.45	1.79	3.04	1.41	3.58	1.81				
18.XI.	4.98	2.79	5.18	3.61	4.91	3.72						
27.XI.	5.27	3.97	5.67	5.06	5.96	5.63	4.76	3.01	2.96	1.59	3.31	1.99
II Population												
21.X.	0.67	0.28										
27.X.	1.36	0.63										
2.XI.	1.87	0.73	2.13	0.95								
6.XI.	2.47	0.90	2.73	1.39	2.40	0.90						
18.XI.	3.53	2.29	4.13	2.48	4.05	2.95	2.73	1.39				
27.XI.	4.47	3.11	4.78	3.34	4.84	3.99	3.96	2.67	2.85	1.12	2.14	1.66

a — Length of thallus in mm

b — Area of thallus in mm².

Considering the results obtained for the combinations exposed to 500 mR and 1000 mR, it can be stated that the stimulative effect of irradiation on the growth of thallus was higher in the originally non irradiated population than in the population from the irradiated habitat (IV); in particular this effect was manifest on the subsequent days of measurements (18.X. and 27.XI.).

Owing to the increased doses of radiation applied in experiment II, the level of irradiations was raised and the time of exposure could be reduced to one day.

Graph: Growth of thallus *Marchantia polymorpha* L. of the population coming from non irradiated habitat (1) and of the populations coming from irradiated habitats (2—5);

A — length in mm, B — area in mm²

Drawing: The representative outlines of thalluses *Marchantia polymorpha* L. from five different ecological populations

Consequently, the growth rate in all populations being comparable, the results of experiments could be analysed by means of mathematical and statistical methods. All investigated populations analysed 2 days after the day of irradiation did not show any significant differences in the size of thallus due to different exposures. The analysis of variability in the length and area of thallus performed on the days of measurement (6, 10, 18 days after irradiation) showed significant differences between the individual combinations, exposures and ecological populations, the response of ecological populations to the exposures being also significant. The significance was proved by F. Snedecor's test.

The results in the form of arithmetical means and the corresponding confidence intervals are presented in Table 2. In all populations of *M. polymorpha* L. (see graph) the growth of thallus was stimulated by doses within 1000 mR — 4000 mR; in some cases, however, this stimulative effect was observed for doses within 500—5000 mR. In our experiment the maximum stimulation was observed in population I exposed to 4000 mR. This maximum is pronounced although it often lies within the limits of the confidence interval (its value ranging from control values to the values obtained for the exposure to 5000 mR). Ten days after irradiation the maximum length of thallus was significantly different. Considering all ecological populations originally irradiated (populations II, III, IV and V) the maximum stimulation of the growth of thallus was observed for the following exposures: 2000 mR (3 cases), 3000 mR (1 case) and 500 mR (1 case). The value of this maximum is, in general, not significantly different from the values obtained for the exposures ranging from 0 to 4000 mR. The maximum growth of thallus most frequently occurs in population II. From the analysis of individual populations originally irradiated it follows that in populations II and III the maximum growth of thallus was obtained after exposures to 2000 mR, and in populations IV and V after exposures to 4000 mR, the difference, however is not significant. Considering the results obtained we can affirm that the maximum growth of thallus in ecological populations derived from radiation anomalies is not so distinct as in the population non irradiated in natural conditions. Exposure to 8000 mR and 10000 mR inhibited the growth of thallus in all cases (graph.). The minimum growth of thallus occurred in population I exposed to 8000 and 10000 mR, and the obtained values differ significantly from the remaining ones. In the same population, however, one can observe the inhibitory effect of lower exposures (6000 and 5000 mR) in further measurements (after 10 and 18 days after irradiation). In populations derived from radiation anomalies the inhibitory effects of irradiation and a simultaneous minimum growth of thallus were noted after exposure to 10000 mR and 8000 mR. In these populations, however, no inhibitory effect due to 6000 and 5000 mR was observed on further days of measurement. In these populations the minimum growth has different values, being in populations III and IV usually near the control value. From the analysis of the experimental material it follows that in populations I and II the growth rate of thallus is similar, whereas population V differs in this respect from the remaining ones, since in its growth neither a distinct minimum nor a maximum is observed. Analysis of variability showed that the populations significantly differ

