QUANTITATIVE STUDY OF YEASTS AND BACTERIA IN A SIGNY ISLAND PEAT

By J. H. BAKER

ABSTRACT. The numbers of yeasts and bacteria in an acid peat on Signy Island were determined monthly at three depths for 18 months. The numbers of yeasts were exceptionally high, averaging approximately 3×10^6 per gram dry weight at the surface and decreasing with depth. The numbers of bacteria were similar to those in temperate peats but increased with depth. Although the yeasts showed no apparent seasonal variation, the bacteria showed a marked seasonal variation at the surface, but the effect was not discernible at 11–12 cm. Some hypotheses are discussed in an attempt to explain these results.

ALTHOUGH the climate of Signy Island, South Orkney Islands (lat. 60°43′S., long. 45°38′W.), is harsh with the highest mean monthly temperature around 0°C, there are extensive formations of acid peat. This peat is ombrogenous and creates banks of varying thickness in the lowland coastal areas. On the west coast of the island the banks form raised, approximately rectangular areas sloping gently towards the sea. One of these banks, slightly north-east of Spindrift Rocks, was the subject of this study. The vegetation of the bank was composed of the moss *Dicranum aciphyllum*, and the gradually decaying remains of this plant also made up the peat. Chemical analyses of this particular site have not been done but the nutrient status of very similar material has been described (Allen and Northover, 1967; Holdgate and others, 1967).

In spite of an increase in Antarctic microbiological literature in recent years, there have been few studies of the quantitative variation in the microbial flora. This study was therefore designed to determine the change in numbers of yeasts and bacteria with respect to season and depth.

METHODS AND RESULTS

Random samples of peat were obtained monthly from June 1966 to December 1967 inclusive. Sub-samples (approximately 2 g. wet weight) were then taken at three depths: 1–2, 6–7 and 11–12 cm. Suspensions of the sub-samples were made by homogenizing them for 15 min. using an MSE machine in which the vortex beaker was cooled in crushed ice. Colony counts of yeasts and aerobic bacteria were made on appropriate dilutions of these suspensions and each monthly estimate is the average of six separate sub-samples (Figs. 1 and 2). Oxoid tryptone soya agar was used for the bacteria and acidified Sabouraud dextrose agar for the yeasts. The numbers of both yeasts and bacteria at the 6–7 cm. depth were generally intermediate between the numbers in the other two depths (Table I), but they have been omitted from Figs. 1 and 2 for clarity.

TABLE I. MEANS OF MICROBIAL NUMBERS (PER g. DRY WEIGHT OF PEAT AND PER cm.^{3}) WITH THE ASSOCIATED ACIDITY DETERMINED AT A SOIL–WATER RATIO OF 1 : 10

Depth of sample (cm.)	*Bulk density* (g./cm.^{3})	*Bacteria* $\times 10^{-3}$		*Yeasts* $\times 10^{-3}$		*pH*
		(per g. dry weight)	(per cm.^{3})	(per g. dry weight)	(per cm.^{3})	
1–2	0·123	486	59	2,870	353	4·1
6–7	0·086	1,160	100	1,370	118	4·2
11–12	0·135	2,200	297	73·4	10	4·4

The field technique for sampling the frozen peat and the subsequent enumeration procedure have been previously described (Baker, 1969). The bulk density of the peat was ascertained by cutting a portion from the appropriate depth into a rectangular parallelepiped which facilitated measurement of the volume. Material obtained in a frozen state during the winter

