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Fungal Biomass Responses in Oil Perturbated Tundra at Barrow, Alaska

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ABSTRACT. The effects of two Prudhoe Bay crude oil treatments of 5 and 12 l/m² on fungal hyphae/gm dry wt of soil and on the grams of mycelium/m² were followed in polygonal tundra for three seasons. A significant depressing effect of oil on fungal hyphae was evident over three seasons. However, no significant difference between oil treatments was recorded. The moisture content of the soil appeared to influence the mobility of the oil. Shifts occur in fungal populations in the presence of oil and the presence of oil biodegradation by filamentous fungi was detected. The influence of bulk density on fungal populations and the penetration of oil into tundra soil is discussed.

RÉSUMÉ. Pendant trois saisons, on a suivi dans les sols polygonaux de la toundra, les effets de deux traitements du brut de Prudhoe Bay, 5 et 12 l/m², sur des "hyphes" (pucerons) de mycetes, en comparaison du poids du sol, à sec, en grammes et par rapport au poids de mycellium en grammes. Au cours de ces trois saisons, un effet significatif déprimant du pétrole était évident sur les "hyphes" de mycetes. Cependent, on n'enregistrait aucune différence significative avec les deux traitements au pétrole. La quantité d'humidité du sol paraissait influencer la mobilité du pétrole. Des changements intervenaient dans les populations de mycetes, en présence de pétrole et en présence de la biodegradation du pétrole par les mycetes filamenteuses. On discute de l'influence de la densité de masse sur les populations de mycetes et sur la pénétration de pétrole dans le sol de la toundra.

Traduit par Alain de Vendigies, Aquitaine Co. of Canada Ltd.

INTRODUCTION

In 1975 a series of oil treated plots were established in polygonal tundra on the area previously used for the IBP (International Biological Program) studies under the Tundra Biome. The overall objective of this study is to investigate the persistence of crude oil in tundra and its effect on the belowground ecosystem. The effect on fungi is only one part of this comprehensive, integrated study. The fungal biomass has been ascertained each season for the past three seasons and the impact of two different levels of crude oil application followed to ascertain population shifts in the soil profile as the oil penetrated into the tundra and to follow these shifts over at least a six year period. In addition, isolation of soil fungi from the plots was carried out in 1976 and a large number of isolates were screened for the ability to tolerate or utilize crude oil. In this paper we are reporting on the results after three seasons.

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MATERIAL AND METHOD

The choice of this area was based on our recognition that five years of careful investigation by our laboratory under the Tundra Biome Program had provided us with much baseline date useful in exploring all effects which might result from oil in the rhizosphere (Miller *et al.*, 1974: Laursen & Miller, 1977; Miller, *et al.*, 1973).

A polygon system on IBP Site 4 was selected for the low center polygon plots and an area on Site 1 for the high center polygon plots. The plots are basically rectangular but most conform to the desired habitat, and range in size from 6.3 to 14 m^2. The following plots were established and designated as indicated in Table 1:

TABLE 1. Plot Types and the Abbreviations for Each Treatment

Plot Type	Control	5 l/m^2	12 l/m^2
High Center Polygon	HCC	HC5	HC12
Low Center Polygon Basin	LCBC	LCB5	LCB12
Low Center Polygon Rim	LCRC	LCR5	LCR12
Low Center Polygon Trough	LCTC	LCT5	LCT12

Prudhoe Bay crude oil was applied by pouring it through a perforated plate to insure even coverage at the rate of 5 and 12 l/m^2 as indicated in the table above. There was no runoff and only very local, small pools at the heavier concentration.

Soil cores were taken to a depth of 8 cm from the plots with a 5 cm diameter soil corer especially designed for Arctic work (Laursen, 1975). Cores were placed in whirl-pac bags and transported directly to the laboratory only 8 km (5 mi) away and refrigerated until the samples were examined. Meters of fungal hyphae per gram dry weight of soil (Table 2) was determined using a modified Jones-Mollison (1948) technique developed by Laursen and Miller (Laursen, 1975; Laursen & Miller, 1977). Fungal mycelium was measured five times in the first season (Table 3) and three times each season in 1976 and 1977 as shown in Tables 7 and 11. Sampling was done at 1, 3 and 6 cm in 1975 and 1977 but only at 1 and 6 cm in 1976.