Table 2

Growth of irradiated thallus of *Marchantia polymorpha* L. from 5 ecological populations

No. of popula- tion	Total accumulated doses of gamma irradiation from cobalt-60 (mr)										C.L.	Cl. of sepa- rate expe- ri-ments	X for popu- lation
	0	500	1000	2000	3000	4000	5000	6000	8000	10000			
I II III IV V X (2,3,4,5)	Length of thallus in mm										0.218 0.184 0.199 0.213 0.143 0.106	0.187	1.83 1.50 1.58 1.63 1.54 C.L. 0.059
	After 6 days												
	1.98	1.87	2.04	1.91	1.91	2.05	1.91	1.89	1.59	1.64			
	1.69	1.42	1.67	1.51	1.53	1.56	1.47	1.46	1.45	1.31			
	1.38	1.62	1.56	1.51	1.87	1.76	1.65	1.56	1.44	1.46			
	1.73	1.82	1.67	1.78	1.67	1.76	1.62	1.60	1.58	1.27			
	1.65	1.58	1.56	1.64	1.58	1.51	1.60	1.59	1.35	1.49			
I II III IV V X (2,3,4,5)	After 10 days										0.300 0.259 0.879 0.511 0.201 0.239	0.355	3.01 2.19 2.47 2.66 2.16 C.L. 0.113
	3.04	3.13	3.18	2.98	3.16	3.53	3.22	2.82	2.58	2.51			
	2.27	2.00	2.35	2.74	2.44	2.07	2.20	2.01	2.05	2.00			
	2.11	2.02	2.51	3.07	2.82	2.89	2.55	2.46	2.18	2.05			
	2.74	2.64	2.69	2.78	2.69	2.89	2.69	2.68	2.56	2.31			
	1.87	2.15	2.28	2.16	2.23	2.42	2.19	2.16	2.15	2.07			
	2.25	2.20	2.43	2.69	2.55	2.57	2.41	2.33	2.24	2.11			
I II III IV V X (2,3,4,5)	After 18 days										0.435 0.668 0.874 1.099 0.448 0.509	0.712	5.00 3.95 4.14 4.60 3.39 C.L. 0.225
	5.16	5.31	5.23	5.05	5.34	5.35	4.82	4.67	4.53	4.42			
	4.53	3.78	4.39	4.47	4.71	4.82	3.65	3.59	2.75	2.82			
	4.45	4.38	4.38	4.59	4.53	3.91	3.88	4.01	3.82	3.47			
	4.61	4.39	4.26	4.31	4.46	4.94	5.35	4.71	4.23	3.82			
	3.41	3.29	3.88	2.81	2.29	4.06	3.09	3.51	3.41	3.18			
	4.25	3.96	4.23	4.55	4.25	4.43	3.92	3.95	3.55	3.32			
I II III IV V x (2,3,4,5)	Area of thallus in mm ²										0.193 0.243 0.247 0.196 0.134 0.069	0.056	1.03 0.97 0.93 0.92 0.87 C.L. 0.018
	After 6 days												
	1.17	1.09	1.08	1.04	1.07	1.06	1.16	1.03	0.74	0.80			
	1.09	0.99	1.15	1.03	1.00	1.03	0.91	0.85	0.69	0.91			
	0.80	0.99	0.91	0.83	1.04	1.08	1.08	0.96	0.96	0.79			
	0.98	0.99	0.97	1.05	0.96	0.98	0.84	0.89	0.90	0.62			
	1.03	0.96	0.88	0.95	0.90	0.84	0.83	0.91	0.66	0.75			
I II III IV V x (2,3,4,5)	After 10 days										0.293 0.275 0.311 0.238 0.253 0.176	0.264	1.77 1.48 1.63 1.69 1.35 C.L. 0.072
	2.05	1.84	1.84	1.75	1.98	2.20	1.95	1.53	1.20	1.27			
	1.44	1.27	1.67	2.07	1.76	1.35	1.44	1.22	1.29	1.24			
	1.40	1.33	1.62	1.95	1.82	1.65	1.60	2.04	1.45	1.44			
	1.80	1.67	1.73	1.75	1.69	1.80	1.73	1.62	1.55	1.55			
	1.11	1.38	1.44	1.42	1.42	1.42	1.35	1.51	1.33	1.15			
	1.44	1.42	1.57	1.80	1.67	1.56	1.53	1.60	1.41	1.34			

