# HYPHOMYCETES DECAYING THE LITTER OF *THUJA PLICATA* DONN

by



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# Abstract

The present study was undertaken to examine the litter decay fungi of red cedar (Thuja plicata Donn). The fungi involved in conifer litter decay have not been examined intensively and there has been no study of red cedar litter decay. Since Thuja is often found in wet, poorly drained areas, it provided an opportunity to observe occurrence of litter decay fungi relative to slight differences in distance from a stream margin. This was determined by observing changes in the frequency of the fungi at various distances from the margin of a stream and also by observing seasonal changes in fungal populations. An ordination of the data was performed to determine if there were species associations which would characterize the relatively minor horizontal and vertical spatial changes in the sites.

The sites were divided into subsites (high, middle and low with respect to the stream) and samples were taken at each subsite. Red cedar branchlets from the L and F litter layers were washed and plated on a selective medium or placed in moist chambers; all observed species were isolated and identified. Most of these were members of the Fungi Imperfecti.

The frequency of occurrence of the more commonly isolated species was utilized in a Principal Components Analysis (PCA) to determine associations of subsites, layers or species. There was little distinction between the three subsites, but there was a general separation of the high subsite from the low subsite, the middle subsite showing affinities to both. The L and F layers

formed more distinct clusters in the ordination, especially in the Site B data. Seasonal distinction among the samples seemed to reflect the extremes of the seasons. The spring and summer samples generally grouped together, as did the fall and winter samples. Species associations reflected various combinations of the above groupings, depending on the species groups involved. Again the most distinct groups represented extremes, eg., species prominent in dry samples, especially in the high subsite, or species prominent in wet samples, especially in the low subsite.

No single variable provided clear distinction among the various subsites, layers, seasons or species. However, the combination of all of these gave general indications as to probable fungal associations.

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# I. Introduction

The production and accumulation of litter in a forest is a process which is important in the biology of the ecosystem. The breakdown of this litter, and the subsequent cycling of nutrients, is responsible for much of the energy flow into and survival of the macroflora present in the forest. Ecologists are well aware of the significance of the decomposition of plant material in influencing the characteristics of forest ecosystems; several workers have reviewed this subject (Bray and Gorham, 1964; Singh and Gupta, 1977; Williams and Gray, 1974).

The organisms involved in the decomposition of litter are mainly bacteria, fungi and invertebrates. The fungi have been recognized as a major component of this habitat and their importance in the decay process is well established. Soil fungi have been examined with respect to their ecology and a number of reviews have been published on substrate relationships (Garrett, 1957), soil as a source of plant pathogens (Burges, 1939; Garrett, 1956, 1970), and general involvement of fungi in the decay process (Parkinson and Waid, 1960; Szegi, 1972). In spite of the importance of the litter layer in the support of the above-ground vegetation, the fungi involved in the decay of litter have only recently come to be studied. The problems involved in studying the decomposition process in litter, the organisms involved and the types of litter that have been examined are reviewed elsewhere (Anderson and Macfadyen, 1976; Dickinson and Pugh, 1974).

One of the basic questions in studying the litter layer is:

what fungi are present and involved in the decay? Attempts to determine this usually involve isolations of the fungi using various techniques. Since soil fungal studies have been carried on longer than litter decay studies, the various soil methods are numerous and have been the subject of much discussion (Chou and Stephen, 1968; Nicholas and Parkinson, 1967; Parkinson, 1970, 1973; Parkinson, Gray and Williams, 1971; Phillipson, 1971 Warcup, 1960). Many of these techniques have also been adopted for use in litter decay studies. The most important consideration in either type of study is the extent to which the techniques give an accurate picture of the organisms involved in decomposition. Some of the more common techniques are discussed here and their applicability evaluated.

The soil dilution plate technique was developed in studies of microorganisms in soil (Waksman, 1927). Because of the dilution procedure, this technique initially appears to provide a means of quantifying the fungi present. Unfortunately this technique does not distinguish between fungi that are actively growing in the soil, and spores or resting stages. Whether growth has been from a single spore, a mass of spores, or hyphal fragments cannot be determined. Consequently, counts of species that produce abundant spores are often exaggerated with regard to the number of individuals involved. For application to litter studies, the dilution technique is modified slightly, with the litter first being homogenized in a waring blender, or otherwise crushed, and then diluted and plated out. This technique has been utilized in a number of litter studies, e.g., by Brandsberg, 1969 (on conifers), Visser and Parkinson, 1975 (on

aspen) and Verona and Rambelli, 1972 (on Monterey pine). The technique has the same drawbacks mentioned earlier in that the number of times a species is isolated only reflects the number of spores or pieces of hyphae present.

Tribe (1957, 1960, 1966) examined litter fungi that became established on buried cellulose film using a technique that involved putting cellulose film, usually cellophane, on the soil or litter, and leaving it for a specified amount of time. Observations were made on the hyphae found growing on the film to assess the fungal activity in the soil or litter. Unfortunately, identification is possible only if the fungi sporulate on the film. Additionally the technique selects for cellulose decomposers and the substratum is actually composed of modified cellulose.

A more promising technique involving fluorescent antibody staining (Preece, 1971) has been used in studies of the mycobiota of Douglas fir (Bernstein et al., 1973). This technique involves preparation of antibodies for a specific fungus and attachment of a fluorescent dye to the antibodies. The material examined, such as a leaf, is "stained" with this mixture and observed using fluorescence microscopy. The presence of the species can be detected by the fluorescence of the antibody. Hyphae on the surface of the substratum therefore can be identified by this method. Since the production of antibodies is a complex process and many fungi are involved in decay, routine use of this method would not be feasible. Furthermore different strains of the same fungus sometimes do not stain with the antibodies, thus contributing to further difficulties.

Several investigators (Edwards and Heath, 1963; Heath et al., 1964; Heath et al., 1966; Tubaki and Yokoyama, 1971, 1972a, 1972b; Yokoyama and Tubaki, 1973; Yokoyama et al., 1977) have used the idea of baiting the litter for the fungi present. They place gas sterilized leaves in mesh bags and put these in the litter layer to be retrieved at some later date. The problems here include interference with invertebrate movements and spore transport if fine mesh bags are used. Invertebrates may be involved in the spread of certain fungi as well as being important in the physical breakdown and processing of the litter. Sterilized leaves, although experimentally ideal for determining the fungi present, are not natural. Normally there are a number of fungi in the leaves when they fall and these fungi may be very important in preparing the leaves for subsequent colonizers. This technique also tends to favor those species which are actively sporulating in the litter layer when the leaves are positioned there. Positioning disturbs the litter layer and the sterile leaves probably are rapidly colonized by fast growing fungi.

A method developed by Harley and Waid (1955) for the study of rhizoplane fungi seems to offer a promising alternative. They washed pieces of roots in numerous changes of sterile water to remove most of the external spores and hyphae. Therefore the fungi which were on the surface or inside the root, presumably actively growing, grew out and could be isolated. The washed roots, or pieces thereof, were placed in sterile moist chambers and observed at later dates. Variations of this technique have been adopted in the study of litter decay of scots pine

(Kendrick and Burges, 1962), bracken fern (Frankland, 1976), silver fir (Gourbiere, 1974a, 1974b, 1975, 1979) and pine-hardwood stands (Watson et al., 1974). A modification of this method is used in the present study.

Most litter decay studies have dealt with angiosperm litter (Jensen, 1974) with little work done in conifer forests (Millar, 1974). Increased interest has been generated in decay of conifer litter, possibly because of the economic importance of conifer forests, but also due to the unique ecosystem of this litter. In the organic horizon of a conifer forest the decomposition rate is low, because of the physical nature of the litter and the tannins and other substances present. As a result of this relatively low rate of decomposition, the accumulation of litter is usually great. Much of the work on the mycobiota of conifer litter has involved describing the fungi present and comparisons of different sites or of various species of trees. The information provided by these studies includes the occurrence and frequency of species isolated and, often, seasonal variations.

The division of litter into various layers, indicating stages in the time sequence of decay, is especially significant with respect to conifer litter, since decomposition is slow and incorporation of litter into the humus may take several years (Dimock, 1958; Kendrick, 1959). Several investigators have found the fungi present in the different layers of the litter to represent distinct ecological groups, and thus have been able to indicate a successional pattern with respect to time (Borowska, 1966; Brandsberg, 1969; Kendrick, 1963; Kendrick and Burges,

1962; Verona and Rambelli, 1972; Visser and Parkinson, 1975; Watson et al., 1974; Wicklow and Wittingham, 1974, 1978; Widden and Parkinson, 1973).

In the present study, the intention has been to examine the fungi involved in the decay of red cedar litter (Thuja plicata Donn) with emphasis on the major component of the mycobiota, the hyphomycetes (Fungi Imperfecti). The distribution of species between the layers of litter, and seasonal changes throughout the year also were investigated.

A number of recent workers have examined the breakdown of litter in aquatic situations (Kaushik and Hynes, 1968, 1971; Sedell et al., 1974; Subberkropp et al., 1975; Wenner et al., 1977). Some investigators have also studied conifer litter in streams and the activities of "aquatic" hyphomycetes in litter breakdown and decay (Arnold, 1970; Barlocher and Kendrick, 1974; Barlocher and Oertli, 1978; Barlocher et al., 1978). Since Thuja often grows along streams, it was ideally suited for an examination of the possible influence of drainage upon terrestrial litter decay. The changes in the mycobiota in the area along the stream margin, and at slightly elevated subsites were investigated to observe what effect this slight topographical variation might have upon the occurrence of decay fungi.

Plant ecologists have often used ordination procedures to help them characterize vegetational groups and ecologically significant associations (Bray and Curtis, 1957; Mueller-Dombois and Ellenberg, 1974; Sneath and Sokal, 1973). Such analyses normally utilize the occurrence of species as the basis for

ordination. In recent years ordination techniques also have been used in studies of soil fungi (Bissett and Parkinson, 1979a, 1979b, 1979c; Dickinson and Kent, 1972; Kent, 1972; Morrall, 1974; Pemadasa and Mueller-Dombois, 1979). As with higher plant ordinations, the distribution of species is utilized to associate sites and species associations can also be determined. In the present study, an ordination was performed to summarize the samples with respect to the mycobiota present and the associations of the various sites and subsites.

In undertaking this study, some specific questions concerning the fungi decaying red cedar litter, were investigated. First, what species were present in red cedar litter? These were isolated and identified. Second, were there differences in the mycobiota as a function of relatively minor vertical or horizontal spatial changes in the site? If so, species associations could be detected which would characterize the sites, subsites or layers. An ordination of the data was utilized to determine this. Last, do slight differences in elevation, hence drainage, influence composition of the mycobiota? This would involve examining seasonal differences in the mycobiota, as well as spatial differences in relation to the stream.

# II. Materials and Methods

## 1. Description of the Study Site

Two study sites were selected along streams in the University Endowment Lands (UEL), University of British Columbia campus, Vancouver, B.C. (49°15' N Lat., 123°12' W Long.). The areas differed somewhat in topography but were both dominated by Thuja. Site A was located in the Ecological Reserve section of the UEL along an unnamed stream. Over approximately five meters, the terrain went from a relatively high, dry area near the base of a tree, down to the water's edge, a drop of slightly over one meter. Site B was located just off Clinton Trail along Tin Can Creek. It was a more open area than Site A, with a fallen tree across the stream but covered approximately the same area. The stream curved around a mound, with the lowest area extending from the stream through a depression on the other side of the mound. The mound itself was 50 - 75 cm above the water level.

Although the two sites were slightly different, they both were part of the Wet Subzone of the Coastal Douglas Fir Biogeoclimatic Zone (Krajina, 1965, 1969). The dominant tree in the immediate area was Thuja plicata Donn, with some Tsuga heterophylla (Raf.)Sarg. The ground cover was sparse and included Gaultheria shallon Pursh. (salal), with Lysichitum americanum Hulten & St. John (skunk cabbage) in some areas. The sites were poorly drained, as indicated by the presence of Thuja.