Isolation of fungi from all plots in 1976 was made directly from soil by placing pieces of organic material on a malt/agar medium. In addition, bits of organic material were ground up and small amounts placed on the surface of the agar. The plates were incubated at 5 °C and 20 °C. Subcultures were made from fungal colonies into screw cap agar tubes and shipped to our laboratory at Virginia Tech to be screened. The fungi were grown in liquid malt and after adequate growth, this mycelium was used to inoculate a Bushnell-Haas liquid medium using crude oil as the only carbon source. Fungi which visually grew in this medium were selected for further study.

TABLE 2. 1975 Fungal Hyphae in m/g dry wt Soil

		Day[1]																			
		183				196				210				224				234			
Treatment	Depth[2]	LCT	LCR	LCB	HC	LCT	LCR	LCB	HC	LCT	LCR	LCB	HC	LCT	LCR	LCB	HC	LCT	LCR	LCB	HC
Control	1	210	591	1251	483	2186	986	391	315	650	1517	574	1375	174	619	457	1602	871	697	325	1305
	3	470	206	1471	685	577	451	185	344	276	312	217	472	804	312	146	367	1819	360	347	1168
	6	71	236	529	422	488	492	122	51	35	458	221	558	20	232	102	126	141	420	93	639
5 l/m² crude oil	1	297	410	703	555	962	762	491	390	991	387	247	858	222	482	237	549	231	584	271	448
	3	177	576	277	407	412	270	82	214	407	202	324	239	454	258	143	196	533	239	406	781
	6	287	820	146	665	115	213	394	194	349	469	309	129	169	411	140	101	349	420	46	415
12 l/m² crude oil	1	338	225	524	250	123	271	361	840	447	310	358	430	1005	411	273	1355	326	547	198	635
	3	1287	6-	181	275	446	311	362	148	654	377	298	—	103	660	148	563	333	607	259	594
	6	1386	149	87	10	464	32	264	—	893	311	97	83	465	107	198	220	313	558	247	498

1. Refers to Julian days in 1975 (183 = July 2, 1975, 196 = July 15, 1975, 210 = July 29, 1975, 224 = Aug. 12, 1975, 234 = Aug. 22, 1975.
2. Depth 1 = 0-2 cm, 3 = 2-4 cm, 6 = 4-8 cm.

TABLE 3. 1975 Fungal Biomass in g/m²

Treatment Depth[2]		Day[1] 183				196				210				224				239			
		LCT	LCR	LCB	HC	LCT	LCR	LCB	HC	LCT	LCR	LCB	HC	LCT	LCR	LCB	HC	LCT	LCR	LCB	HC
Control	1	.19	1.16	1.72	2.70	1.95	1.65	1.06	1.96	1.30	3.88	1.66	7.09	.31	2.69	1.35	7.66	1.36	4.16	1.01	8.18
	3	.84	85	2.78	5.23	.90	1.54	65	3.22	.58	1.11	.78	3.34	1.97	2.07	.56	2.97	4.25	2.51	1.35	8.88
	6	.55	2.56	2.89	4.49	2.24	4.18	1.11	.75	.26	5.41	1.87	6.39	.20	2.34	.98	2.01	2.92	5.03	1.07	5.90
5 l/m²	1	.55	.81	2.31	2.90	1.32	3.02	1.73	3.41	1.84	1.36	1.00	5.95	.65	2.75	.90	2.18	.55	1.60	1.09	2.79
	3	.17	.70	.89	1.79	.67	1.59	.28	1.56	.66	.81	1.61	2.17	.72	1.67	.67	1.11	.71	1.34	1.39	5.47
	6	.65	6.97	.81	5.80	1.61	3.07	2.82	3.27	1.97	4.86	4.55	1.79	1.09	5.26	1.70	1.33	1.28	4.58	.33	3.34
12 l/m²	1	.68	.72	1.36	1.45	.34	1.16	1.46	5.70	1.28	1.32	1.43	2.95	2.57	1.49	1.14	9.84	1.08	1.89	.60	4.92
	3	1.34	.25	.48	1.[illegible]	1.42	1.73	1.48	1.28	1.87	2.12	1.81	—	.28	1.93	.49	4.95	.99	2.61	.93	7.25
	6	4.93	1.86	.62	.15		.62	2.37	—	4.51	4.75	1.45	1.49	3.46	1.45	1.53	3.48	1.98	6.20	2.48	7.99