C.L. = Confidence limits

X(2,3,4,5) = Mean of 2,3,4,5 populations.

from one another in the size of thallus (Table 2). As it follows from the value of the confidence interval, population I differs significantly from the populations derived from radiation anomalies. On the 6th and 10th days after irradiation populations II and V did not differ significantly in the length of thallus but showed a significant difference in its surface area. A significant difference in the length in the thallus noted on the last day of measurement, i.e. 18 days after irradiation proves that in population II the growth rate was higher. Population III and V did not differ significantly in the length of thallus 6 days after irradiation, a significant difference found on further days of measurement proved that the growth rate of population V was lower than in the remaining populations. Populations III and IV measured 6 days after irradiation did not differ significantly in the length of thallus, this difference became significant on further days of measurement. As far as the surface area of thallus is concerned, the differences between all the populations were not significant on all days of measurement. Within 6–18 days after the day of irradiation the length of thallus increased 2.6–2.8 times in populations I, II, III, IV and 2.2 times in population V.

Some irregularities in the development of thallus observed in our experiments after the growth of gemmae had been initiated, were different in the individual combinations. Besides normally growing bipolar thalluses, we observed thalluses either monopolar or entirely inhibited in growth, or such which did not develop uniformly on both poles as well as thalluses that early initiated the development of a greater (mostly three) number of lobes (figure). At the beginning of the experiment, 2 days after irradiation, the highest frequency of bi-polar and multilobate thalluses was observed in the control combinations and in combinations exposed to 500–4000 mR (Table 3). At the end of the experiment (16 days after irradiation) this high frequency subsisted mostly in the control combinations and those subjected to 500–2000 mR. At the beginning of the experiment the highest frequency of multilobate thalluses was observed in populations exposed to 3000 and 5000 mR, after two weeks however, this high frequency subsisted only in population I exposed to 2000 mR. On the first day of measurement a decreasing frequency of normally growing plants was observed in populations I and V subjected to 5000 mR and higher doses. In the remaining populations (II, III, IV) the differences in the growth of thalluses was not so distinctly manifested. This may probably be explained by a certain retardation observed in the development of these populations. On the next day of measurement a decreasing frequency of normally growing plants was observed starting from: 5000 mR (populations I and II), 4000 mR (population III) and 2000 mR (population V). Population IV appeared to be most uniform in this respect. The advantageous effect of low doses (500–4000 mR) on the normal growth of thalluses as compared with the control population could be observed in population II. In populations III, IV and V the advantageous effect of low doses was not observed, moreover, the frequency of normally growing thalluses decreased with the increasing irradiation doses.

The drawings of the growing thalluses of *M. polymorpha* L. (presented in the plate) made 10 days after irradiation, illustrate the growth and the degree of diffe-

rentiation of the lobes in various populations subjected to different exposures. The drawings (made in scale) show the differences in growth and shape of thalluses within populations subjected to different exposures, as well as the differences among individual populations.

Table 3

Percentage of bipolar and multipolar thalluses of *Marchantia polymorpha* L.