At each study site, A and B, the area was divided into three subsites, designated low, middle and high. The names reflect a general indication of their proximity to, and elevation above, the stream. At Site A, the low subsite was a rectangular area, 150 x 60 cm, located along the stream margin. It was submerged much of the time and consequently was very silty. With respect to the water level in the stream, it ranged from 0 - 19 cm above. The middle subsite was slightly higher and further from the stream, but the litter of this subsite was saturated much of the time. It was 20 - 47 cm above the stream, depending on the water level, and covered an area approximately 260 x 200 cm. The high subsite was situated near the base of a tree, on a very gentle ridge (51 - 114 cm above the water level). It measured 160 x 125 cm and was the furthest from the stream. All three subsites were wet during periods of high rainfall, but drainage rapidly resulted in loss of much of the water at the highest subsite.

Site B was geographically sightly different from Site A, and was divided into three subsites. The low area was 120 x 75 cm and was not as frequently flooded as the corresponding subsite in Site A. It ranged from 0 - 35 cm above the stream level. The middle subsite was a mound along the stream margin and measured 250 x 100 cm and was 49 - 70 cm above the water level. Although this subsite was close to the stream, it was designated as the middle subsite because it was higher in elevation above the stream. The high area was beyond the low depression, raised 39 - 69 cm above the stream level, and measured 200 x 175 cm.

The information on precipitation and temperature was taken from the Climatological Station Report of the Atmospheric Environment Service of Environment Canada. The data were gathered at station 94238, 110 8487-267 BC, which is located at the UBC agricultural plots, approximately 2 km N of the study sites. This is presented to give a general indication of the climate in the area and is summarized for the sample dates in Table I and Table II. In these tables the average temperature and the total precipitation are given for one and two weeks prior to the sampling date.

Table I. Climatic Data For Sample Dates At Site A

| | | Rainfall | | Temperature | |
|---|---|---|---|---|---|
| | | For prior 2 weeks | For prior week | For prior 2 weeks | For prior week |
| Sample | Date | in mm | in mm | in °C | in °C |
| A2 | Apr 5, 77 | 13.22 | 0.00 | 6.98 | 8.33 |
| A3 | Jul 25, 77 | 17.54 | 0.00 | 16.08 | 17.03 |
| A4 | Nov 7, 77 | 107.57 | 50.86 | 8.26 | 7.27 |
| A5 | Feb 13, 78 | 69.70 | 29.40 | 4.95 | 4.69 |
| A6 | May 19, 78 | 68.30 | 51.90 | 11.50 | 12.04 |
| A7 | Jul 26, 78 | 0.00 | 0.00 | 19.11 | 20.31 |

Table II. Climatic Data For Sample Dates At Site B

| | | Rainfall | | Temperature | |
|---|---|---|---|---|---|
| | | For prior 2 weeks | For prior week | For prior 2 weeks | For prior week |
| Sample | Date | in mm | in mm | in °C | in °C |
| B1 | May 17, 77 | 20.83 | 17.29 | 10.24 | 9.76 |
| B2 | Sep 21, 77 | 34.55 | 33.31 | 13.32 | 12.98 |
| B3 | Jan 18, 78 | 63.10 | 5.80 | 4.76 | 5.59 |
| B4 | Apr 5, 78 | 66.00 | 26.00 | 8.71 | 8.15 |

## 2. Classification of the Litter

Litter has been divided classically into layers segregated with respect to the degree of decay (Kubiena, 1953). The L or litter layer is the freshly fallen litter, which is just beginning to decay. In this layer, the litter is still recognizable as to its origin and has usually turned brown. Below this lies the F or fermentation layer of decomposing litter. This layer sometimes can be divided into the F1 and the F2, based on completeness of decay. The F1 layer is characterized by leaves which are beginning to break down completely but are still identifiable. Often they have begun to turn blackish to gray. In the F2 layer, leaves are less recognizable, fragmentary, gray and almost completely decayed. This division of the fermentation layer may be observed easily in many types of litter but not in the case of the present study. A third layer, the H or humus layer, consists of unrecognizable organic matter, and lies directly on the mineral soil. This layer was not investigated in the current study.

Thuja litter is not made up of distinct leaves, but of pieces of branchlets which have fallen with the scale-like leaves still attached. Therefore any further mention of litter or leaves actually refers to branchlets. The division of the litter into the layers outlined above proved to be impossible. The even distribution of the different stages of decay was hampered by the inconsistency of the size of the branchlets and the large amount of silt within the litter layer. Thus the litter was divided into only two layers. The uppermost or L

layer contained the freshly fallen and less decomposed litter. It was characterized by branchlets which were rather long (up to 20 cm), brown to black and just beginning to show signs of decay. Sometimes, as after a recent storm, the L layer contained branchlets which were still green or just beginning to turn yellow. The layer below this was the F layer. It was made up of shorter pieces of litter, brown to black to gray, showing definite signs of decay. They were typically fragile, flattened, and with very little internal tissue remaining. In many, the scale-like leaves were detached from the axis.

The low subsite of Site A, on the stream margin, was extremely silty, such that the F layer appeared to be mainly silt. The L layer was up to 1 cm deep, with silt prominent in the lower portion. In consequence the F layer was completely intermixed with mud and was up to 2 cm thick. The middle subsite had a thicker L layer, as much as 2 cm, with little silt. The F layer was approximately 3 cm thick, saturated and silty, but less than in the low subsite. The high subsite had little or no silt, with the L layer up to only 1.5 cm thick. The F layer was approximately 4 cm thick and, in the lower portion, intermixed with the humus.

Site B had a similar low subsite and was also silty; the L layer was 0 - 0.5 cm deep. The F layer was mixed with mud and was approximately 2.5 cm thick. The middle subsite was on the mound, and thus was not very silty. The L layer was up to 1 cm deep and the F layer was approximately 2 cm deep. The high subsite had a relatively thick L layer, up to 2.5 cm deep, and the underlying F layer was approximately 4 cm thick.

Although litter can be divided into layers, it is important to realize that there are no clear divisions. The entire litter layer is made up of branchlets in varying stages of decay. Their relative placement on top of one another reflects the time they originally fell from the tree. Those that have been in the litter longest would theoretically also be the most decayed, and would be expected in the lower layers. Therefore, the fungi present in the two layers would reflect a sequence in the decay; the L layer species would be early colonizers, while the F layer species would be secondary colonizers. But invertebrates, fungal mycelia and spores can possibly move from one leaf to the next, or from one layer to the next. Thus the distribution of the species involved in decay does not completely indicate their position in the time sequence of decay, but tendencies can be observed. The purpose of dividing up the litter was to try to determine what fungi were present in the leaves at their respective stages of decay and thus observe a sequence of succession.

## 3. Treatment of the Samples

Branchlets were collected approximately once every three months over a period of about a year (Site A, 6 times in 15 months, Table I; Site B, 4 times in 12 months, Table II). One sample was made in each of the three sub-areas in the site and divided into the L and F layers. The leaves were placed in fresh plastic bags and brought to the laboratory for processing; this

was completed within 48 hours.

The positions of the samples in the subsites varied throughout the sampling period. Each sample position was characterized by the distance from the stream and the elevation above the stream. The water level in the stream was also measured. These three variables were combined in a graph to give some idea of the spatial relationship of the samples (Figs. 1 and 2).

The branchlets were cut into pieces about 4 cm long, if necessary, and then washed according to the method described by Harley and Waid (1955) as modified slightly (Bandoni and Barr, 1976). The leaves were washed in sterile water and jars for 2 minutes on a rotary shaker at 400 rpms. They were then transferred to new sterile jars and water, and the process was repeated 30 times. The addition of a 30 second soak in 50% ethanol between washes 25 and 26 was instituted to help keep down the yeast and bacterial growth on the outside of the leaves. The short duration of the soak precluded its penetration into the leaves and thus the internal fungi seemingly were unaffected.

After washing, the leaves were blotted dry on sterile paper towels and treated in three ways. The first group was placed on six agar plates, two leaves per plate, and incubated at 15° C. They were turned every 24 hours for four days and then removed. The medium employed was Sorbose-Yeast-Tetracycline (SYT), slightly modified from that used by Bandoni and Barr (1976). It consisted of 0.4% sorbose, 0.05% yeast extract, and 1.5% agar (Bandoni, 1977). After autoclaving and cooling to 45° C, 100

mg/l of tetracycline hydrochloride was added to the medium. Sorbose was first used to produce colonial paramorphs in Neurospora studies (Tatum et al., 1949). It seems to affect the cell wall composition and restricts hyphal spread (Terra and Tatum, 1961). Tetracycline, a broad spectrum antibiotic, prevents the growth of bacteria. The plates were examined on the second and third days after the leaves were first put in and frequently thereafter. The fungi isolated were usually from the first two spots, which represented those that were actively growing within the leaves. Later spots were usually overgrown quickly and represented duplicates of those colonies present on the first two spots. This treatment provided the majority of the cultures obtained.

The remainder of the leaves were divided among four sterile petri plates. One was filled with sterile water and baited with pollen for chytrid isolation. The other three plates contained sterile wet paper towel and were used as moist chambers. Two were kept at 15° C, while the third was put at 5° C. Not all of the conidiophores produced in the 15° C plates were isolated since they were numerous. The number of times a species was isolated gave a relative indication of its abundance. Isolations were made after one and two weeks.

Figure 1. Spatial Arrangement Of The Samples At Site A

2 - 7 = Sample Dates (see Table I)