1. Refers to Julian days in 1975 (183 = July 2, 197[illegible] July 15, 1975, 210 = July 29, 1975, 224 = August 12, 1975, 234 = Aug. 22, 1975
2. Depth 1 = 0-2 cm, 3 = 2-4 cm, 6 = 4-8 cm.

The Statistical Analyses System (SAS) was used to analyze the data following data reduction which involved a combined PL/I-SAS program previously outlined by Laursen (1975). The experimental design is a four way analysis of variance with no replication. The main effects are habitats — low center basin, low center rim, low center trough, high center; treatments (oil spilled) — none, 5 l/m², 12 l/m²; depths — 0-2 cm, 2-4 cm, 4-8 cm; and days — five days for 1975, three days for 1976 and 1977.

RESULTS

The analyses of fungal mycelium per gram dry weight of soil is reported in Tables 4, 8 and 12 for 1975, 1976 and 1977. The most important analyses was the control vs. 5 and 12 l/m² of oil which was significant for all three years. The contrast between 5 and 12 l/m² of oil was not significant. The contrast between the dry plots (LCR & HC) and the wet plots (LCT & LCB) was significant in 1975 but non-significant in 1976 and 1977. Differences in depth were significant in 1975 and 1976 but not in 1977.

The analyses of grams of mycelium/m² is reported in Tables 5, 9 and 12 for 1975, 1976 and 1977. The important analyses of control vs. 5 and 12 l/m² of

TABLE 4. Analyses of Fungal Hyphae in m/g dry wt Soil
1975

Effect	Significance Level
HABITAT	.0039
CON 1 LCR & HC vs. LCT & LCB[1]	.0016
CON 2 LCR vs. HC	non-significant
CON 3 LCT vs. LCB	non-significant
PLOT	.0007
CON 4 Control v. 5 & 12 l/m² crude oil	.0002
CON 5 5 l/m² vs. 12 l/m² crude oil	non-significant
DEPTH	.0001
CON 6 0-2 cm vs. 2-4 cm & 4-8 cm	.0001
CON 7 2-4 cm vs. 4-8 cm	.0120
DAY	non-significant
HABITAT*PLOT	non-significant
HABITAT*DEPTH	non-significant
HABITAT*DAY	.0169
PLOT*DEPTH	.0075
PLOT*DAY	non-significant
DEPTH*DAY	.0267
HABITAT*PLOT*DEPTH	non-significant
HABITAT*PLOT*DAY	.0004
HABITAT*DEPTH*DAY	non-significant
PLOT*DEPTH*DAY	non-significant

1. CON = Contrast, see Table for abbreviations to plot types

TABLE 5. Analyses of Fungal Biomass in g/m²
1975

Effect	Significance Level
HABITAT	.0001
CON 1 LCR & HC vs. LCT & LCB[1]	.0001
CON 2 LCR vs. HC	.0001
CON 3 LCT vs. LCB	.0001
PLOT	non-significant
DEPTH	.0001
CON 6 0-2 cm vs. 2-4 & 4-8 cm	non-significant
CON 7 2-4 cm vs. 4-8 cm	.0001
DAY	.0001
CON 8 183 vs. 196[2]	non-significant
CON 9 183 & 196 vs. 210, 224, 239	.0001
CON 10 210 vs. 224, 239	non-significant
CON 11 224 vs. 239	.0007
HABITAT*PLOT	.0043
HABITAT*DEPTH	.0001
HABITAT*DAY	.0001
PLOT*DEPTH	non-significant
PLOT*DAY	.0169
DEPTH*DAY	.0059
HABITAT*PLOT*DEPTH	non-significant
HABITAT*PLOT*DAY	.0024
HABITAT*DEPTH*DAY	non-significant
PLOT*DEPTH*DAY	non-significant