No. of population	Total accumulated doses of gamma irradiation from cobalt-60 (mr)									
	0	500	1000	2000	3000	4000	5000	6000	8000	10 000
after 2 days										
I	97(7)	86(10)	75(7)	76(12)	79(32)	74(17)	58(22)	69(1)	62(7)	50(0)
II	60(0)	55(1)	46(1)	34(1)	64(38)	40(0)	45(18)	35(0)	54(8)	25(0)
III	48(6)	50(8)	24(1)	32(0)	55(10)	28(1)	50(10)	24(1)	31(1)	27(6)
IV	32(1)	21(1)	34(1)	24(0)	27(1)	40(8)	25(0)	23(1)	21(0)	24(0)
V	48(1)	42(1)	63(26)	56(12)	62(15)	65(13)	45(7)	45(12)	17(1)	34(6)
after 16 days										
I	84(14)	90(14)	100(9)	100(39)	97(3)	97(0)	81(4)	89(3)	62(0)	74(0)
II	73(0)	89(0)	93(2)	70(0)	77(0)	75(2)	54(0)	55(0)	56(0)	59(0)
III	91(3)	92(4)	87(3)	85(1)	78(1)	64(1)	77(1)	70(1)	65(1)	58(0)
IV	45(3)	39(1)	35(0)	33(0)	36(0)	43(0)	44(0)	35(0)	36(0)	27(0)
V	58(0)	45(1)	49(0)	25(0)	23(0)	20(0)	25(0)	22(0)	25(0)	23 0)

Population I is characterized by either bilateral or multilobate large thalluses. The most regular shape of the thalluses observed in control plants is maintained over the exposures ranging from 500 to 2000 mR. A slight waviness of marginal line of thallus observed in plants exposed to 2000 mR becomes more distinct in plants exposed to 3000 mR and results in an irregular growth (tiny lobes, dentation and outgrowths). Within exposures to 4000–10000 mR the growth of thallus becomes more and more irregular, the thalluses are differently shaped, and plants with distinctly thickened thalluses are observed. The plants growing less intensive at one of their poles appear starting from an exposure to 5000 mR. An additional reduction in the size of the thallus was observed in this population when exposed to 8000 and 10000 mR. Population II, taken from a habitat with a low natural radioactivity is characterized by extensive thalluses, this is distinctly seen under the exposure to 500–3000 mR. The slight waviness of the marginal line observed under exposure to 0–3000 mR becomes more pronounced under exposures to 4000–6000 mR, and results in formation of lateral lobes. In some thalluses of this population exposed to 8000 mR, the marginal line is strongly deformed, and the formation of numerous lateral lobes with a simultaneous reduction in the size of thallus is observed. The thalluses are broad, thickened, their growth is distinctly inhibited. In population III the wavy marginal line of the thallus and tiny lateral lobes in its nonapical portion are observed beginning with an exposure to 500 mR. Starting from 4000 mR, moreover, a distinct widening and thi-

ckening of thalluses is seen, the branching of the apical portion of the thallus is also more frequently encountered. Under exposures to 8000 and 10000 mR a remarkable reduction in size and nonuniform growth at both poles of the thallus are observed. In population IV the frequency of plants characterized by non-uniform growth at both poles of the thallus and by a strongly differentiated marginal line is very high even under low exposures. The thalluses in this population do not differ in size, more remarkable differences are observed under exposure to 10000 mR. The most changed is population V. Even in control plants its distinctness is manifested by the waviness of the marginal line. This population exposed to 500 mR forms distinct tiny lateral lobes; starting from 3000 mR one observes a disproportion in the growth of both poles of the thallus. The formation of numerous lateral lobes on different planes is observed starting from the exposure to 6000 mR. A distinct reduction in size of thallus due to higher exposures is shown on drawings.

Representative outlines of the thalluses presented in the plate are consistent with results of biometric measurements and their analysis.

