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Effect of Fuel Burning on the Microbial Population of Soil

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ABSTRACT. An attempt was made to study the effect of different amount of fuel burning on the microbial populations of forest soil. Maximum effect of fire was observed in the surface layer of soil and not much variation was seen in the distribution of soil microflora. However, with increasing amount of fuel burned, the effect became higher, microorganisms being destroyed to a depth of 70 mm. Qualitatively, there was no significant difference in the composition of fungal species in comparison with the control soil. Similar types of fungal species were isolated from all the types of burned soil, *Aspergillus*, *Penicillium*, *Trichoderma*, *Fusarium* and *Phoma* being the predominant genera.

Forest fires cause damage to soil. Since soil microbial populations are influenced by various ecological factors, any unbalance relating to these factors will also disturb the microbial life of the soil. The effects of fire on soil microorganisms were studied only infrequently (Ahlgren and Ahlgren 1965; Renbuss *et al.* 1973; Widden and Parkinson 1975). It is probable that the effects of burning on soil microorganisms depend on the climatic conditions, soil type, duration and intensity of fires. The present study was done to establish the effect of different fire intensity on soil microorganisms by burning known amounts of fuel.

MATERIAL AND METHODS

Study area. The experimental plot was set up at Burnihat (Meghalaya), India, where slash-and-burn agriculture (shifting cultivation) is extensively practised. The plot is situated at an altitude of 100 m above sea level (latitude about 25 °N, longitude about 90 °E). The climate of the region is subtropical. The details of the study area were described elsewhere (Deka and Mishra 1982).

Methods. A 200 m^2 plot of land was selected by clearing the above ground vegetation, where three 2 m^2 areas were burned by a known amount of bamboo fuel (20, 60 and 100 kg by mass). The burned area were at least 3 m from each other. A piece of unburned land which was 10 m away served as control. Soil samples were collected aseptically from three depths, *viz.* 0—20, 20—70 and 70—140 mm, using a sterilized trowel. In each case random sampling was done from five different points and the samples then mixed to make it a bulk composite sample for each depth. To determine the micro-

bial counts we used the soil dilution plate method (Martin 1950). Fungi were grown on a peptone-dextrose-rose bengal agar medium, bacteria and actinomycetes were estimated on nutrient agat and a starch-casein agar medium, respectively. The plates for fungi were incubated at 25 ± 1 °C for 6 d, those for bacteria and actinomycetes at 30 °C for 1 and 7 d, respectively. Three replicates were done for each set.

RESULTS

The levels of fungal, bacterial and actinomycete populations of the soil just after burning different amount of fuel are presented in Figs 1—3. Immediately after the fire, no fungal flora could be isolated from the surface