1. CON = Contrast, see Table 1 for abbreviations to plot types
2. See Table 3 for actual dates for each Julian day

oil was not significant in 1975, significant in 1976 and not significant at the 8% level in 1977. The contrast between 5 and 12 l/m² of oil was not significant. The contrast between dry plots (LCR & HC) and the wet plots (LCT & LCB) which have rather different bulk densities was significant in all three years. The differences in depth were significant in 1975 and 1977.

Oil penetration and its subsequent impact on the filamentous fungi in grams/m² is closely tied to soil moisture. The amount of organic matter, depth of thaw and other factors are also important. However, initial penetration of the oil into the plots with rather high soil moisture such as the low center polygon trough (LCT) and the low center basin (LCB) was irregular or restricted during the very wet first season. Moist but unsaturated soils on the high center polygon plots (HC) were penetrated much more evenly and rapidly by the oil (Atlas, *et al.*, 1976) and Tables 2 and 3 clearly show the depressing effect on the mycelial levels per gram dry weight of soil as well as on the grams/m². In 1976, control plots were significantly different from the oil treatment plots (Tables 6 & 7). Substantially reduced fungal biomass

TABLE 6. 1976 Fungal Hyphae in m/g dry wt Soil

Day 11

		183				198				218			
Treatment	Depth	LCT	LCR	LCB	HC	LCT	LCR	LCB	HC	LCT	LCR	LCB	HC
Control	1	3278	2078	725	643	465	1039	2395	621	1171	2325	1358	2417
	6	1220	508	200	408	406	665	81	255	370	499	466	1112
5 l/m²	1	1405	787	410	1052	1516	304	577	317	563	301	488	1051
crude oil	6	1167	573	664	975	397	354	84	408	1202	108	119	732
12 l/m²	1	447	1391	428	680	394	1378	392	101	790	737	130	519
crude oil	6	1082	506	247	131	529	392	191	36	579	324	81	62

TABLE 7. 1976 Fungal Biomass in g/m²

Day 11

Control	1	4.89	7.00	1.94	1.22	.79	4.46	7.85	3.03	2.19	14.34	3.44	13.54
	6	9.79	5.13	1.46	4.19	2.89	7.77	.84	1.86	2.98	3.99	3.84	10.73
5 l/m²	1	2.24	2.09	1.60	3.44	2.33	1.06	2.54	2.51	1.76	2.19	2.45	6.43
crude oil	6	3.24	3.93	4.18	5.05	1.79	2.73	.78	6.05	6.98	1.70	1.10	12.11
12 l/m²	1	1.54	5.99	1.75	4.08	1.76	10.43	2.49	.47	3.59	3.76	.72	4.21
crude oil	6	5.20	6.67	1.84	1.93	6.18	5.23	2.12	.53	4.49	3.36	.95	.52

1. Refers to Julian days in 1976 (183 = July 2, 1975, 198 = July 17, 1976, 218 = Aug. 6, 1976).
2. Depth 1 = 0-2 cm, 3 = 2-4 cm, 6 = 4-8 cm.

TABLE 8. Analyses of Fungal Hyphae in m/g dry wt Soil
1976

Effect		Significance Level
HABITAT	(.0790)	non-significant
CON 1 LCR & HC vs. LCT & LCB[1]		non-significant
CON 2 LCR vs. HC		non-significant
CON 3 LCT vs. LCB		.0166
PLOT		.0057
CON 4 Control vs. 5 & 12 l/m² crude oil		.0022
CON 5 5 l/m² vs. 12 l/m² crude oil		non-significant
DEPTH		.0010
DAY		non-significant
HABITAT*PLOT		non-significant
HABITAT*DEPTH		non-significant
HABITAT*DAY		non-significant
PLOT*DEPTH		.0167
PLOT*DAY		non-significant
DEPTH*DAY		non-significant
HABITAT*PLOT*DEPTH		non-significant
HABITAT*PLOT*DAY		non-significant
HABITAT*DEPTH*DAY		non-significant
PLOT*DEPTH*DAY		non-significant

1. CON = Contrast, See Table 1 for abbreviations to plot types

occurred particularly in the 12 l/m² plot at day 218. The low center polygon basin (LCB) had very low biomass (Table 7) which probably resulted because of heavy oil penetration as the soil dried out in the late season of 1975.