DISCUSSION

Since it follows from the investigations of La Rue and Narayanaswami (1957) and Taren (1958) that gemmae within the cups show inhibition of growth under the influence of auxines, the experiments described in the present paper were based on already sprouted gemmae. The results obtained revealed a significant difference in the reaction to irradiation (manifested in the growth of thallus) between the ecological population of *M. polymorpha* L. nonirradiated in natural conditions, and the populations derived from radiation anomalies (Sarosiek and Woźakowska-Natkaniec 1967). It was found that doses 500 and 1000 mR exert a better stimulative effect on the growth of thallus in the ecological population not irradiated in natural conditions than in populations derived from radiation anomalies. In the population not irradiated in natural conditions, the maximum stimulation of the growth of thallus occurred also under a dose higher than that required for analogical maxima in populations derived from radiation anomalies. The differences in the reaction to higher exposures were also manifested in the inhibition of growth of thallus. In the population not irradiated in natural conditions the inhibition of thallus growth took place after exposures to 5000 and 6000 mR, whereas in populations irradiated in natural conditions this effect was observed after exposures to 8000 and 10000 mR. Similar although not so remarkable, differences of growth due to different exposures were noted between ecological populations of *M. polymorpha* L. derived from different radiation anomalies (between population II and population IV and V). The differences between populations III and IV revealed in some cases were smaller and not significant. It is known from the former investigations (Sarosiek and Woźakowska-Natkaniec 1967) that differences between these two populations were very small. The reactions to

acute gamma irradiation shown by populations irradiated in natural conditions being different from that shown by the population originally not irradiated prove a different radiosensitivity of these populations. The inhibition of growth occurring in the nonirradiated population after exposures to lower doses allows to infer that its radiosensitivity is higher than that of populations derived from radiation anomalies, although in both ecological groups of *M. polymorpha* L. the reaction to irradiation occurred for the lowest dose (500 mR). A better tolerance to higher doses of gamma irradiation, exhibited by populations of *M. polymorpha* L. derived from radiation anomalies, can be explained by the fact that the activity of growth auxines had been changed in those populations at the stage of their adjustment. Skoog (1935) while investigating the effect of irradiation on the growth of *Helianthus* sp. demonstrated the inactivation of auxines due to X-radiation, and according to Gordon and Weber (1950, 1955) the rate of inhibition of the synthesis of auxines increases with the irradiation dose. Hence, it may be supposed that the populations of *M. polymorpha* L. derived from radiation anomalies being adapted at the stage of adjustment, their reaction to irradiation (manifested in inhibition of production of their growth substances) would not be so strongly pronounced as in populations which in natural conditions were not exposed to chronic radiation.

According to Miller and Sparrow (1965) who did not observe any stimulation of the growth of thallus in *M. polymorpha* L. after exposures within 3.5–7.0 kR, the stimulative effect of low-level ionizing irradiation is not yet sufficiently known.

Owing to the lower level of gamma radiation used in our experiments the stimulation of growth of the thallus in *M. polymorpha* L. could be demonstrated for exposures to 1000–4000 mR, and in some cases to 500 and 5000 mR. Stimulation of the growth of plants exposed to low-level chronic irradiation was also obtained by Donini and his coworkers (1964). Mergen and Johansen (1964) observed stimulation of the growth of roots and increase in fresh weight in *Pinus rigida* Mill. Mc Cormick and Rushing (1964) report stimulation of the growth of roots in *Sedum pulchellum* Michx. subjected to gamma irradiation ranging within 1450–5800 R at an intensity of 1450 R/min. According to Süss and Haisch (1964) the borderline between stimulation and inhibition is in the case of irradiation vague and depends on an unknown variability. Johnson (Gunckel 1965) found that plants which exhibited stimulation of growth due to X-irradiation in the first stage of their development differed very little from control plants when growing older. From the present investigations on *M. polymorpha* L. it follows that the differences in growth rate between the individual ecological populations become wider in the further days of observation. Populations I and II have a similar growth rate, whereas population V derived from the highest radiation anomaly shows the greatest differences as compared with the remaining ones.

