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EFFECTS OF GAMMA RADIATION
ON LICHENS

Progress Report

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PROGRESS REPORT ABSTRACT

This past year was spent in the completion of the Parmelia sulcata study of the Enterprise Radiation Forest. The extended study (December through June) of irradiated Cladonia sylvatica podetia was carried out during this period.

The Cladonia study indicated that lichens respond to gamma radiation, basically only after passing through a prolonged growth period. Lichens kept in summer conditions (in a growth chamber) during the seven month study period did not exhibit radiation damage as did irradiated field lichens. This was conclusively shown in photosynthesis experiments and light microscopy studies. Evidence from oxygen uptake and usnic acid content studies was much too variable and must be repeated. A means to measure podetial tensile strength was perfected and this test will be used in the final tests of this study.

The investigator spent 100% of the summer and 10% of the academic year on the project.

During the past year data analysis and experimentation was carried out with chronically and acutely irradiated lichens. The analysis included the completion of the Enterprise Radiation Forest study and the beginning of the Parmelia subaurifera study, and the examination of Xanthoria polycarpa apothecia. The experimentation dealt with an extended period study (December through June) of the effects of gamma radiation of Cladonia sylvatica. In this study photosynthesis, respiration, and usnic acid concentration was monitored. Also, a technique for the determination of podetial tensile strength was perfected. Cytological changes of Cladonia podetica were observed with the light microscope.

A manuscript detailing with the usnic acid study, (Funky, 1974) was written and submitted to the New Phytologist. A manuscript of the photosynthesis study (Barstow, 1974) was written and is currently being circulated for critical comments. The Parmelia sulcata manuscript was submitted to the North Central Forest Experiment Station in Rhinelander, Wisconsin, for inclusion in the post-irradiation volume being published by ERDA (Erbisch, 1976).

Parmelia Study

The results of the Parmelia sulcata study indicated that this lichen is affected more by gamma radiation than microclimatic changes. Microclimatic changes were suggested by Brodo (1964) as being the primary cause of lichen damage in the Brookhaven Radiation Forest.

Damage was not manifested by P. sulcata until the late spring of the year following the radiation. This damage was seen macroscopically through a cessation or slowdown of growth, browning of the thallus, and an increase in the amount of rhizinal branching. Microscopically, this damage was seen as a coalescing and browning of fungal hyphae and a disintegration of algal chloroplastids. (See Table 1 for general information, Table 2 for growth data.) Bark temperature

was monitored for it was thought that this might indicate an area of environmental stress. An increase of bark temperature would increase the rate of water evaporation from the lichen; however, the increase in bark temperatures did not occur (Table 3). Therefore, temperature changes were not responsible for the changes exhibited by the lichens. Other climatic changes; i.e., increase in solar radiation, also did not affect the lichens. Lichens from trees 2001, 2002, and 2003 were in the same approximate area and within the same kind of climatic changes, yet only lichens on tree 2001 died. The lichens on tree 2001 received the most radiation of any lichens in the study area.

Another lichen in the area was also studied, Parmelia subaurifera. Although not all the data has been analyzed, it appears that the results with this species parallels that of P. sulcata.

Xanthoria polycarpa study

Not all of the 1000 or so slides have been examined yet, but it does not appear that ascus and ascospore development was affected in the lichens collected. This study will be completed by early June of this year.

Cladonia sylvatica study

C. sylvatica podetia were irradiated in November, 1974 and harvested monthly through June and examined. The point of this study was to prove the hypothesis that lichens must pass through a prolonged period suitable for growth before radiation damage is manifested. Immediately after irradiation lichens were placed either in a growth chamber or in the field. Non-irradiated lichens (controls) were included with each set of irradiated lichens. The growth chamber lichens were kept at summer conditions throughout the study period. It was assumed that the growth chamber lichens would not change but the growth chamber ones would in the late spring. Photosynthesis (O_2 uptake), respiration (O_2 uptake), microscopic structure, and usnic acid levels were monitors. With the techniques used only the photosynthetic and the structure studies proved reliable.

The results of the photosynthetic study are shown in Figure 1 and Table 4. The results not only showed differences between irradiated and control lichens, but also differences between field and growth chamber grown lichens.

The structural study has shown that coalescing and browning of hyphae did not take place until May. Algal cells began to break up soon after irradiation, but not extensively until the spring - most damage was seen in irradiated field lichens. More data will be forthcoming from this phase of the study.

The respiration data can be seen in Figure 2 and Table 5. The results are extremely variable and must be repeated to determine if this variability is real or due to experimental technique. However, the results do show that all of the lichens in the study approach the low respiration rates of summer (dormant?) lichens. Perhaps this indicates that oxygen uptake is not affected by gamma radiation.

The usnic acid analysis has proven inconclusive thus far. This analysis will be repeated. It was expected that the usnic acid content of the irradiated field grown lichens would decrease in the spring while the acid content of the rest would remain unchanged.

It had been hoped that the tensile strength experiment could have been included in the study; however, the equipment arrived too late to include it. The technique has been perfected and repeatable results are now being obtained (Table 6). A decrease in tensile strength appears to be the first structural change evidenced by irradiated lichens. This technique will be included in the repeat of the study when oxygen uptake and usnic acid content are re-evaluated.

The indications are that when the Cladonia experiment is repeated there will be conclusive proof that lichens need a prolonged growth period before radiation damage is manifested. This would, in turn, indicate that lichens are not as resistant to gamma radiation as reported from short-term experiments.