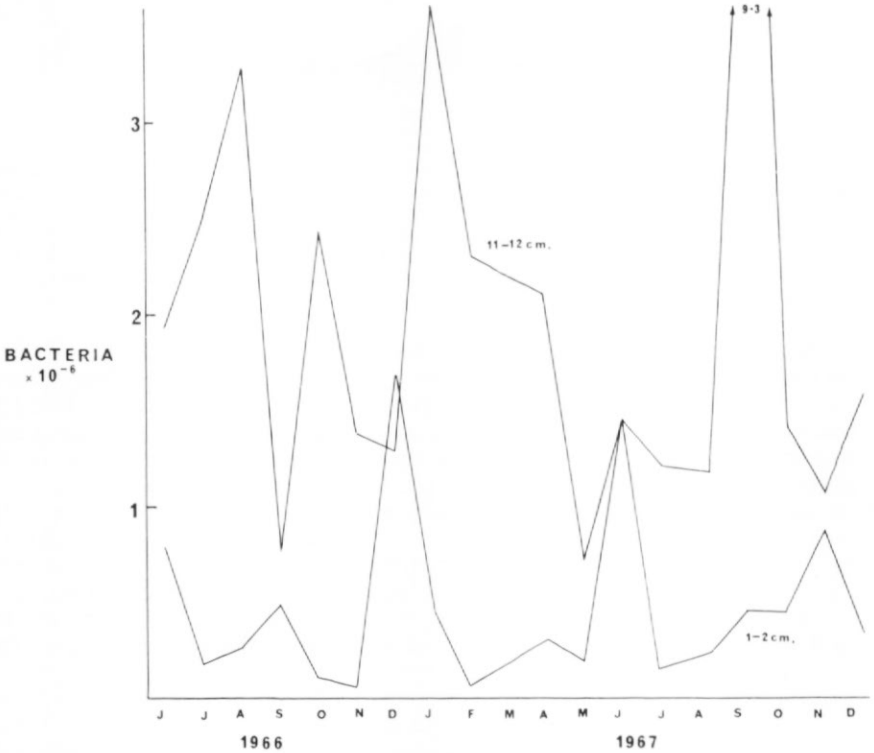

Fig. 1. Plot of the monthly estimates of bacteria at 1–2 cm. (bottom) and 11–12 cm. depth.

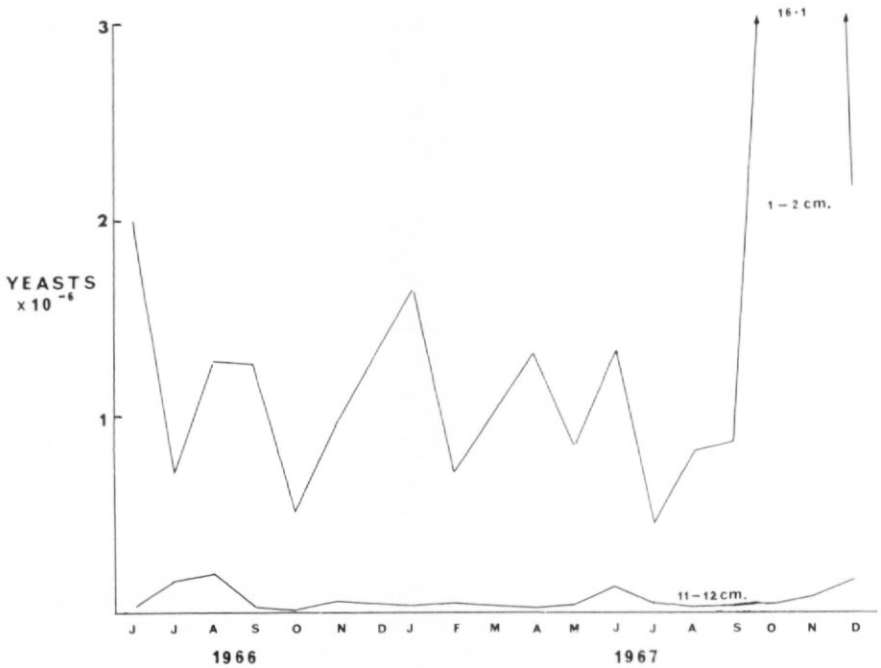

Fig. 2. Plot of the monthly estimates of yeasts at 1–2 cm. (top) and 11–12 cm. depth.

was not allowed to thaw during the cutting process so that the chance of distortion was eliminated. The cut portion was then dried at 105°C to constant weight and weighed.