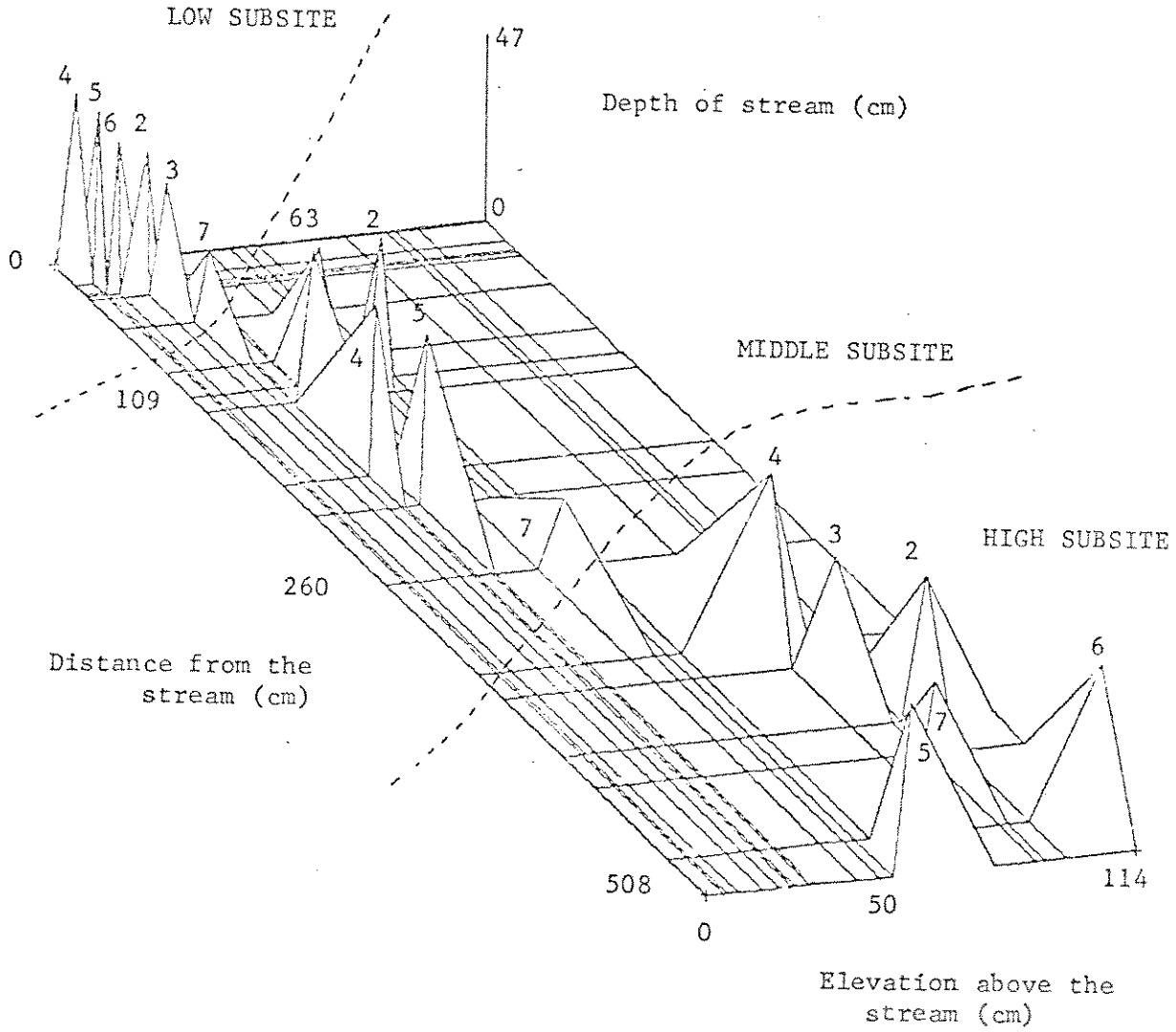
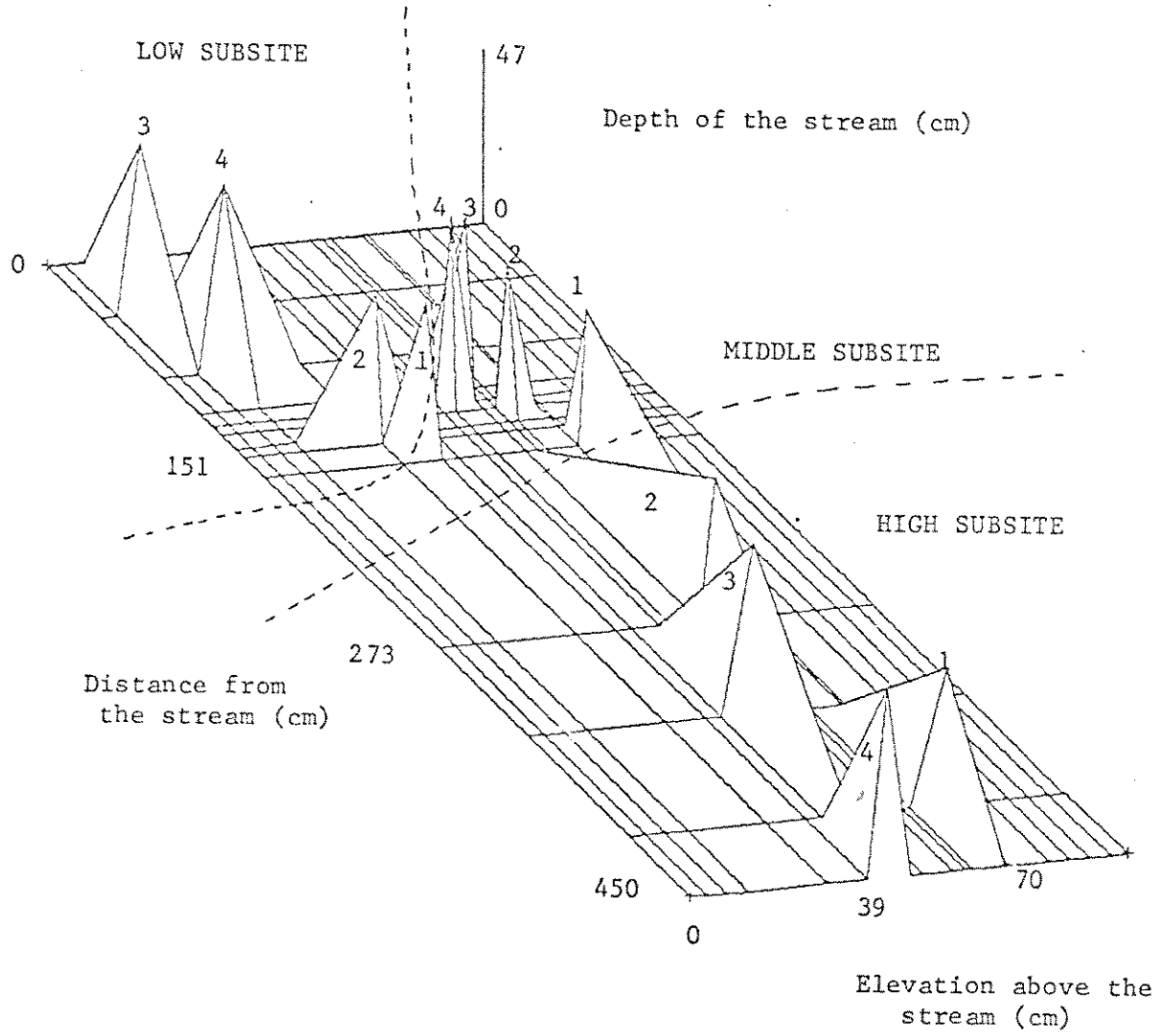


Figure 2. Spatial Arrangement Of The Samples At Site B

1 - 4 = Sample Dates (see Table II)



## 4. Multivariate Analysis of the Data

The species isolated from the SYT plates and the moist chambers were used to characterize the samples. They were identified and the number of times they were isolated was taken as an indication of their relative importance, or abundance.

Each sample, i.e. L or F layer in the high, middle or low subsites, was considered a distinct unit. They were included in a principal component analysis (PCA), with the occurrence of the species of fungi characterizing the samples. This is a multivariate analysis based either on a covariance or correlation matrix from which an axis is drawn representing the largest amount of variation among all the samples. A second axis, at ninety degrees to the first, spreads the points out further, and the analysis continues like this in a stepwise fashion. The result is a multi-dimensional picture in which the closeness of points reflects their similarities. By using this type of analysis the raw data could be visually represented and trends of species associations or sample associations would be easily seen. In addition to PCA, a minimum variance clustering of samples based on Euclidean distance was performed. The results, presented in the form of a dendrogram, illustrate the hierarchical relationships which exist among the samples. Both of these types of analyses provide a way of illustrating the data such that trends apparent from the isolations could be seen graphically and other possible associations, not so apparent, would be discovered.

The computer analysis was run on the MIDAS program

distributed by the Statistical Research Laboratory of the University of Michigan (Fox and Guire, 1976), which is available on the UBC computer (an Amdahl 470V/6 Model II, run under the Michigan Terminal System). In this program the analysis was based on a cases vs. variables matrix. The data were structured such that the cases were the individual sample units (eg. L layer from low subsite, F layer from low subsite, L layer from middle subsite, etc.). The variables were the various species of fungi that were isolated in the subsites and layers. The data for Site A and Site B were analyzed separately. Only the more frequently isolated species were utilized in the analysis, as they were thought to represent the fungi most actively decaying the litter at the sampling time.

The PCA was performed with both the unscaled and scaled options. The unscaled option means that the data are centered by species, but are left unstandardized. This ensures that the more frequently isolated species are more important in determining the final relationships. The basic premise is that these species are the fungi most active in the decay process, and their involvement is related directly to the number of isolations made. The importance of the less frequently isolated species could therefore be overlooked. The scaling option means that in addition to centering by species, the data are standardized by dividing through by species standard deviations. This step equalizes the importance of species in the analysis, with the effect of giving weight to less common species. From this combined approach, a better visualization of the species associations and sample associations could be obtained.

# III. Results And Observations

In the course of this investigation, 1641 cultures, representing 68 species, were isolated using the techniques outlined above. All of the species isolated from Site A are listed in Tables III - V, along with their distribution throughout the sampling time. Each of the tables gives the distribution of species in one of the three subsites (high, middle, or low). The same information is also given for Site B in Tables VII - IX. The information concerning the species isolated from the living leaves is given in Table VI, for both sites.

Two of the techniques employed in this work either worked poorly or provided no useful information, e.g., the moist chambers incubated at 5° C. Most of the fungi which occurred on the leaves incubated at 15° C also appeared on the 5° C plates but at a much slower rate. Because of the length of time it took fungi to develop, these 5° C plates often became infested with mites. For this reason and since no new information was obtained from them, the isolates from the 5° C plates were omitted from the study.

Another technique which proved relatively unsuccessful was the chytrid isolation method. Only one species was isolated and it was tentatively identified as Rhizophydium sphaerotheca Zopf. In most cases thalli developed on the pollen grains but other filamentous fungi also appeared. Isolation of the chytrid was difficult because of these other fungi and also because of bacterial growth. The chytrid also proved somewhat sensitive to

tetracycline, so eliminating the bacteria often eliminated the chytrid as well. Any treatment of its seasonality was felt to be somewhat biased because of these technical difficulties, therefore its distribution was not included in the discussions. Observations made during the course of this study indicate that this chytrid was present on almost all sample dates at all sites and subsites. The occurrence of chytrids on terrestrial litter has been reported previously by Bandoni and Barr (1976), but this is the first report from washed conifer litter.

Sterile mycelia typically are isolated in litter studies. These isolates usually are divided into two groups, sterile white mycelia and sterile dark mycelia. Often studies on litter and soil fungi include these groups in their discussions on seasonality and spatial distribution. This is an unsatisfactory practice since neither group represents known taxa. The sterile dark mycelia isolated in this study grew very slowly in culture. Their vegetative morphology was similar to that found in isolates of Endophragmia alternata, which also were often slow in forming spores. In fact many of the isolates of E. alternata were first isolated as sterile dark mycelia. Because of the artificial, and possibly heterogenous, nature of these groupings neither was included in the analyses although they are recorded in the species lists provided.

Decomposition of the litter is a complex process involving many variables and organisms. In the present study, the filamentous fungi (predominantly Fungi Imperfecti) involved in decay are examined. In selecting for imperfect fungi, bacteria and yeasts have been selected against. The involvement of these

two groups of organisms in the decomposition process has been reviewed elsewhere (Anderson and Domsch, 1973; Faure-Raynaud and Gourbiere, 1976; Last and Deighton, 1965; Last and Warren, 1972; Remacle, 1970; Suberkropp and Klug, 1976). Invertebrates are also involved in the breakdown of litter and are important in the preparation of the litter for subsequent colonization by fungi. Their involvement has been ignored here since other workers have reviewed their effect on decay (Cummins et al., 1973; van der Drift and Witkamp, 1960; Hayes, 1963; Sedell et al., 1975; Triska and Buckley, 1978; Witkamp and Crossley, 1966).

No Basidiomycetes and few Ascomycetes were isolated, possibly a result of their slow growth rate. This, plus the difficulties involved in identification, has usually eliminated them from most researches on decomposition of litter. Nevertheless a few workers have examined their involvement (Chastukhin, 1946, 1962; Cromack et al., 1975; Egorava, 1968; Lindberg, 1946; Mikola, 1956, 1960; Saito, 1965). Only the Fungi Imperfecti were examined in this study since they represent the majority of fungi involved in the decay of litter, and are readily isolated and identified.