The inhibition of the apical growth of thallus in *M. polymorpha* L. noted for higher radiation doses is accompanied by the formation of numerous irregular lobes which develop not only in the wing area (Miller, Sparrow, Rogers 1965) or in the region of the midrib (Miller and Sparrow 1965) but in various sites

of the thallus. The development of accessory lobes and irregular nonapical outgrowths as well as the stimulation of the growth of thallus after lower doses is probably conditioned by the acceleration of mitosis caused by irradiation. This phenomenon described by Quastler and Baer (Gunckel 1965) occurred provided the rate of cell elongation was not inhibited. The difference in radiosensitivity between apical and nonapical cells of thallus in *M. polymorpha* L. can be explained (Miller and Sparrow, 1965) by the differences in the size of the nuclei. According to the quoted authors, in apical cells the nuclei are larger than in nonapical ones, therefore their tolerance to irradiation is smaller. The population not irradiated in natural conditions differs remarkably from the populations derived from radiation anomalies in respect to the formation of accessory lobes and to other abnormalities of the thallus; these differences show that these populations have also a different radiosensitivity.

CONCLUSIONS

1. Sprouted gemmae of *M. polymorpha* L. taken from an ecological population originally nonirradiated and from ecological populations derived from radiation anomaly react to acute low-level gamma irradiation (min. 500 mR, max. 10000 mR).
2. Exposure to 1000—4000 mR stimulated the growth of the thallus of *M. polymorpha* L. in all cases, in some cases the stimulative effects were extended over the range 500 to 5000 mR.
3. Exposure to 6000—10000 mR inhibited apical proliferation inducing initiation of nonapical outgrowths in various regions of the thallus, and particularly a more pronounced lobation in the wing area.
4. In the ecological population of *M. polymorpha* L. originally nonirradiated, the reaction to irradiation is similar to that shown by populations of *M. polymorpha* L. derived from radiation anomalies, it however differs as regards the irradiation range.
5. Maximum stimulation of the growth of thallus in the ecological population of *M. polymorpha* L. originally nonirradiated occurred after exposure to 4000 mR, while in populations of *M. polymorpha* L. derived from radiation anomalies the maximum was observed after exposure to 3000 mR. Inhibition of apical proliferation of the thallus in the population of *M. polymorpha* L. originally nonirradiated occurred after exposure to 5000 and 6000 mR, being more pronounced after exposure to 8000 and 10000 mR. In the ecological populations of *M. polymorpha* L. derived from radiation anomalies an analogous process occurs for the exposures to doses as high as 8000 and 10000 mR.
6. In some cases the inhibition of apical proliferation of the thallus of the naturally irradiated ecological populations of *M. polymorpha* L. is preceded by the initiation of nonapical outgrowths of the thallus.
7. The differences between the individual ecological populations of *M. polymorpha* L. become greater in the course of development of the irradiated gemmae,

the number of abnormally growing thalluses of *M. polymorpha* L. increasing beginning with the exposure to 5000 mR.

8. The growth rate of the thalluses of ecological population II is similar to that of ecological population I. Population V differs markedly from the remaining populations as regards growth rate.

9. The reaction to low-level gamma irradiation observed in the ecological population of *M. polymorpha* L. not irradiated under natural conditions, shows a higher radiosensitivity of this population compared with the ecological populations of *M. polymorpha* L. derived from radiation anomalies. Thus the ecological populations of *M. polymorpha* L. derived from radiation anomalies show a higher tolerance to irradiation.

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Wpływ niskich dawek promieniowania gamma na wzrost *Marchantia polymorpha* L. z kilku ekologicznych populacji

Streszczenie

Autorzy w poprzedniej swej pracy (J. Sarosiek i H. Wożakowska-Natkaniec 1967) stwierdzili istotne różnice między ekologicznymi populacjami *Marchantia polymorpha* L. pochodzącymi z naturalnych siedlisk o różnej intensywności naturalnego, chronicznego promieniowania.