In 1977, the oil had become rather well dispersed within the soil following the first two seasons of alternate drying and soaking of the tundra soil (Atlas, per. comm.). The habitat differences which were significant in 1975 (Table 5) between the wet polygon centers and troughs and the dryer rims and high center polygons were significant in 1976 and 1977 (Tables 9 & 13). Significant difference with depth (Table 13) show the sharp decline in fungal biomass with depth which is thought to be conditioned by soil temperature, OM concentration and 0^2 levels. This phenomenon has been reported before by Laursen (1975) and Miller & Laursen (1974). The significant differences with time reflect the normal upswing in fungal biomass at peak growing season and decline toward fall which has been documented by Laursen and Miller (1977).

DISCUSSION

In the interpretation of our data it must be remembered that with no replication it is necessary to use the fourth order interaction mean square as

TABLE 9. Analyses of Fungal Biomass in g/m²
1976

Effect	Significance Level
HABITAT	.0261
CON 1 LCR & HC vs. LCT & LCB[1]	.0074
CON 2 LCR vs. HC	non-significant
CON 3 LCT vs. LCB	non-significant
PLOT	(.0550) non-significant
CON 4 Control vs. 5 & 12 l/m² crude oil	.0186
CON 5 5 l/m² vs. 12 l/m² crude oil	non-significant
DEPTH	non-significant
DAY	non-significant
HABITAT*PLOT	non-significant
HABITAT*DEPTH	non-significant
HABITAT*DAY	non-significant
PLOT*DEPTH	non-significant
PLOT*DAY	non-significant
DEPTH*DAY	non-significant
HABITAT*PLOT*DEPTH	non-significant
HABITAT*PLOT*DAY	non-significant
HABITAT*DEPTH*DAY	non-significant
PLOT*DEPTH*DAY	non-significant

1. CON = Contrast, see Table 1 for abbreviations to plot types

the error of the mean square. If this fourth order interaction is significant then the computed F statistic for all other higher order interactions and main effects will be deflated. A non-significant F test, therefore, may be truly non-significant or its significance may be masked by an inflated denominator mean square. Main effect significance can also be masked by significant two factor interactions. If, for example, habitat by depth is significant we conclude the effect of habitat is not consistent over depths and the test on the main effects habitat and depth is not as meaningful as when habitat by depth is non-significant. Significant higher order interactions are treated analogously.

It is apparent from an examination of the analysis of contrast between the control fungal hyphae/gram dry weight of soil and the fungal hyphae on plots at 5 and 12 l of oil/gram dry weight of soil (Tables 4, 8 & 12) that they are significantly different over the three years of the study. However, when the same contrast is expressed in fungal biomass the results are variable. There were no significant differences in biomass in 1975 (Table 5), significant in 1976 (Table 9) and no significant differences in 1977 (Table 13). The variability is introduced when one has to use bulk density to convert the fungal mycelium to a metre square value. The heavily organic low bulk density peat soils give way to a fine clay mineral soil with a high bulk density. The same hyphal counts in two soils with equal amounts of organic matter can vary greatly