Table III. Species Isolated In The High Subsite At Site A

| | HIGH SUBSITE | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | L LAYER | | | | | | F LAYER | | | | | |
| | AP | JU | NO | FE | MY | JU | AP | JU | NO | FE | MY | JU |
| Acremonium strictum | | 1 | | 2 | | | | | | | | |
| Acrodontium craterifor. | | 1 | | | | | | | | | | |
| Articulospora tetracla. | 4 | | | | | | | | | | | |
| Chaetomium sp. | | | | | | | | | | | | 1 |
| Chalara constricta | | 3 | 1 | 2 | | | 4 | | | 1 | | |
| C. cylindrosperma | | 1 | | | | | | | | | | |
| C. longipes | | | | 2 | | | | | 1 | | | |
| Cladosporium cladospor. | | 3 | 1 | | 2 | | | | 2 | | 2 | |
| Cylindrocarpon didymum | 1 | 2 | | | | | | | 1 | | 1 | 1 |
| C. tenue | 1 | | 7 | 5 | 12 | 1 | 9 | 2 | 4 | 4 | 5 | |
| Endophragmia alternata | 1 | | | 1 | | | | | | | | |
| Flagellospora stricta | 3 | | | | | | | | | | | |
| Fusarium lateritium | | | | | | | 1 | | | | | |
| Gliocladium roseum | | | | | | | | 2 | 1 | | 1 | |
| Gliomastix sp. | | | | | | 1 | | | | | | |
| Helicodendron triglitz. | 11 | | | | | | 2 | | | | | |
| Kriegeria seaveri | | | 1 | | | | | | | | | |
| Libertella sp. | 5 | | | | | | | | | | | |
| Monocillium state | | | | | | | | | | 1 | | |
| Mortierella isabellina | | 2 | | | | | | | | | | |
| M. ramanniana var. ram. | | | | | | | | 1 | | | | |
| Mucor hiemalis f. hiem. | | 1 | 4 | | | 4 | 1 | 2 | 2 | | | |
| Paecilomyces sp. | | 1 | | | | | | | | | | |

Table III. (continued)

| | HIGH SUBSITE | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | L LAYER | | | | | | F LAYER | | | | | |
| | AP | JU | NO | FE | MY | JU | AP | JU | NO | FE | MY | JU |
| Penicillium brevi-compactum | | | 1 | | | | | 1 | 3 | | | |
| P. citrinum | | 3 | | | | | | | | 1 | | |
| P. decumbens | | 1 | | | | | | | | | | |
| P. frequentans | | | | | | | | | 2 | | | |
| P. nigricans | | 4 | | | 2 | 3 | 2 | 3 | 3 | 3 | 4 | 4 |
| P. notatum | | | | | | | 1 | | | | | |
| P. raistrickii | | 3 | | | 1 | 2 | | 2 | | | 3 | 5 |
| P. verrucosum var. cyc. | 1 | | 3 | 1 | 1 | | | 1 | 1 | 1 | 1 | |
| Pestalotia monochaet. | | | | 1 | | | | | 1 | | | |
| Polyscytalum fecundiss. | 1 | 1 | 1 | | | | 1 | | | | | |
| Ramichloridium subulat. | | 2 | | 1 | | | | | | | | |
| Selenophoma sp. | | 2 | | 1 | | | | | | | | |
| Septonema chaetospira | 2 | | | | | | | 1 | | | | |
| S. chaetosp. var. pini | | | | 1 | | | | | 3 | | | |
| Thysanophora penicilli. | | | | | | | | | 1 | | | |
| Trichoderma koningii | | | 1 | 1 | 2 | | | | | 6 | | |
| T. polysporum | | | | | 1 | | | 1 | | | | |
| T. viride | | 1 | 1 | | | 3 | | 2 | | | | 2 |
| Varicosporium elodeae | 1 | | | | | | | | | | | |
| Verticillium bulbillos. | | | | | | | 1 | 2 | | | | |
| V. lecanii | | 1 | | | | | 1 | 1 | | | | |
| Sterile Dark Mycelia | | | | 1 | 1 | | 1 | | | | | |

Table IV. Species Isolated In The Middle Subsite At Site A

| | MIDDLE SUBSITE | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | L LAYER | | | | | | F LAYER | | | | | |
| | AP | JU | NO | FE | MY | JU | AP | JU | NO | FE | MY | JU |
| Acremonium strictum | 1 | 1 | | | | | | 1 | | | | |
| Acrodontium craterifor. | | 1 | | | | | | | | | | |
| Articulospora tetracla. | | 4 | 1 | 2 | 1 | 1 | | 8 | 2 | 3 | | 1 |
| Chalara constricta | | 1 | | 2 | 1 | | 5 | | | | | |
| C. longipes | | | | | | | 1 | | | | | |
| Cladosporium cladospor. | 2 | 2 | 1 | | | | 1 | | | | | |
| Cylindrocarpon didymum | | | | | | | | 9 | 2 | 2 | | |
| C. tenue | 2 | 9 | 5 | 1 | 9 | 2 | 5 | 2 | 7 | 4 | 6 | 9 |
| Endophragmia alternata | | | | | | | | | 1 | | | |
| Epicoccum sp. | | 1 | | | | | | | | | | |
| Flagellospora stricta | | 2 | | | | | | | | | | |
| Helicodendron triglitz. | 4 | 7 | 1 | 2 | 2 | | 5 | | 2 | 1 | | 1 |
| Helicoon fuscosporum | | | 1 | 3 | | | | 1 | 1 | | | |
| Kriegeria seaveri | | | 2 | | | | | | | | | |
| Libertella sp. | | | | | | | | | 1 | | | 1 |
| Monocillium state | 1 | | | | | | | | | | | |
| Mucor hiemalis f. hiem. | | | 1 | 1 | | 1 | 1 | | | 1 | | 1 |
| Oedocephalum sp. | | | | | | | | 1 | | | | |
| Paecilomyces sp. | | 1 | | | | | | | | | | |
| Penicillium brevi-compactum | | | 3 | | | | | | | | | |
| P. citrinum | | | 2 | | | | | | 2 | | | |
| P. echinulatum | | | 1 | | | | | | | | | |

Table IV. (continued)

| | MIDDLE SUBSITE | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | L LAYER | | | | | | F LAYER | | | | | |
| | AP | JU | NO | FE | MY | JU | AP | JU | NO | FE | MY | JU |
| P. frequentans | | | | | | | 1 | | | | | |
| P. nigricans | | 2 | | | | | 1 | 1 | | 1 | | 5 |
| P. notatum | | | | | | | | | | 1 | | |
| P. raistrickii | | | | | | 1 | | 2 | | | | |
| P. verrucosum var. cyc. | | | 1 | 1 | | | | 1 | 1 | 3 | | |
| Periconiella sp. | | | | | | | | 1 | | | | |
| Pestalotia monochaet. | | | 3 | | 2 | 4 | | | | | | |
| Polyscytalum fecundiss. | 8 | 1 | 1 | | 2 | | 3 | 1 | 1 | | | |
| Ramichloridium subulat. | | | | 1 | | | | | | | | |
| Selenophoma sp. | 1 | | | 5 | | 1 | | | | | | |
| Septonema chaetospira | | 2 | | | | | | 1 | | | 1 | |
| S. chaetosp. var. pini | | 1 | | | | | 2 | | | | | |
| Sporidesmium flexum | | 1 | | | 5 | 1 | 1 | | | | 5 | 1 |
| Trichoderma koningii | | | 1 | | | | | | 1 | | | |
| T. viride | | 5 | | | | | | 2 | | | 8 | 4 |
| Varicosporium elodeae | | | 2 | | | | | | | | | |
| Verticillium bulbillos. | | | | | | | | 1 | | | | |
| Sterile Dark Mycelia | | 1 | 1 | | 1 | | | 2 | 1 | | | 1 |
| Sterile White Mycelia | | 1 | 2 | | 1 | | 1 | 1 | | 1 | 2 | |

Table V. Species Isolated In The Low Subsite At Site A

| | LOW SUBSITE | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | L LAYER | | | | | | F LAYER | | | | | |
| | AP | JU | NO | FE | MY | JU | AP | JU | NO | FE | MY | JU |
| Articulospora tetracla. | | 5 | 2 | 1 | 1 | | 3 | 6 | | | 1 | 2 |
| Chalara constricta | 4 | | | | | | 2 | | | | | |
| C. longipes | 4 | | 1 | | | | 1 | | | | | |
| C. stipitata | | | | | | | 2 | | | | | |
| Cladosporium cladospor. | 2 | 2 | 1 | 1 | | 1 | | 3 | 2 | | 1 | |
| Cylindrocarpon didymum | | | | | 1 | 2 | | | | 1 | 1 | |
| C. tenue | 3 | 10 | 1 | 3 | 2 | | 2 | 3 | 2 | 1 | 1 | |
| Endophragmia alternata | | 1 | | | | | | 1 | | | | |
| Flagellospora stricta | | 1 | | | | | | | | | | |
| Fusarium lateritium | | | | | | | | | | 1 | | |
| Gliomastix sp. | | | | | | | 1 | | | | | |
| Gnomonia sp. | | | | | | | | 5 | | | | |
| Helicodendron giganteum | | | | | | | | | | | | 1 |
| H. triglitziensis | 1 | 5 | 1 | 2 | 5 | 1 | 4 | 3 | | 3 | 5 | 1 |
| Hyalodendron lignicola | | | | | | | 3 | | | | | |
| Idriella sp. | | 1 | | | | | | 1 | | | | |
| Kriegeria seaveri | | | 2 | | | | | | 1 | | | |
| Libertella sp. | | 1 | | 1 | | | | 1 | | 2 | 1 | 1 |
| Monocillium state | | | | | | | | | | | 2 | |
| Mortierella isabellina | 1 | | | | | | | | | | | |
| M. ramanniana var. ram. | | 1 | | | | | | | | | | |
| Mucor hiemalis f. hiem. | 1 | | | | | | | | | 1 | | |
| Penicillium brevi-compactum | | | | | | | | 1 | | | | |

Table V. (continued)

| | LOW SUBSITE | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | L LAYER | | | | | | F LAYER | | | | | |
| | AP | JU | NO | FE | MY | JU | AP | JU | NO | FE | MY | JU |
| P. citrinum | | | 1 | | | | | | | | | |
| P. decumbens | | | | | | | | 1 | | | | |
| P. nigricans | 1 | | | | | | | 2 | | | 1 | |
| P. notatum | | | | | | | | | 2 | | | |
| P. raistrickii | | | | | | | | 1 | | | | |
| P. verrucosum var. cyc. | 1 | | 3 | 1 | 1 | | 2 | | 2 | | | |
| Pestalotia monochaet. | | | 1 | | | | | | | | | 1 |
| Polyscytalum fecundiss. | 1 | 3 | 3 | 1 | 2 | | 6 | 1 | 2 | | | |
| Ramichloridium subulat. | | | | | | | | | | 1 | | |
| Selenophoma sp. | 1 | 1 | | | | | 1 | | | 1 | | |
| Septogloeum sp. | 1 | | | | | | | | | | | |
| Septonema chaetospira | 1 | 3 | 1 | | 2 | 2 | 5 | 5 | 5 | | 5 | 2 |
| S. chaetosp. var. pini | 4 | | | | | | | 1 | | 1 | | 1 |
| Sesquicillium sp. | | | | 1 | | | | | 1 | 1 | | |
| Sporidesmium flexum | | 1 | | | | 1 | | | | | 2 | 1 |
| Trichoderma koningii | 1 | | | 1 | | | | | | | | |
| T. polysporum | | | | | | | | 4 | | | | |
| T. viride | | 3 | 1 | 1 | | 2 | | 6 | | 2 | | |
| Tripospermum myrti | 1 | | | | | | | | | | | |
| Varicosporium elodeae | | 1 | 1 | | 2 | 2 | 2 | 5 | 1 | 1 | 1 | 2 |
| Verticillium bulbillos. | | 1 | | | | | 1 | | | | | |
| V. cephalosporium | | | | | | | 1 | | | | | |
| Sterile White Mycelia | 1 | 3 | 2 | 2 | 6 | 2 | 1 | 2 | | | 3 | 4 |