W niniejszej pracy, wykiełkowane już rozmnożki *M. polymorpha* L. z 5 ekologicznych populacji wyróżnionych w poprzedniej pracy, poddano różnym dawkom promieniowania gamma ^{60}Co o niskim zakresie: 500, 1000, 2000, 3000, 4000, 5000, 6000, 8000 i 10000 mR, o mocy dawki 1000 mR/h.

Wykiełkowane rozmnożki *M. polymorpha* L. z ekologicznej populacji nie napromieniowanej w warunkach naturalnych i z ekologicznych populacji pochodzących z naturalnej anomalii radiacyjnej, wykazują reakcję na zastosowane dawki promieniowania gamma ^{60}Co (min. 500 mR, max. 10000 mR). Dawki promieniowania w granicach od 1000 do 4000 mR we wszystkich przypadkach stymulują wzrost plechy *M. polymorpha* L.; w niektórych przypadkach efekt stymulacji stwierdzono już przy dawce 500 mR, a nawet przy dawce 5000 mR. Dawki w granicach od 6000 do 10000 mR ograniczają apikalną proliferację plech. Jednocześnie wraz z ograniczeniem apikalnej proliferacji plechy, powodują inicjację pozaszczytowych wyrośli w różnych miejscach plechy, oraz silniejsze jej rozczłonowanie, szczególnie w partii szczytowej.

Ekologiczna populacja *M. polymorpha* L. w naturalnych warunkach nie napromieniowana wykazała podobną reakcję na promieniowanie, jak ekologiczne populacje *M. polymorpha* L. pochodzące z siedlisk o podwyższonej naturalnej radioaktywności, przy czym reakcje te występują w innym zakresie dawek promieniowania. Ekologiczna populacja *M. polymorpha* L. nie napromieniowana w naturze wykazuje maksymalną stymulację wzrostu plechy przy dawce 4000 mR, natomiast ekologiczne populacje *M. polymorpha* L. napromieniowane w naturze już przy dawce 3000 mR. Ograniczenie apikalnej proliferacji plechy u ekologicznej populacji *M. polymorpha* L. nie napromieniowanej w warunkach naturalnych występuje już przy dawkach 5000 i 6000 mR, i wzrasta przy dawkach 8000 i 10000 mR, natomiast analogiczne zjawisko u populacji *M. polymorpha* L. napromieniowanych w naturze występuje dopiero przy dawce 8000 i 10000 mR. Inicjacja pozaszczytowych wyrośli plechy populacji *M. polymorpha* L. napromieniowanych w naturze, w niektórych przypadkach poprzedza zahamowanie apikalnej proliferacji plechy.

Wraz z rozwojem napromieniowanych rozmnożek *M. polymorpha* L. pogłębiają się różnice w ich rozwoju między poszczególnymi ekologicznymi populacjami. Wraz ze wzrostem dawek promieniowania od dawki 5000 mR wzwyż, wzrasta ilość nienormalnie rosnących plech.

Tempo rozwoju plech populacji *M. polymorpha* L. pochodzącej z naturalnego siedliska o najniższej radioaktywności, jest zbieżne z tempem wzrostu plechy populacji w naturalnych warunkach nie napromieniowanej, natomiast tempo wzrostu populacji pochodzącej z naturalnego siedliska o najwyższej radioaktywności jest najbardziej odrębne od tempa wzrostu plech pozostałych ekologicznych populacji.

Reakcja na zastosowane dawki promieniowania gamma ekologicznej populacji *M. polymorpha* L. nie napromieniowanej w naturze wskazuje na wyższą jej radiowrażliwość, niż radiowrażliwość ekologicznych populacji *M. polymorpha* L. pochodzących z siedlisk o podwyższonej naturalnej radioaktywności. Ekologiczne populacje *M. polymorpha* L. pochodzące z naturalnej anomalii radiacyjnej wykazują więc wyższą tolerancję wobec promieniowania.