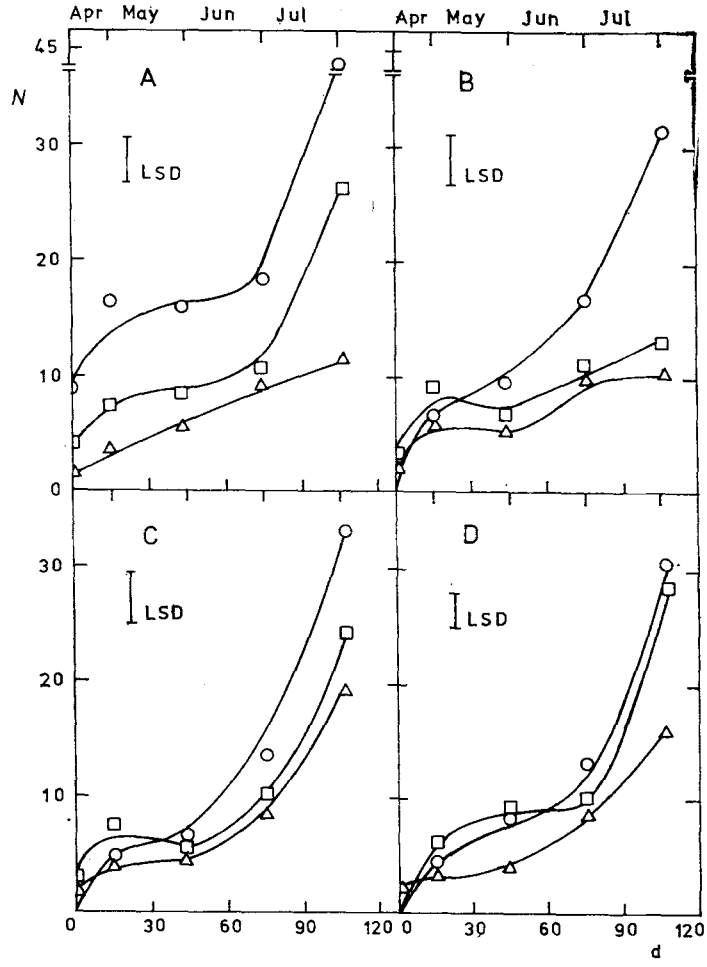

FIG. 1. Colonization of fungal population in the different types of fuel-burned soil (year 1980); **A** — unburned, **B** — 20 kg fuel, **C** — 60 kg fuel, **D** — 100 kg fuel, $p = 0.05$; N — number of fungi per g dry soil $\times 10^{-4}$, LSD — least significant difference; *circles* — 0—20 mm, *squares* — 20 to 70 mm, *triangles* — 70—140 mm.

layer of soil (0—20 mm) where 20 kg of fuel was burnt. But the flora of the ower depth o f soil was apparently unaffected by the fire. Fungal succession of burned soil surface took place within 15 d after the fire and thereafter it increased at a rapid rate. Likewise, bacterial and actinomycete populations were also reduced greatly in the upper 20 mm layer of soil but beyond this depth no affect was noticed (Figs 2 and 3).

Qualitatively, only a limited number of fungal species recolonized the burned soil area; *Mucor hiemalis*, *Aspergillus niger*, *Cephalosporium coremioides*, *Penicillium* spp., *Trichoderma viride* and *Phoma* sp. were frequently isolated taxa. Filamentous yeasts also occurred in a high frequency and were quite dominant (Table I).

In areas after 60 kg fuel burning, the effect was apparently similar to that where a 20 kg amount of fuel was burned. The mycoflora of the 0—20 mm zone was killed by the fire and the forms could only be isolated after 15 d. Though the bacterial and actinomycete populations were not completely eliminated by the fire, their number was much reduced. Qualitatively a few forms of fungal species, such as *Penicillium* spp., *Phoma* sp., *T. viride*, *C. coremioides*, *A. niger*, as well as yeasts were found to be the most dominant forms (Table I).

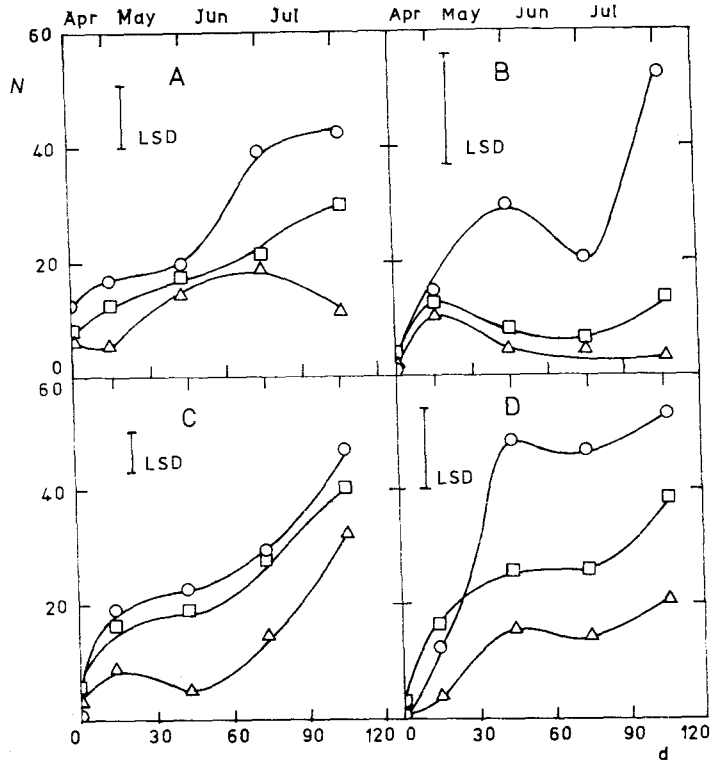

FIG. 2. Colonization of bacterial population in the different types of fuel-burned soil (year 1980); N — number of bacteria per g dry soil $\times 10^{-5}$; for further symbols see Fig. 1.