Table VI. Species Isolated From Living Leaves At Both Sites

| | SITE A | | | SITE B | |
|---|---|---|---|---|---|
| | AP 77 | MY 78 | JU 78 | SE 77 | AP 78 |
| Acrodontium crateriforme | 6 | | | | |
| Cladosporium cladosporioides | 1 | | 4 | 1 | |
| Endophragmia alternata | | 1 | | | |
| Hyalodendron lignicola | 2 | | | | |
| Kriegeria seaveri | | 2 | | 1 | |
| Oedocephalum sp. | | 1 | | | |
| Penicillium brevi-compactum | 4 | | | 2 | |
| P. notatum | 1 | | | | |
| P. verrucosum var. cyclopium | 1 | | | | |
| Pestalotia monochaetioides | | 2 | 4 | | |
| Selenophoma sp. | | | | 5 | 2 |
| Septogloeum sp. | | 2 | | 2 | 3 |
| Trichoderma koningii | 1 | | | | |
| T. viride | | | 2 | | 1 |
| Tripospermum myrti | 5 | | | | |

Table VII. Species Isolated In The High Subsite At Site B

| | HIGH SUBSITE | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | L LAYER | | | | F LAYER | | | |
| | MY | SE | JA | AP | MY | SE | JA | AP |
| Acremonium strictum | | | 1 | | | | | |
| Acrodontium crateriforme | | | | | 1 | | | |
| Chalara constricta | | 1 | 1 | | | | | |
| C. cylindrosperma | | 1 | | | | 1 | | |
| C. longipes | | 8 | | | | 1 | | |
| C. stipitata | 1 | | | | | | | |
| Chloridium virescens var. chlamyd. | 3 | | | | 1 | | 2 | |
| Cladosporium cladosporioides | | | | | | 1 | 2 | 2 |
| Cylindrocarpon tenue | 1 | 8 | 9 | 9 | | 6 | 9 | 11 |
| Endophragmia alternata | | 1 | | | | | | |
| Epicoccum sp. | | 1 | | | | | | |
| Flagellospora stricta | | 1 | | 1 | 1 | 1 | | |
| Fusarium lateritium | 1 | | | | | 1 | | |
| Gliocladium roseum | 2 | 2 | | | 3 | 1 | 4 | |
| Helicodendron triglitziensis | 1 | 2 | | | | | | |
| Hyalodendron lignicola | 2 | 3 | | | | | | |
| Mortierella isabellina | | 1 | | | | | | |
| M. ramanniana var. ramanniana | 1 | 1 | | | | | | |
| Mucor hiemalis f. hiemalis | | 2 | 1 | | 2 | | | 2 |
| Penicillium brevi-compactum | | 2 | 3 | | 1 | 2 | | |
| P. decumbens | 1 | | | | | | | |
| P. frequentans | | | | | | 1 | | |
| P. nigricans | | | | | | | 3 | |

Table VII. (continued)

| | HIGH SUBSITE | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | L LAYER | | | | F LAYER | | | |
| | MY | SE | JA | AP | MY | SE | JA | AP |
| P. raistrickii | | | | | | 3 | | 1 |
| P. verrucosum var. cyclopium | 1 | 1 | 1 | | | 3 | 6 | 2 |
| Pestalotia monochaetioides | | | 1 | | | | | |
| Polyscytalum fecundissimum | 1 | | 2 | 1 | 1 | | | |
| Selenophoma sp. | 1 | 3 | 9 | 4 | | | | |
| Septogloeum sp. | | | 1 | | | | | |
| Septonema chaetospira | | 1 | | | | | | |
| S. chaetospira var. pini | | 2 | 2 | 2 | | | | 1 |
| Torula sp. | | | | | 1 | | | |
| Trichoderma koningii | 6 | 2 | | | 1 | 2 | 1 | |
| T. polysporum | | | | | | | 1 | |
| T. viride | | | | | | | 1 | |
| Triposporium elegans | 1 | | | | | | | |
| Sterile Dark Mycelia | 2 | | 1 | | 1 | 1 | | 1 |
| Sterile White Mycelia | | 1 | | | | | | |

Table VIII. Species Isolated In The Middle Subsite At Site B

| | MIDDLE SUBSITE | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | L LAYER | | | | F LAYER | | | |
| | MY | SE | JA | AP | MY | SE | JA | AP |
| Acremonium strictum | 1 | | | | 3 | | 1 | |
| Botrytis sp. | | | | | | | 2 | |
| Chalara cylindrosperma | | | | | 1 | 3 | 1 | 1 |
| Cladosporium cladosporioides | | | 3 | 2 | | 1 | 2 | 1 |
| Cylindrocarpon tenue | | 3 | 4 | 5 | 1 | 6 | 4 | 3 |
| Endophragmia alternata | | | | | | | 1 | |
| Flagellospora stricta | 2 | | | | 1 | 1 | | |
| Fusarium lateritium | | 1 | | | | | | |
| Gliocladium roseum | 1 | | | | 1 | 2 | 1 | 2 |
| Helicodendron triglitziensis | | 1 | | | | | | |
| Hyalodendron lignicola | | 5 | | 1 | | | | |
| Libertella sp. | | 1 | | | | | 1 | |
| Mortierella ramanniana var. raman. | | 2 | | | | | 1 | |
| Mucor hiemalis f. hiemalis | | | | | 1 | | | 1 |
| Penicillium brevi-compactum | | 6 | | | 1 | 5 | | |
| P. citrinum | | 1 | | | | | | |
| P. frequentans | | | | | | | 1 | |
| P. nigricans | | | | | | 2 | 1 | |
| P. verrucosum var. cyclopium | | 1 | | 2 | 1 | 1 | 3 | 1 |
| Pestalotia monochaetioides | | | 3 | | | | | |
| Polyscytalum fecundissimum | 1 | 1 | | 3 | | 1 | | |
| Selenophoma sp. | 4 | 1 | 2 | 6 | 2 | | | |
| Septogloeum sp. | | | | 1 | | | | |

Table VIII. (continued)

| | MIDDLE SUBSITE | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | L LAYER | | | | F LAYER | | | |
| | MY | SE | JA | AP | MY | SE | JA | AP |
| Septonema chaetospira var. pini | | 1 | | | | | | |
| Thysanophora penicillioides | | 1 | | | | | | |
| Torula sp. | 1 | | | | | | | |
| Trichoderma koningii | 1 | | 3 | 1 | 7 | 2 | | |
| T. polysporum | | 1 | | | | 2 | 1 | 4 |
| T. viride | | | 1 | | | | | |
| Triposporium elegans | | 3 | | | | 1 | | |
| Sterile Dark Mycelia | 2 | 3 | 1 | 1 | 1 | | | |

Table IX. Species Isolated In The Low Subsite At Site B

| | LOW SUBSITE | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | L LAYER | | | | F LAYER | | | |
| | MY | SE | JA | AP | MY | SE | JA | AP |
| Alternaria sp. | 1 | | | | | | | |
| Articulospora tetracladia | | | | | | | 1 | |
| Chalara constricta | 1 | 1 | | | | | | |
| C. cylindrosperma | | | | 1 | | | | |
| C. stipitata | | | 1 | | | | | |
| Cladosporium cladosporioides | 2 | 1 | | | 1 | | | |
| Clathrosphaerina sp. | | | | | | 2 | | |
| Cylindrocarpon tenue | 2 | 8 | 4 | 8 | 1 | 2 | 8 | 4 |
| Cylindrocarpon didymum | 1 | | | | | | | |
| Gliocladium roseum | | | 1 | | | | 2 | |
| Harposporium sp. | | | | | | | | 1 |
| Helicodendron triglitziensis | 1 | 2 | | 1 | | 1 | | 1 |
| Hyalodendron lignicola | 1 | | | | | | | |
| Libertella sp. | 1 | | 2 | | | 1 | | |
| Monocillium state of Niesslia | | | | | | | | 1 |
| Mortierella isabellina | | | | | | | | 1 |
| M. ramanniana var. ramanniana | | 1 | | | | | | |
| Mucor hiemalis f. hiemalis | | | | | | | | 1 |
| Penicillium brevi-compactum | | 5 | | | | 4 | | |
| P. frequentans | | | | | | 1 | | |
| P. nigricans | | 1 | | | | | | |
| P. notatum | 1 | | | | | | | |
| P. raistrickii | | | | | | 1 | | |

Table IX. (continued)

| | LOW SUBSITE | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | L LAYER | | | | F LAYER | | | |
| | MY | SE | JA | AP | MY | SE | JA | AP |
| P. verrucosum var. cyclopium | | | | 1 | 1 | | 1 | 5 |
| Periconiella sp. | | | | | | 1 | | |
| Pestalotia monochaetioides | | 2 | | | | | | |
| Polyscytalum fecundissimum | | 5 | | 2 | | | | |
| Selenophoma sp. | 3 | 3 | 2 | 6 | | | | 1 |
| Septogloeum sp. | 1 | | | | | | | |
| Septonema chaetospira | 1 | | | 1 | | | 2 | |
| Sesquicillium sp. | | | | | 1 | | | |
| Trichoderma koningii | 3 | 7 | 2 | 1 | 10 | 6 | 9 | 1 |
| T. polysporum | 2 | | | | | | | |
| T. viride | | | | | | 1 | 1 | 1 |
| Tripospermum myrti | 1 | | | | | | | |
| Verticillium bulbillosum | | | | | | 1 | | |
| V. lecanii | | | | | | 2 | | |
| Sterile Dark Mycelia | | 1 | | | | | | |
| Sterile White Mycelia | | | | | | | | 1 |

In examining the decomposition of red cedar litter and seasonality of the fungal species involved, the data can be presented in a number of ways. Some of these tend to confuse the reader, so preliminary guidelines are presented. Not all species listed in Tables III - IX were deemed important in the decay process. In fact, many of these were isolated only once or twice during the entire sampling period. Only the more frequently isolated species are discussed.

In the following discussions emphasis is placed on the litter layers in the different sites and subsites. The first portion concerns the dominant fungi in the L and F layers and their distribution in the subsites of each site. The seasonal variation in each layer is then discussed, followed by a list of the important species and their characteristics.

## 1. Predominant Species in the L Layer

The species isolated from the L layer in Site A varied in seasonal occurrence and between subsites. Generally there were species which occurred more frequently in one or two of the different subsites. Other species tended to occur at all three subsites, although the number of isolations at each might have been different. Tables X and XI summarize the distribution of species in the L layer at Sites A and B, respectively. The species have been divided into groups based on their occurrence in the subsites; Group I - species which occurred equally in all three subsites; Group II - species found in the high and low

subsites; Group III - species found in the middle and low subsites; Group IV - species found in the high and middle subsites; Group V - species found in the high subsite; Group VI - species found in the middle subsite; Group VII - species found in the low subsite.