Assuming the wet weight of an average bacterium is $1 \cdot 5 \times 10^{-12}$ g. (Alexander, 1961), the weight of the bacteria counted per gram wet weight of peat can be calculated from the estimates of numbers (Table II). Table II also shows the biomass of the yeasts which have been calculated by assuming that they are spheres of radius 3 μm. and have a specific gravity similar to that of bacteria, i.e. 1·1 (Ruffilli, 1933). Drops of the aqueous peat suspensions were also fixed and stained for direct observation by the method of Bunt and Tchan (1955) and this revealed that, even after homogenization, the yeasts often remained in groups of about 10–20. Assuming that each group gave rise to only one colony in the plate counts, the figures for yeasts in Tables I and II may be multiplied by 10 for an approximate direct count.

TABLE II. MEANS OF MICROBIAL NUMBERS (PER g. WET WEIGHT OF PEAT) AND THE DERIVED BIOMASS FIGURES ON THE SAME BASIS

Depth of sample (cm.)	*Mean percentage water content*	*Colonies* $\times 10^{-3}$*/g. wet weight*		μ*g. organisms/g. wet weight*	
		Bacteria	*Yeasts*	*Bacteria*	*Yeasts*
1–2	81·9	88	520	0·132	64·5
6–7	85·1	173	204	2·59	25·3
11–12	86·3	302	10	4·53	12·4

An attempt to demonstrate the presence of myxobacteria using a bacterial cell suspension agar (Skerman, 1959) proved unsuccessful. This may be because the bacterium offered as a food supply was unsuitable, although it was an unpigmented Gram negative rod, a type previously shown to be preferred (Singh, 1948). Counting the yeasts was made difficult by their tendency to be overgrown by the faster-growing moulds. In an attempt to overcome this problem 0·35 per cent sodium propionate was added to the acidified agar as recommended for soil isolation work (Etchells and others, 1954). This procedure proved unsuccessful, however, as yeast growth was also severely inhibited.

At the time of sampling, peat temperatures were measured at the three chosen depths using a mercury-in-glass thermometer. This method was suitable for unfrozen ground but less accurate when the peat was frozen (i.e. for about 8 months of the year), as it was difficult to ensure the necessary contact between bulb and peat, even with a hole drilled to the correct size. Nevertheless, it seems that temperatures, at least in the surface zone, were high enough for the active proliferation of mesophiles.

DISCUSSION

Bacterial abundance in the Signy Island peat was found to be of the same order as that recorded in comparable studies. Latter and others (1967) found similar numbers of aerobic bacteria/cm.^{3} in their "mixed moor" site on blanket peat in the northern Pennines. The climate there, though warmer than Signy Island, is comparable to that of southern Iceland (Manley, 1936). Also, Stout (1961) obtained similar plate counts for a peat from the sub-Antarctic Campbell Island. At no time during the present study, however, were numbers recorded as low as 4,000/cm.^{3}, although this figure has been given by Heal and others (1967) for a Signy Island peat. In general, the numbers of bacteria found in acid peats are considerably lower than in brown earth soils and results show that Signy Island peat is no exception.

Little attention appears to have been paid to soil yeasts even in temperate regions, but a mean count in excess of 2×10^6/g. and a maximum of 16×10^6 as recorded for the 1–2 cm. layer in the Signy Island peat both seem to be greater than any previously recorded for soil anywhere. In a study of the yeasts in soils from the Pamirs (Bab'yeva, 1964), the maximum number recorded, 13,300/g., was also from a peat soil. Menna (1966), who pioneered recent work on "wild" terrestrial yeasts, has recorded greater than 10^5 yeasts for a continental Antarctic soil. The presence of such large numbers of yeasts on Signy Island compared with

the average for cool moist soils of 20,000–80,000/g. (Menna, 1968) is not easy to explain. The acidity of the peat (Table I) is likely to restrict bacteria and this may make more food material available to the more acid-tolerant yeasts. The fact that the decrease in acidity with depth is accompanied by an increase in bacterial numbers and a decrease in yeasts lends support to this hypothesis. However, there are other factors involved. For example, the increase in moisture content (Table II) indicates a decrease in aeration, a factor thought adversely to affect yeast populations (Menna, 1968).