The effect of heat where 100 kg fuel was burned was more drastic as compared with the other intensities of fire. On the first sampling date, no fungi could isolated from the 0—20 mm depth as well as from the immediate sub-layer of soil, *i.e.* 20—60 mm depth. The population of the surface layer remained low till 45 d after the fire and then there was a rapid increase in the population. Simultaneously, the bacterial and actinomycete populations were drastically reduced in the beginning and thereafter they increased rapidly.

Qualitatively the fungal species composition was similar to that of the other two intensities of fire. *M. hiemalis*, *A. niger*, *C. coremioides*, *Phoma* sp., *Penicillium* spp., and *T. viride* were the most abundant species and were isolated at a high frequency. Filamentous yeast flora was also isolated frequently and was quite dominant (Table I)

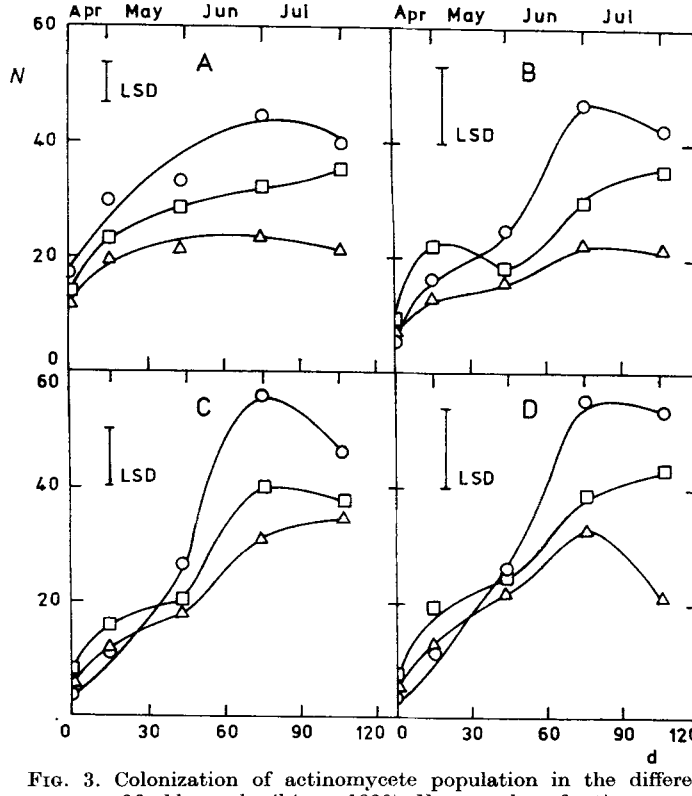

FIG. 3. Colonization of actinomycete population in the different amount of fuel burned soil (year 1980); N — number of actinomycetes per g dry soil $\times 10^{-5}$; for further symbols see Fig. 1.

DISCUSSION

The present data show that with increasing amounts of fuel burning, the effect on soil microorganisms was more drastic (Figs 1—3). The fungal population was found to be more sensitive in comparison with bacterial or actinomycete population and it was probably due to the formation of heat-resistant structures in bacteria and actinomycetes (Bollen 1969). Except in the 100 kg

TABLE I. Percentage relative abundance of fungal species isolated in relation to different amount of fuel burning

Fungal species	Amount of fuel burnt, kg			
	0	20	60	100
Absidia spinosa Lendner	5.23	1.90	0.67	1.59
Acremonium sp.	2.13	—	—	—
Alternaria alternata (Fr.) Keissler	—	6.20	3.61	1.56
Ascomycetes sp.	0.30	—	—	—
Aspergillus niger Van Tieghem	5.44	12.29	8.43	8.95
A. fumigatus Fressenius	2.32	3.25	3.56	4.41
Cunninghamella echinulata Thaxter	—	1.37	1.99	—
Curvularia lunata (Wak.) Boedijin	0.77	4.75	4.29	5.31
Cephalosporium coremioides Raillo	5.12	3.25	3.32	5.38
Cladosporium herbarum (Pers.) Link	3.06	2.36	2.52	5.98
Fusarium solani (Mart.) Sacc.	4.31	2.00	3.37	4.01
Geotrichum candidum Link ex Pers.	0.98	—	—	—
Gongronella butleri (Lend.) Peyron & Del Vesco	1.35	—	—	—
Mucor circinelloides Van Tieghem	0.57	—	—	—
M. hiemalis Wehmer	—	2.00	4.52	2.95
Monilia sp.	1.35	—	0.47	1.03
Papularia sphaerosperma (Pers.) Von Hohn.	0.33	—	—	—
Penicillium chrysogenum Thom.	14.33	9.17	9.21	8.72
Penicillium sp.	6.28	6.68	6.61	4.12
Phoma sp.	0.37	3.43	9.86	11.04
Pythium sp.	0.32	—	—	—
Trichoderma viride Pers. ex S.F. Gray	5.02	9.60	13.88	8.97
Filamentous yeasts	35.86	29.35	19.05	20.21
Sterile mycelia	4.56	2.40	4.73	5.77