Table X. Distribution Of Species In The L Layer At Site A

| | TOTAL # OF ISOLATES | | |
|---|---|---|---|
| | HIGH SUBSITE | MIDDLE SUBSITE | LOW SUBSITE |
| GROUP I (all sites) | | | |
| Cylindrocarpon tenue | 26 | 28 | 19 |
| Helicodendron triglitziensis | 11 | 16 | 15 |
| Cladosporium cladosporioides | 6 | 5 | 7 |
| Trichoderma viride | 5 | 5 | 7 |
| Chalara constricta | 6 | 4 | 4 |
| GROUP II (high and low) | | | |
| Penicillium verrucosum var. cyclopium | 6 | 2 | 6 |
| Trichoderma koningii | 4 | 1 | 2 |
| Cylindrocarpon didymum | 3 | | 3 |
| GROUP III (middle and low) | | | |
| Polyscytalum fecundissimum | 3 | 12 | 10 |
| Articulospora tetracladia | 4 | 9 | 9 |
| GROUP IV (high and middle) | | | |
| Flagellospora stricta | 3 | 2 | 1 |
| Penicillium citrinum | 3 | 2 | 1 |
| Acremonium strictum | 3 | 2 | |
| GROUP V (high) | | | |
| Mucor hiemalis f. hiemalis | 9 | 3 | 1 |
| Penicillium nigricans | 9 | 2 | 1 |
| Penicillium raistrickii | 6 | 1 | |
| Libertella sp. | 5 | | 2 |
| Ramichloridium subulatum | 3 | 1 | |
| Endophragmia alternata | 2 | | 1 |
| GROUP VI (middle) | | | |
| Selenophoma sp. | 3 | 7 | 2 |
| Pestalotia monochaetioides | 1 | 9 | 1 |
| Sporidesmium flexum | | 7 | 2 |
| Helicoon fuscosporum | | 4 | |
| Penicillium brevi-compactum | 1 | 3 | |
| GROUP VII (low) | | | |
| Septonema chaetospira | 2 | 2 | 9 |
| Varicosporium elodeae | 1 | 2 | 6 |
| Chalara longipes | 2 | | 5 |
| Septonema chaetospira var. pini | 1 | 1 | 4 |

Table XI. Distribution Of Species In The L Layer At Site B

| | TOTAL # OF ISOLATES | | |
|---|---|---|---|
| | HIGH SUBSITE | MIDDLE SUBSITE | LOW SUBSITE |
| GROUP I (all sites) | | | |
| *Cylindrocarpon tenue* | 27 | 12 | 22 |
| *Selenophoma* sp. | 17 | 13 | 14 |
| *Penicillium brevi-compactum* | 5 | 6 | 5 |
| *Polyscytalum fecundissimum* | 4 | 5 | 7 |
| *Septogloeum* sp. | 1 | 1 | 1 |
| GROUP II (high and low) | | | |
| *Trichoderma koningii* | 8 | 5 | 13 |
| *Helicodendron triglitziensis* | 3 | 1 | 4 |
| *Chalara constricta* | 2 | | 2 |
| GROUP III (middle and low) | | | |
| *Cladosporium cladosporioides* | | 5 | 3 |
| *Pestalotia monochaetioides* | 1 | 3 | 2 |
| GROUP IV (high and middle) | | | |
| *Hyalodendron lignicola* | 5 | 6 | 1 |
| *Penicillium verrucosum* var. *cyclopium* | 3 | 3 | 1 |
| *Mortierella ramanniana* var. *ramanniana* | 2 | 2 | 1 |
| *Flagellospora stricta* | 2 | 2 | |
| *Fusarium lateritium* | 1 | 1 | |
| GROUP V (high) | | | |
| *Chalara longipes* | 8 | | |
| *Septonema chaetospira* var. *pini* | 6 | 1 | |
| *Gliocladium roseum* | 4 | 1 | 1 |
| *Chloridium virescens* var. *chlamydosporum* | 3 | | |
| *Mucor hiemalis* f. *hiemalis* | 3 | | |
| GROUP VI (middle) | | | |
| *Triposporium elegans* | 1 | 3 | |
| GROUP VII (low) | | | |
| *Libertella* sp. | | 1 | 3 |
| *Septonema chaetospira* | 1 | | 2 |
| *Trichoderma polysporum* | | 1 | 2 |

From an examination of the preceding tables, it is evident that different species were often found at the two sites, and those that were common between the sites, were often not found in the same subsites. The species isolated in the L layer at Site A, but not Site B, were:

*Acremonium strictum*
*Articulospora tetracladia*
*Cylindrocarpon didymum*
*Endophragmia alternata*
*Helicoon fuscosporum*
*Penicillium citrinum*
*P. nigricans*
*P. raistrickii*
*Ramichloridium subulatum*
*Sporidesmium flexum*
*Trichoderma viride*
*Varicosporium elodeae*

Some of these species were totally absent from the other site; others did occur, but only once or twice. The species found at Site B, but not Site A, included:

*Chloridium virescens* var. *chlamydosporum*
*Fusarium lateritium*
*Gliocladium roseum*
*Hyalodendron lignicola*
*Mortierella ramanniana* var. *ramanniana*
*Septogloeum* sp.
*Trichoderma polysporum*
*Triposporium elegans*

Despite the above differences, a few species had similar distributions in both Site A and Site B. Only one species was present in Group I in both sites, and that was *Cylindrocarpon tenue*. This was not surprising, since it was the fungus most frequently isolated in this study. *Trichoderma koningii* was

found in Group II (high and low subsites); Flagellospora stricta was present in Group IV (high and middle subsites); Mucor hiemalis f. hiemalis was a member of Group V (high subsite); Septonema chaetospira was found in Group VII (low subsite), in both Site A and Site B.

## 2. Predominant Species in the F Layer

The F, or fermentation layer, represents leaves which have undergone decay for a longer period of time. Some of the species isolated were the same as in the L layer, but some were new. Many of the same species were distributed differently among the subsites. The species found in this layer are summarized in Tables XII and XIII, for Site A and Site B, respectively. They are divided into the same groups as for the L layer.

Table XII. Distribution Of Species In The F Layer At Site A

| | TOTAL # OF ISOLATES | | |
|---|---|---|---|
| | HIGH SUBSITE | MIDDLE SUBSITE | LOW SUBSITE |
| GROUP I (all sites) | | | |
| *Penicillium verrucosum* var. *cyclopium* | 4 | 5 | 4 |
| *Septonema chaetospira* var. *pini* | 3 | 2 | 3 |
| *Chalara longipes* | 1 | 1 | 1 |
| GROUP II (high and low) | | | |
| *Cladosporium cladosporioides* | 4 | 1 | 6 |
| GROUP III (middle and low) | | | |
| *Helicodendron triglitziensis* | 2 | 9 | 16 |
| *Articulospora tetracladia* | | 14 | 12 |
| *Trichoderma viride* | 4 | 14 | 8 |
| GROUP IV (high and middle) | | | |
| *Cylindrocarpon tenue* | 24 | 33 | 9 |
| *Chalara constricta* | 5 | 5 | 2 |
| *Mucor hiemalis* f. *hiemalis* | 5 | 3 | 1 |
| GROUP V (high) | | | |
| *Penicillium nigricans* | 19 | 8 | 3 |
| *Penicillium raistrickii* | 10 | 2 | 1 |
| *Trichoderma koningii* | 6 | 1 | |
| *Penicillium brevi-compactum* | 4 | | 1 |
| *Verticillium bulbillosum* | 3 | 1 | 1 |
| *Gliocladium roseum* | 4 | | |
| GROUP VI (middle) | | | |
| *Cylindrocarpon didymum* | 3 | 13 | 2 |
| *Sporidesmium flexum* | | 7 | 3 |
| GROUP VII (low) | | | |
| *Septonema chaetospira* | 1 | 2 | 22 |
| *Polyscytalum fecundissimum* | 1 | 5 | 9 |
| *Varicosporium elodeae* | | | 12 |
| *Libertella* sp. | | 2 | 5 |
| *Trichoderma polysporum* | 1 | | 4 |
| *Penicillium notatum* | 1 | 1 | 2 |
| *Hyalodendron lignicola* | | | 3 |

Table XIII. Distribution Of Species In The F Layer At Site B

| | TOTAL # OF ISOLATES | | |
|---|---|---|---|
| | HIGH SUBSITE | MIDDLE SUBSITE | LOW SUBSITE |
| GROUP I (all sites) | | | |
| *Cylindrocarpon tenue* | 26 | 14 | 15 |
| *Penicillium verrucosum* var. *cyclopium* | 11 | 6 | 7 |
| *Penicillium brevi-compactum* | 3 | 6 | 4 |
| *Penicillium frequentans* | 1 | 1 | 1 |
| GROUP IV (high and middle) | | | |
| *Gliocladium roseum* | 8 | 6 | 2 |
| *Cladosporium cladosporioides* | 5 | 4 | 1 |
| *Penicillium nigricans* | 3 | 3 | |
| *Flagellospora stricta* | 2 | 2 | |
| GROUP V (high) | | | |
| *Mucor hiemalis* f. *hiemalis* | 4 | 2 | 1 |
| *Penicillium raistrickii* | 4 | | 1 |
| *Chloridium virescens* var. *chlamydosporum* | 3 | | |
| GROUP VI (middle) | | | |
| *Trichoderma polysporum* | 1 | 7 | |
| *Chalara cylindrosperma* | 1 | 6 | |
| *Acremonium strictum* | | 4 | |
| *Selenophoma* sp. | | 2 | 1 |
| GROUP VII (low) | | | |
| *Trichoderma koningii* | 4 | 9 | 26 |
| *Trichoderma viride* | 1 | | 3 |
| *Septonema chaetospira* | | | 2 |

As can be observed, there were again some species in the F layer which were present only at Site A. These included:

Articulospora tetracladia
Chalara constricta
Chalara longipes
Cylindrocarpon didymum
Helicodendron triglitziensis
Hyalodendron lignicola
Libertella sp.
Penicillium notatum
Polyscytalum fecundissimum
Septonema chaetospira var. pini
Sporidesmium flexum
Varicosporium elodeae
Verticillium bulbillosum

Species present at Site B, but not Site A included:

Acremonium strictum
Chalara cylindrosperma
Chloridium virescens var. chlamydosporum
Flagellospora stricta
Penicillium frequentans
Selenophoma sp.

In the F layer, there were fewer species common to the same groups at the two sites, than in the L layer. The only species found consistently in Group I was Penicillium verrucosum var. cyclopium. Cylindrocarpon tenue was the most frequently isolated species, but at Site B it occurred more often in the high and middle subsites, than it did in the low subsite. Penicillium raistrickii was present in Group V (high subsite); Septonema chaetospira was found in Group VII (low subsite).

In an overall view of the distribution of the species isolated from the various subsites, regardless of which layer

they were isolated from, certain species were always representative of particular groups, when they occurred. The species are as follows:

Group I (all subsites)
*Cylindrocarpon tenue*

Group III (middle and low)
*Articulospora tetracladia*

Group IV (high and middle)
*Flagellospora stricta*
*Mortierella ramanniana* var. *ramanniana*
*Penicillium citrinum*
*Fusarium lateritium*

Group V (high)
*Penicillium nigricans*
*Penicillium raistrickii*
*Mucor hiemalis* f. *hiemalis*
*Gliocladium roseum*
*Chloridium virescens* var. *chlamydosporum*
*Verticillium bulbillosum*
*Ramichloridium subulatum*
*Endophragmia alternata*

Group VI (middle)
*Sporidesmium flexum*
*Chalara cylindrosperma*
*Helicoon fuscosporum*
*Tripospórium elegans*

Group VII (low)
*Septonema chaetospira*
*Varicosporium elodeae*
*Penicillium notatum*

In examining the distribution of the fungi isolated at Site A and Site B, including all species isolated from the L layer, F layer and living leaves, some species tend to be found exclusively in one or the other site. These are summarized in Table XIV, and are listed in decreasing order of frequency of occurrence.

Table XIV. Species Restricted To One Or The Other Main Site

(see Tables XXI and XXII for number of isolates)

SITE A

*Articulospora tetracladia*

*Cylindrocarpon didymum*

*Varicosporium elodeae*

*Sporidesmium flexum*

*Penicillium citrinum*

*Helicoon fuscosporum*

*Tripospermum myrti*

*Verticillium bulbillosum*

*Penicillium notatum*

*Ramichloridium subulatum*

SITE B

*Chalara cylindrosperma*

*Septogloeum* sp.

*Chloridium virescens* var. *chlamydosporum*

*Mortierella ramanniana* var. *ramanniana*

*Triposporium elegans*

*Fusarium lateritium*

## 3. Comparison of Species Found in the L and F Layers

In the foregoing discussions, the distribution of species in the L and F layers, between the different subsites, have been treated. These subsites were subjectively defined areas in the sites that were intended to show what variations might exist in species composition, with slight changes in distance from a stream. The L and F layers, as mentioned earlier, represent different stages in the decay of the litter, and thus are a more objectively defined group. These two layers have many fungal species in common, but also have some species which are found predominantly in one or the other layer. Tables XV and XVI list the species, common to both layers, found predominantly in the L layer, and found predominantly in the F layer, for Site A and Site B respectively. In these Tables, the species are listed in decreasing frequency of occurrence.