It is possible that the yeasts are not all true soil organisms but that some are contaminants from the overlying plants. Antarctic mosses are known to be a habitat for considerable numbers of yeasts (Menna, 1960*a*), but in the present study no microbiological investigation of the moss forming the peat was made. However, yeasts from pasture leaves have been shown not to persist in soils and yeast species have been found in soil that do not occur on the vegetation (Menna, 1960*b*). Although Lund (1958) regarded the soil merely as a reservoir for yeasts and stated that they hardly grow in poor soils, such a theory must be regarded as no longer tenable in view of the above evidence.

In most soils, including peats, the number of organisms tends to fall off with increasing depth (Burges, 1958) so the increase in number of bacteria demonstrated in the present study is of some interest. The positive correlation of this with decreasing acidity has been noted above. The 11–12 cm. depth differed from the other two in that it corresponded to a much more mineral horizon and this change in nature of the substrate may also account for the increase in numbers. But it does not explain the difference between the other two depths which were very similar horizons of fibrous peat, both of which contain similar total quantities of plant nutrients (Holdgate and others, 1967).

The vertical distribution of the yeasts follows the expected decrease in numbers with depth, and a similar pattern has been shown in a New Zealand peat (Menna, 1968). It is possible that the small yeast population at 11–12 cm. depth is not an indigenous one but represents cells washed down by the throughput of drainage water. However, the quantity of water percolating through the profile is likely to be small since the snow, which accounts for most of the precipitation, tends to be blown off the raised peat banks and accumulates in lower-lying areas. Moreover, the total annual precipitation is low, estimated to be only 40 cm. (Holdgate and others, 1967). The biomass figures (Table II) are worthy of further comment; there is 500 times as much yeast protoplasm in the 1–2 cm. zone as bacterial protoplasm, and in the deepest zone, although bacteria outnumber yeasts in the ratio 30 : 1, there is still nearly three times as much weight of yeasts as bacteria.

Seasonal variation in numbers of bacteria at 1–2 cm. depth (Fig. 1) has already been discussed (Baker, 1969) but unlike *Juncus* peat (Latter and Cragg, 1967) there is no clearly defined seasonal variation at the lower levels. Statistical analysis of the results made possible by the use of a computer shows that at the 0·01 level of probability there is a significant correlation between the 1–2 and 6–7 cm. layers for both bacteria and yeasts. A slight seasonal variation at 6–7 cm. depth has therefore been detected for bacteria but not for yeasts since these show no seasonal effect in the surface horizon either (Fig. 2). The latter result agrees with the findings of Menna (1960*b*), but Latter and others (1967) reported yeasts as being more common in winter without commenting on the reason, and a study of Danish soils revealed more yeasts in March than August (Lund, 1954). Unfortunately, Lund's work did not include counts for intermediate months. The fact that there is no seasonal variation is in itself interesting since one might reasonably expect a proportion to die during the long winter in which there is no possibility of active proliferation.

The computer analysis also showed that only at the surface level were there any significant differences between the logarithmic transformations of the means of both yeasts and bacteria on different dates. These were the obvious maxima for yeasts in October and November 1967, and bacteria in December 1966 and June 1967. Also, the bacteria were significantly fewer in November 1966 and February 1967. No ecological significance has been attached to the very high yeast counts in October and November 1967. A principal-component analysis was also carried out on the correlations between the numbers of yeasts and bacteria at the three levels. The first four components accounted for 96·5 per cent of the total variability contained in the counts (personal communication from J. N. R. Jeffers) and none of these showed a statistically

significant correlation coefficient with the corresponding mean monthly screen temperature. In short, the data suggested that there is no very clear linear relationship between the numbers of yeasts and bacteria at the three levels.

The Antarctic has been divided into two distinct climatic zones: the maritime zone, which includes Signy Island, and continental Antarctica (Holdgate, 1964). Acid peats, though fairly common in the maritime Antarctic, do not occur in the continental zone (Campbell and Claridge, 1969). Peats found in the Arctic, however, exhibit a seasonal variation in bacterial numbers (Boyd, 1958) very similar to that illustrated in Fig. 1. Signy Island peat therefore appears to be more akin to Arctic soils than those of continental Antarctica.

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