Tree Number	Tree Species	Distance from Source (meters)	Exposure rates (Roentgens) Daily R/20 hr. day	Cumulative Total R	<u>P.</u> <u>Number of</u> <u>sulcata</u> <u>thalli</u> <u>Studied</u>
2001	Acer rubrum	5.1	900	122,272	5
2002	Acer rubrum	7.8	580	78,797	10
2003	Acer rubrum	7.7	590	80,156	7
3008-9	Acer rubrum	8.8	490	66,570	13
3040-41	Acer saccharum	11.8	310	42,116	11
3064	Acer rubrum	22.4	84	11,412	3
3164	Fraxinus niger	33.3	30.6	4,157	4
3176	Acer rubrum	39.6	19.0	2,581	4
3194	Acer rubrum	44.1	14.4	1,956	4

Table 1.

Location and radiation data for the *Parmelia sulcata* thalli studied at Site 1 of the Enterprise Radiation Forest. The lichens studied were within 30 cm of the DBH mark and in direct line with the ¹³⁷Cs source.

<u>Tree Number</u>	<u>Average Radial Growth Increase, in Millimeters</u>		
	April-April 1972 1973	April-Nov. 1973 1973	Nov.-Nov. 1973 1974
2001	0.76	-1.72	-0.98
2002	1.22	0.34	0.53
2003	1.10	0.33	0.38
3008-9	1.37	0.70	0.94
3040-41	1.32	0.97	1.28
3064	2.20	1.00	1.40
3164	1.15	0.45	0.85
3176	1.04	0.94	0.92
3194	1.20	1.75	1.10
Controls	1.23	0.73	1.23

Table 2.

Increase in average radial growth during the radiation period (April, 1972 - April, 1973), the period following radiation in which damage was manifested (April, 1973 - November, 1973), and the following year (November, 1973 - November, 1974).

Site: Tree with Probe	Year		
	1971 Pre-irradiation Period	1972 Irradiation Period	1973 Post-Irradiation Period
2002	18	4	14
2003 (average of 2 probes)	16	11(5)	26
3040-41	16	11(6)	15
3184	0	12(6)	10
3188 (average of 2 probes)	3.5	12(2)	7

T₁ Table 3.

Number of days, approximately 15 May through 15 September, in which bark temperature exceeded ambient forest temperature by 6°F. The figure in parenthesis is the number of days in which the bark temperature remained 6°F above ambient for more than 6 hours.

	<u>Field Control</u>	<u>Field Irradiated</u>	<u>Growth Chambers Control</u>	<u>Growth Chambers Irradiated</u>
Dec.	5887(1339)	1998(413)	4054(1588)	189(200)
Jan.	4130(95)	521(134)	3029(1181)	130(127)
Feb.	-	-	-	-
Mar.	1863(510)	25(20)	2434(408)	153(141)
April	3653(826)	271(11)	2624(580)	53(56)
May	3520(410)	155(17)	857(56)	30(53)
June	4150(969)	74(85)	398(273)	85(82)

Table 4. Comparison of labeled CO_2 uptake by irradiated and non-irradiated - field and growth-chamber grown Cladonia sylvatica podetia. The numbers represent average counts per minute per gram of dry tissue. The number in parenthesis equals one standard deviation.

	<u>Field Control</u>	<u>Field Irradiated</u>	<u>Growth Chamber Control</u>	<u>Growth Chamber Irradiated</u>
Dec.	1816	1155	323	323
Jan.	352(?)	981	535	237
Feb.	2606	649	570	269
Mar.	2073	2398(?)	2003(?)	940
April	894	939	1038	479
May	780	234	553	514
June	353	250	349	195

Table 5. Comparison of oxygen uptake by irradiated and non-irradiated - field and growth chamber grown Gladonia sylvatica podetia. The numbers represent average ml of O₂ taken up/gram of dried podetia/hour.

Non-irradiated growth chamber grown		Irradiated growth chamber -grown
287.5 gm/sq. mm.		273.2 gm/ sq. mm.
585.6		205.2
756.5		374.0
699.4		240.6
429.9		174.2
197.5		81.3
1002.6		205.2
255.2		397.6
<hr/>		
-Average of tensile strength	530	237
Standard deviation	280	97

Table 6. Some representative data from the tensile strength experiment. All of the lichens had been kept in the growth chamber for more than 1 year and were all in poor shape. Non-irradiated podetia tensile strength was much more variable than irradiated podetia. All numbers represent the force needed to break a podum and is given in grams/ square millimeter of podetium.

Figure 1. Labeled CO_2 uptake by irradiated (1000 krad) and non-irradiated Cladonia sylvatica podetia. Growth chamber lichens were kept at summer conditions
- 75° F day, 60° F night, 16 hr. light, 8 hr. dark.

- = non-irradiated, field grown
- = irradiated, field grown
- = non-irradiated, growth chamber grown
- = irradiated, growth chamber grown

Figure 2. Oxygen uptake of irradiated (1000 krad) and non-irradiated Cladonia sylvatica podetia. Growth chamber lichens were kept at summer conditions - 75° F day, 60° F night, 16 hr. light, 8 hr. dark.

- = non-irradiated, field grown
- = irradiated, field grown
- = non-irradiated, growth chamber grown
- = irradiated, growth chamber grown

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