Table XV. Comparison Of Species In The L And F Layers At Site A

Species common to both L and F layers

*Cylindrocarpon tenue*
*Articulospora tetracladia*
*Penicillium verrucosum* var. *cyclopium*
*Chalara constricta*
*Sporidesmium flexum*
*Septonema chaetospira* var. *pini*
*Libertella* sp.
*Trichoderma koningii*
*Penicillium brevi-compactum*
*Endophragmia alternata*

Species found predominantly in the L layer

*Helicodendron triglitziensis*
*Polyscytalum fecundissimum*
*Cladosporium cladosporioides*
*Mucor hiemalis* f. *hiemalis*
*Selenophoma* sp.
*Pestalotia monochaetioides*
*Chalara longipes*
*Flagellospora stricta*
*Penicillium citrinum*
*Acremonium strictum*
*Helicoon fuscosporum*
*Ramichloridium subulatum*

Species found predominantly in the F layer

*Penicillium nigricans*
*Trichoderma viride*
*Septonema chaetospira*
*Cylindrocarpon didymum*
*Varicosporium elodeae*
*Penicillium raistrickii*
*Trichoderma polysporum*
*Verticillium bulbillosum*
*Gliocladium roseum*
*Penicillium notatum*
*Hyalodendron lignicola*

Table XVI. Comparison Of Species In The L And F Layers At Site B

Species common to both L and F layers

*Cylindrocarpon tenue*
*Penicillium brevi-compactum*
*Cladosporium cladosporioides*
*Flagellospora stricta*
*Chloridium virescens* var. *chlamydosporum*
*Septonema chaetospira*
*Fusarium lateritium*

Species found predominantly in the L layer

*Selenophoma* sp.
*Polyscytalum fecundissimum*
*Hyalodendron lignicola*
*Chalara longipes*
*Helicodendron triglitziensis*
*Septonema chaetospira* var. *pini*
*Pestalotia monochaetioides*
*Mortierella ramanniana* var. *ramanniana*
*Chalara constricta*
*Libertella* sp.
*Triposporium elegans*
*Septogloeum* sp.

Species found predominantly in the F layer

*Trichoderma koningii*
*Penicillium verrucosum* var. *cyclopium*
*Gliocladium roseum*
*Trichoderma polysporum*
*Chalara cylindrosperma*
*Mucor hiemalis* f. *hiemalis*
*Penicillium nigricans*
*Penicillium raistrickii*
*Acremonium strictum*
*Trichoderma viride*
*Penicillium frequentans*

## 4. Seasonality of Fungi in the L and F Layers

In the course of this study, samples were taken at various intervals throughout the year, and the fungi present were isolated and identified. The occurrence of these species at the sample dates (i.e., number of times isolated), reflected a pattern of distribution throughout the year. Of course, the seasonal distribution of species is not absolutely defined since conditions vary from year to year, but nevertheless general trends of occurrence can be discerned. The times of the year when samples were taken and the corresponding climatic conditions are summarized for Site A in Table I and for Site B in Table II.

In the following discussions on seasonality, the mention of a species as occurring during a certain time of year simply indicates that its relative frequency is higher at that time of the year. It may have occurred at other times, but at a much lower frequency. Some species showed little seasonal fluctuation and were thus labelled nonseasonal. Various seasonal patterns were exhibited by the remaining species, depending on the site or layer examined. The most clearly distinguished groups were those occurring in the spring and summer, summer, and fall and winter.

The seasonal distribution of species throughout the sampling time is shown in Tables XVII and XVIII, for isolates from the L layer at Site A and Site B, respectively. It should be noted that the samples from Site B were not made at the same time as those in Site A, so comparison between the two sites is

slightly different. The same information is given in Tables XIX and XX for the isolates from the F layer.

Table XVII. Seasonal Distribution Of Species In The L Layer At Site A

| | TOTAL # OF ISOLATES | | | | | |
|---|---|---|---|---|---|---|
| | APR | JUL | NOV | FEB | MAY | JUL |
| NONSEASONAL | | | | | | |
| Cylindrocarpon tenue | 6 | 19 | 13 | 9 | 23 | 3 |
| Polyscytalum fecundissimum | 10 | 5 | 5 | 1 | 4 | |
| Varicosporium elodeae | 1 | 1 | 3 | | 2 | 2 |
| SPRING & SUMMER | | | | | | |
| Helicodendron triglitziensis | 16 | 12 | 2 | 4 | 7 | 1 |
| Articulospora tetracladia | 4 | 9 | 3 | 3 | 2 | 1 |
| Cladosporium cladosporioides | 4 | 7 | 3 | 1 | 2 | 1 |
| Septonema chaetospira | 3 | 5 | 1 | | 2 | 2 |
| Sporidesmium flexum | | 2 | | | 5 | 2 |
| Chalara longipes | 4 | | 1 | 2 | | |
| Libertella sp. | 5 | 1 | | 1 | | |
| Flagellospora stricta | 3 | 3 | | | | |
| Septonema chaetospira var. pini | 4 | 1 | | 1 | | |
| Acremonium strictum | 1 | 2 | | 2 | | |
| SUMMER | | | | | | |
| Trichoderma viride | | 9 | 2 | 1 | | 5 |
| Penicillium nigricans | 1 | 6 | | | 2 | 3 |
| Penicillium raistrickii | | 3 | | | 1 | 3 |
| Cylindrocarpon didymum | 1 | 2 | | | 1 | 2 |
| FALL & WINTER | | | | | | |
| Penicillium verrucosum var. cyclopium | 2 | | 7 | 3 | 2 | |
| Mucor hiemalis f. hiemalis | 1 | 1 | 5 | 1 | | 5 |
| Selenophoma sp. | 2 | 3 | | 6 | | 1 |
| Pestalotia monochaetioides | | | 4 | 1 | 2 | 4 |
| Trichoderma koningii | 1 | | 2 | 2 | 2 | |
| Penicillium citrinum | | 3 | 3 | | | |
| Helicoon fuscosporum | | | 1 | 3 | | |
| Penicillium brevi-compactum | | | 4 | | | |
| SPRING, SUMMER & WINTER | | | | | | |
| Chalara constricta | 4 | 4 | 1 | 4 | 1 | |
| Ramichloridium subulatum | | 2 | | 2 | | |
| Endophragmia alternata | 1 | 1 | | 1 | | |

Table XVIII. Seasonal Distribution Of Species In The L Layer At Site B

| | TOTAL # OF ISOLATES | | | |
|---|---|---|---|---|
| | MAY | SEP | JAN | APR |
| NONSEASONAL | | | | |
| Cylindrocarpon tenue | 3 | 19 | 17 | 22 |
| Cladosporium cladosporioides | 2 | 1 | 3 | 2 |
| Penicillium verrucosum var. cyclopium | 1 | 2 | 1 | 3 |
| Septonema chaetospira var. pini | | 3 | 2 | 2 |
| Libertella sp. | 1 | 1 | 2 | |
| SPRING | | | | |
| Chloridium virescens var. chlamydosporum | 3 | | | |
| SPRING & FALL | | | | |
| Trichoderma koningii | 10 | 9 | 5 | 2 |
| Polyscytalum fecundissimum | 2 | 6 | 2 | 6 |
| Gliocladium roseum | 3 | 2 | 1 | |
| Flagellospora stricta | 2 | 1 | | 1 |
| Septonema chaetospira | 1 | 1 | | 1 |
| Trichoderma polysporum | 2 | 1 | | |
| Fusarium lateritium | 1 | 1 | | |
| FALL | | | | |
| Penicillium brevi-compactum | | 13 | 3 | |
| Hyalodendron lignicola | 3 | 8 | | 1 |
| Chalara longipes | | 8 | | |
| Helicodendron triglitziensis | 2 | 5 | | 1 |
| Mortierella ramanniana var. ramanniana | 1 | 4 | | |
| Chalara constricta | 1 | 2 | 1 | |
| Triposporium elegans | 1 | 3 | | |
| Mucor hiemalis f. hiemalis | | 2 | 1 | |
| WINTER | | | | |
| Pestalotia monochaetioides | | 2 | 4 | |
| SPRING & WINTER | | | | |
| Selenophoma sp. | 8 | 7 | 13 | 16 |
| Septogloeum sp. | 1 | | 1 | 1 |

Table XIX. Seasonal Distribution Of Species In The F Layer At Site A

| | TOTAL # OF ISOLATES | | | | | |
|---|---|---|---|---|---|---|
| | APR | JUL | NOV | FEB | MAY | JUL |
| NONSEASONAL | | | | | | |
| *Cylindrocarpon tenue* | 16 | 7 | 13 | 9 | 12 | 9 |
| *Mucor hiemalis f. hiemalis* | 2 | 2 | 2 | 2 | | 1 |
| *Libertella* sp. | | 1 | 1 | 2 | 1 | 2 |
| SPRING | | | | | | |
| *Helicodendron triglitziensis* | 11 | 3 | 2 | 4 | 5 | 2 |
| *Polyscytalum fecundissimum* | 10 | 2 | 3 | | | |
| *Chalara constricta* | 11 | | | 1 | | |
| *Sporidesmium flexum* | 1 | | | | 7 | 2 |
| *Chalara longipes* | 2 | | 1 | | | |
| *Hyalodendron lignicola* | 3 | | | | | |
| SUMMER | | | | | | |
| *Penicillium nigricans* | 3 | 6 | 3 | 4 | 5 | 9 |
| *Articulospora tetracladia* | 3 | 14 | 2 | 3 | 1 | 3 |
| *Trichoderma viride* | | 10 | | 2 | 8 | 6 |
| *Cylindrocarpon didymum* | | 9 | 3 | 3 | 2 | 1 |
| *Penicillium raistrickii* | | 5 | | | 3 | 5 |
| *Varicosporium elodeae* | 2 | 5 | 1 | 1 | 1 | 2 |
| *Trichoderma polysporum* | | 5 | | | | |
| *Verticillium bulbillosum* | 2 | 3 | | | | |
| *Gliocladium roseum* | | 2 | 1 | | 1 | |
| FALL & WINTER | | | | | | |
| *Penicillium verrucosum* var. *cyclopium* | 2 | 2 | 4 | 4 | 1 | |
| *Trichoderma koningii* | | | 1 | 6 | | |
| *Penicillium notatum* | 1 | | 2 | 1 | | |
| SPRING, SUMMER & FALL | | | | | | |
| *Septonema chaetospira* | 5 | 7 | 5 | | 6 | 2 |
| *Cladosporium cladosporioides* | 1 | 3 | 4 | | 3 | |
| *S. chaetospira* var. *pini* | 2 | 1 | 3 | 1 | | 1 |
| *Penicillium brevi-compactum* | | 2 | 3 | | | |

Table XX. Seasonal Distribution Of Species In The F Layer At Site B

| | TOTAL # OF ISOLATES | | | |
|---|---|---|---|---|
| | MAY | SEP | JAN | APR |
| NONSEASONAL | | | | |
| Cylindrocarpon tenue | 2 | 14 | 21 | 18 |
| Trichoderma koningii | 18 | 10 | 10 | 1 |
| Gliocladium roseum | 4 | 3 | 7 | 2 |
| Cladosporium cladosporioides | 1 | 2 | 4 | 3 |
| FALL & SPRING | | | | |
| Trichoderma polysporum | | 2 | 2 | 4 |
| Flagellospora stricta | 2 | 2 | | |
| WINTER & SPRING | | | | |
| Penicillium verrucosum var. cyclopium | 2 | 4 | 10 | 8 |
| SPRING | | | | |
| Mucor hiemalis f. hiemalis | 3 | | | 4 |
| Acremonium strictum | 3 | | 1 | |
| Selenophoma sp. | 2 | | | 1 |
| FALL | | | | |
| Penicillium brevi-compactum | 2 | 11 | | |
| Chalara cylindrosperma | 1 | 4 | 1 | 1 |
| Penicillium raistrickii | | 4 | | 1 |
| FALL & WINTER | | | | |
| Penicillium nigricans | | 2 | 4 | |
| Trichoderma viride | | 1 | 2 | 1 |
| Penicillium frequentans | | 2 | 1 | |
| WINTER | | | | |
| Chloridium virescens var. chlamydosporum | 1 | | 2 | |
| Septonema chaetospira | | | 2 | |

In the preceding treatment of the seasonality of the species found in the L and F layers, observations were made at two major sites, designated A and B. These sites were not identical with respect to the species present or their distribution. Furthermore, the number of samples at each site was not the same. Despite these differences, some statements can be made on the seasonality of the species found in the two layers, based on their occurrences in both sites.