TABLE 10. 1977 Fungal Hyphae in m/g dry wt Soil

		Day[1]											
		182				203				237			
Treatment	Depth	LCT	LCR	LCB	HC	LCT	LCR	LCB	HC	LCT	LCR	LCB	HC
Control	1	1100.8	3127.1	1218.5	2054.4	340.4	378.8	1245.1	1135.6	2712.9	2523.4	0.00	3433.4
	3	2710.0	897.9	1101.7	3476.5	2412.9	1083.3	1129.3	812.5	1455.7	1257.4	1067.5	2249.4
	6	6054.8	353.0	1143.2	275.9	615.1	338.8	394.7	686.2	1087.7	810.0	*	1856.9
5 l/m² crude oil	1	333.1	00.0	2117.5	166.9	217.8	465.8	33.9	802.7	483.4	281.2	808.6	970.4
	3	1540.1	1046.1	1508.2	1927.5	1726.4	24.6	78.3	525.9	722.7	2046.2	577.0	621.7
	6	1232.8	582.4	703.4	1216.4	1022.6	396.1	239.5	363.0	360.9	468.6	709.4	618.7
12 l/m² crude oil	1	516.8	972.9	1076.6	551.8	366.2	599.1	143.0	84.4	273.4	1751.0	675.1	473.0
	3	3064.9	1499.5	1644.8	510.0	678.2	262.4	00.0	216.8	333.1	2021.4	427.0	820.4
	6	578.3	2107.2	1466.7	591.4	727.9	359.3	384.3	119.3	643.3	2587.0	1011.0	792.9

1. Refers to Julian days in 1977 (182 = June 30, 1977, 203 = July 21, 1977, 237 = August 24, 1977).
2. Depth 1 = 0-2 cm, 3 = 2-4 cm, 6 = 4-8 cm.

TABLE 11. 1977 Fungal Biomass in gm/m^2

		Day[1]											
		182				203				237			
Treatment	Depth	LCT	LCR	LCB	HC	LCT	LCR	LCB	HC	LCT	LCR	LCB	HC
Control	1	1.95	7.72	2.52	10.15	0.46	1.37	3.26	5.46	7.38	2.39	0.00	17.07
	3	5.28	3.24	6.29	16.62	3.43	4.93	4.31	6.34	4.87	8.93	3.81	19.11
	6	45.57	2.99	11.16	2.48	3.98	3.73	3.55	7.04	14.63	16.71	*	20.07
5 l/m^2 crude oil	1	0.78	0.00	9.81	1.01	0.73	3.55	0.19	4.25	1.84	1.57	3.74	6.14
	3	3.33	9.05	5.98	12.27	3.72	0.25	0.40	3.55	2.06	13.20	2.98	4.23
	6	7.66	9.88	6.73	14.79	5.84	7.12	2.37	3.86	3.76	7.93	7.84	7.38
12 l/m^2 crude oil	1	2.03	4.81	3.82	4.67	1.81	4.00	0.69	0.57	1.29	10.20	3.79	3.67
	3	9.79	7.02	8.40	4.33	2.37	1.81	0.00	1.53	1.41	11.39	2.37	8.49
	6	7.67	23.67	13.75	11.29	4.58	6.62	3.75	1.93	7.28	33.39	10.86	14.50

1. Refers to Julian days in 1977 (182 = June 30, 1977, 203 = July 21, 1977, 237 = August 24, 1977).
2. Depth 1 = 0-2 cm, 3 = 2-4 cm, 6 = 4-8 cm.

from each other if the organic matter is mixed with high bulk density clay or mixed with water. One must consider, therefore, both the hyphae/gram dry weight of soil and the grams of fungi/m^2 in order to properly interpret the data.

It is also apparent that the irregular and uneven penetration of oil leaves a marbled profile and pockets of the soil escape perturbation by the oil (Everett, 1976, p. 53). As the dose rate rises, these oil-free areas are reduced and one would expect that the residual available fungal biomass, which can quickly colonize available substrates, would also be lower. It takes longer, therefore, for areas where fungi have been killed on initial contact from oil to be recolonized. If this picture of the effect of oil perturbation is realistic then the decomposition rates should be lower in oil treated litter on both the 5 and 12 l/m^2 plots than on the controls. This is in fact the case with untreated litter averaging 14.5% lignin after one year while oil treated litter averaged 6.3% lignin of the litter samples processed to date. Firstly, the direct infiltration of the litter by oil tends to inhibit fungal invasions. Secondly, the litter bags placed in the 5 and 12 l oil/m^2 plots have fewer fungi present to recolonize the litter compared to the control areas.