fuel area, there was hardly any effect of fire on the microflora of the subsurface layer of soil. It may be due to the fact that soil is a poor conductor of heat and only a small portion of heat produced during burning is transferred downward to the soil (Debano 1974). Wright and Tarrant (1957) also stated that the maximum effect of burning was in the upper surface of the soil and only in the severely burned soil was there any influence of fire below 40 mm. Within a month after fire, the microbial populat'ons recolonized the burned soil surface. In places where 20 and 60 kg of fuel was burned, the fungal population remained low till 15 d after the fire and then increased rapidly. Whereas in the 100 kg fuel area the fungal flora of the 0—20 mm layer soil was overridden by the population of subsurface layer within 45 d of fire. The bacterial and actinomycete populations were drastically reduced by the fire. Probably the microorganisms remained dormant during heating of the soil and subsequently they became active and colonized the burned soil area on receiving an adequate amount of moisture. At the onset of the first monsoon some other factors, such as intensity and duration of burning appear to determine the occurrence of organisms (Wright and Tarrant 1957, 1958; Ahlgren 1974). Wright and Tarrant (1957) further interpreted that the amount of time between burning and sampling probably has an important effect on the degree of change in the microflora that can be attributed to burning. Several other workers also reported an initial reduction in populations followed by a gradual and continuous recovery to preburn level (Meiklejohn 1955; Wright and Bollen 1961; Berry 1970). However, in the present study, an analysis of variance showed that the differences in the microbial biomass

TABLE II. Analysis of variance for soil populations between treatments with differentfire intensities of fire (0—20 mm depth)

Population	Sources of variations	Degree of freedom	Sum of squares $\times 10^{10}$	Variance ratio calculated
Fungal	between treatments	3	0.0263	27.73*
	between sampling periods	4	0.240	189.89*
	error	12	0.004	—
Bacterial	between treatments	3	2.528	1.103
	between sampling periods	4	43.064	14.09*
	error	12	9.168	—
Actinomycete	between treatments	3	0.699	0.561
	between sampling periods	4	56.619	34.08*
	error	12	4.983	—

* Values significant at 1 % level.

between different amounts of fuel burning were statistically significant (Table II).

Qualitatively, there was not much difference in the composition of fungal species of both burned and unburned control soil. A similar result was observed by Meiklejohn (1955). Again, Jorgensen and Hodges (1971) stated that there appeared to be minor differences in the total number of genera or species as a result of burning treatment. In the present study, most of fungal species isolated belonged to deuteromycetes, the majority of which are typical soil inhabiting saprophytic fungi. Though the distribution of fungal taxa are not uniform, their occurrence is similar in all the types of burned soil. The genera *Aspergillus*, *Penicillium*, *Trichoderma*, *Cladosporium*, *Cephalosporium*, *Fusarium*, filamentous yeasts and a dark sterile mycelia were the predominant fungal taxa in the unburned soil. Several investigators had reported that the species of *Trichoderma*, *Penicillium*, *Zygomycetes* and *Fusarium* were killed by the fire (Bollen 1969; Cooke 1971; Widden and Parkinson 1975). However, these species were isolated frequently from the burned soil surface as well as from the unburned control soil (Table I).

Though the increasing amount of fuel burning or intensity of fire did not have any significant influence on the composition of fungal species, their effect was much more drastic on the quantity. However, the type of fuel burning and duration of burning also decide the fate of soil microbial populations.

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