The question of which fungi survive and why can only be approached indirectly. The studies of Antibus *et al.*, (1978) have shown that shifts in the

TABLE 12. Analyses of Fungal Hyphae in m/g dry wt Soil
1977

Effect	Significance Level
HABITAT	non-significant
PLOT	.0059
CON 4 Control vs. 5 & 12 l/m^2 crude oil	.0017
CON 5 5 l/m^2 vs. 12 l/m^2 crude oil	non-significant
DEPTH	non-significant
DAY	.0018
CON 8 182 vs. 203[2]	.0004
CON 10 182 & 203 vs. 237	non-significant
HABITAT*PLOT	non-significant
HABITAT*DEPTH	non-significant
HABITAT*DAY	non-significant
PLOT*DEPTH	non-significant
PLOT*DAY	non-significant
DEPTH*DAY	non-significant
HABITAT*PLOT*DEPTH	non-significant
HABITAT*PLOT*DAY	non-significant
HABITAT*DEPTH*DAY	non-significant
PLOT*DEPTH*DAY	non-significant

1. CON = Contrast, see Table 1 for abbreviations to plot types
2. See Table 10 for actual dates for each Julian day

TABLE 13. Analyses of Fungal Biomass in g/m^2
1977

Effect		Significance Level
HABITAT	(.12)	non-significant
CON 1 LCR & HC vs. LCT & LCB		.0212
CON 2 LCR vs. HC		non-significant
CON 3 LCT vs. LCB		non-significant
PLOT	(.08)	non-significant
DEPTH		.0006
CON 6 0-2 cm vs. 2-4 cm & 4-8 cm		.0025
CON 7 2-4 cm vs. 4-8 cm		.0039
DAY		.0006
CON 8 182 vs. 203[2]		.0007
CON 10 182 & 203 vs. 237		.0322
HABITAT*PLOT		non-significant
HABITAT*DEPTH		non-significant
HABITAT*DAY		non-significant
PLOT*DEPTH		non-significant
PLOT*DAY		non-significant
DEPTH*DAY		non-significant
HABITAT*PLOT*DEPTH		non-significant
HABITAT*PLOT*DAY		non-significant
HABITAT*DEPTH*DAY		non-significant
PLOT*DEPTH*DAY		non-significant

1. CON = Contrast, see Table 1 for abbreviations to plot types
2. See Table 10 for actual dates for each Julian day

species of mycorrhizal fungi take place in oiled soil. Studies in progress by the authors have shown that many common soil fungi survive and can be isolated from oil treated soil. In laboratory studies carried out at Virginia Tech, it has been found that a small number of these fungi were able to either tolerate or utilize oil in direct contact. Subsequent analyses of the oil used as a sole carbon source by the most vigorous of the fungi which grow in oil is being carried out (Sexstone *et al.*, unpublished data). Initial results show varying levels of oil biodegradation and suggests that shifts in fungal populations toward oil decomposer populations may hasten the decomposition of crude oil in Arctic tundra. Studies must be initiated to explore the distribution of these hydrocarbon utilizing fungi in a wider variety of tundra habitats.

CONCLUSIONS

1. The depressing effect of oil on fungal hyphae was clearly detected 28 days (day 210) following oil treatment and remain significantly different after 3 years.

2. Treatments at 5 and 12 l/m^2 of oil were not significantly different.
3. The moisture content of the tundra soil has the greatest influence over the rapidity of oil penetration and the subsequent direct impact on the fungi.
4. A rapid depression in fungal biomass occurs in high center polygons following an oil spill. This correlates with the rapid penetration of oil in these sites shown by Sexstone and Atlas (1977).
5. Fungal biomass in the wet habitats (low center trough and basin) was significantly different from the low center rim and high center polygon plots the first season (Table 5). It was less so in 1976 (Table 9) and not significant in 1977 (Table 12). The possible influence of delayed oil penetration of the wet sites on the fungi is discussed in the text.

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