Of all the species occurring in the L layer, only one showed little or no seasonal variation and that was Cylindrocarpon tenue. The rest of the species could be placed in three groups, spring and summer, summer, and fall and winter. The spring and summer group included (in decreasing order of frequency):

Articulospora tetracladia
Septonema chaetospira
Flagellospora stricta
Acremonium strictum
Sporidesmium flexum
Chloridium virescens var. chlamydosporum

The summer group comprised:

Trichoderma viride
Penicillium nigricans
P. raistrickii
Cylindrocarpon didymum

The fall and winter group was characterized by:

Mucor hiemalis f. hiemalis
Pestalotia monochaetioides
Penicillium brevi-compactum
Hyalodendron lignicola
Mortierella ramanniana var. ramanniana
Triposporium elegans
Chalara constricta
Penicillium citrinum

The F layer contained also Cylindrocarpon tenue as the only species which showed little seasonal variation. The groups at this layer were spring, summer, and fall and winter. The species found in the spring were:

Helicodendron triglitziensis
Polyscytalum fecundissimum
Chalara constricta
Sporidesmium flexum
Hyalodendron lignicola

The summer group included:

Articulospora tetracladia
Cylindrocarpon didymum
Varicosporium elodeae
Verticillium bulbillosum

The species present in the fall and winter included:

Penicillium verrucosum var. cyclopium
P. notatum
P. frequentans
Chalara cylindrosperma

The complexity of the interaction between species involved in the decay process is such that definite roles or associations among species are hard to elucidate. In the foregoing sections, an attempt has been made to point out generalizations of species

occurrence with respect to position within the sites, sequence in decay and seasonality. The species isolated have been grouped in each of these instances, but an overall indication of their involvment in the decay has been hard to illustrate. The following section deals with the species as individuals, discussing their distributions and seasonality.

## 5. Fungal Species Isolated

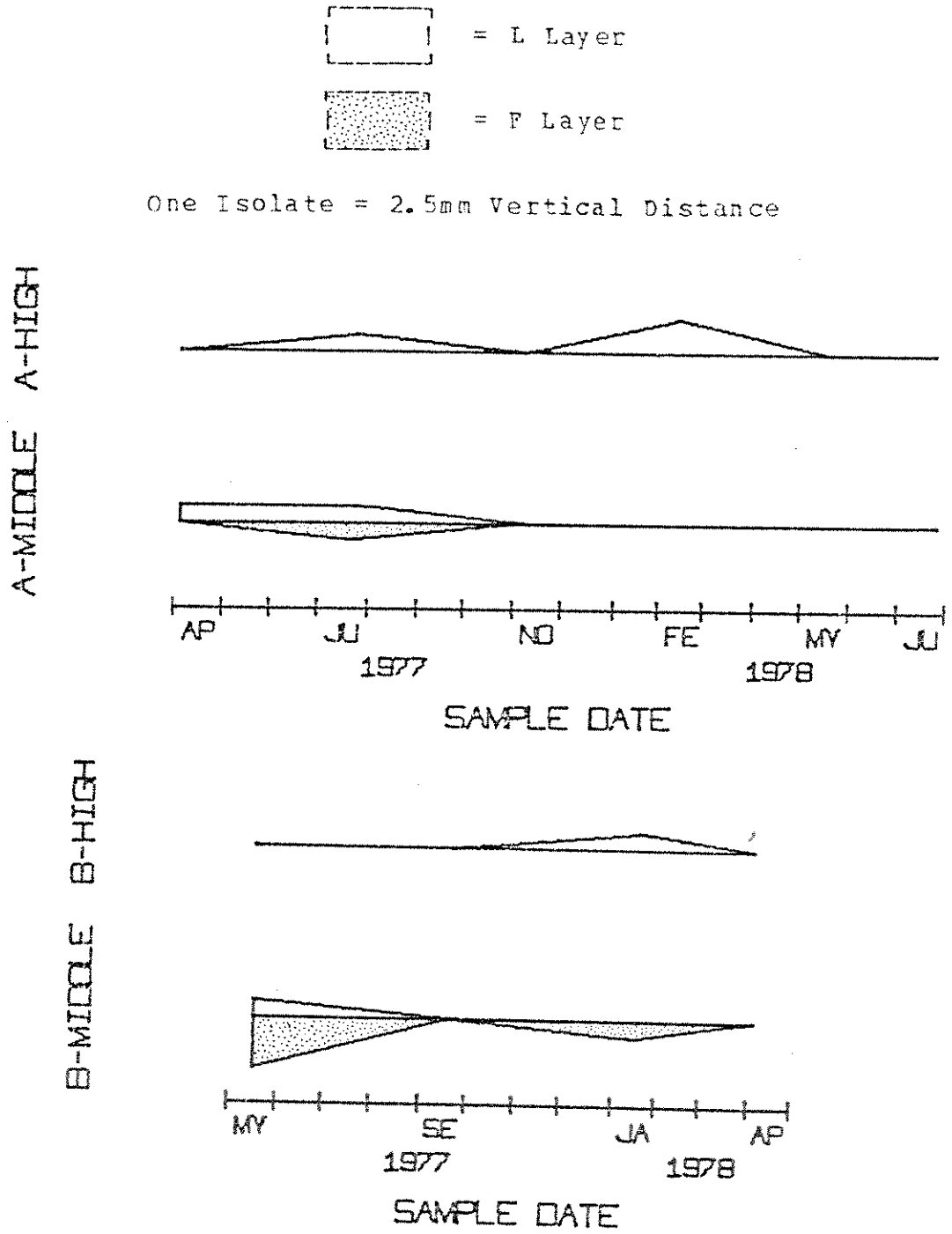
The preceding discussions have been concerned with the distribution and seasonality of the species isolated, with respect to the sites and subsites. The result has been a tentative grouping of certain species together, representing different sites, subsites or seasons. In the following section the individual species are treated in order to point out distinctive features, and comment on their distribution.

Acremonium strictum Gams. Cephalosporium-artige Schimmelpilze 42. 1971.

Colonies white to pinkish, usually with little aerial mycelium; phialides often in groups of three or produced laterally on funiculose strands, 27.0 - 46.8 x 1.8 um; spores irregular to somewhat curved, 3.6 - 7.2 x 1.2 - 3.0 um.

A. strictum was isolated most often from leaves in moist chambers; it was found relatively infrequently (Fig. 3). It was absent from the low subsite in both Site A and B, and was found only sporadically in the L and F layers. This is a common soil fungus that is also found on organic debris (Gams, 1971; Domsch and Gams, 1972).

Figure 3. Seasonal Distribution - Number Of Isolates Of *Acremonium strictum*



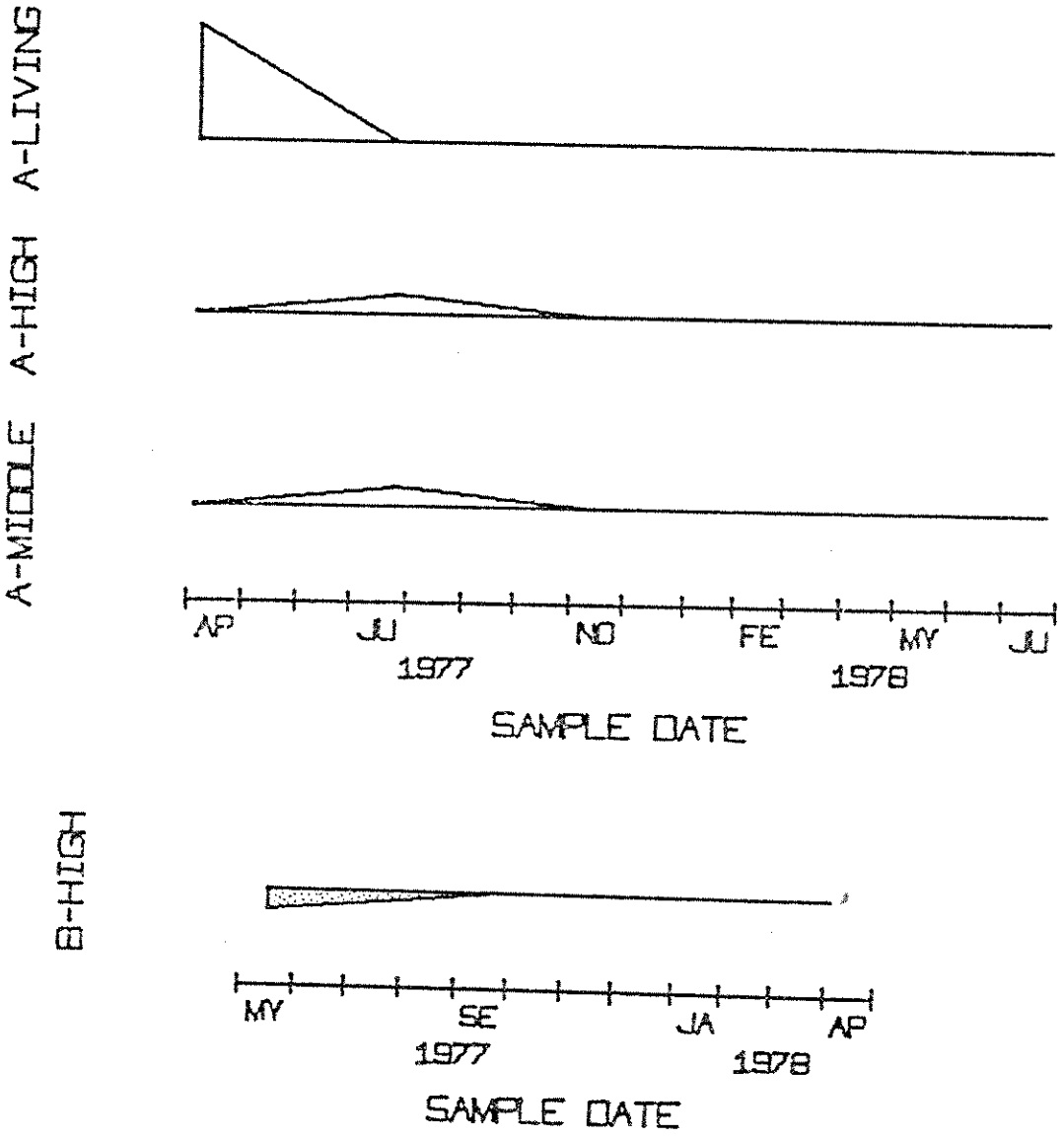
Acrodontium crateriforme (Van Beyma)de Hoog. Stud. Mycol. 1:26. 1972.

Colonies cottony to floccose, gray; conidiophores usually funiculose, conidiogenous cells sympodial, very thin with minute denticles, conidia 3.6 x 1.8 um. The cultures fit the description given by de Hoog (1972).

A. crateriforme was isolated infrequently from either site, its largest occurrence being on living leaves at the spring sample from Site A. It was found in the L layer at the summer sample, probably from leaves which were still on the tree at the previous sample. This species was prominent only during the spring and summer (Fig. 4). De Hoog (1972) reported A. crateriforme from various substrata including leaves of numerous plants; one report was from living leaves of Fraxinus excelsior. Yokoyama et al. (1977) also reported this species on sterilized leaves embedded in litter.

Figure 4. Seasonal Distribution - Number Of Isolates Of *Acrodontium crateriforme*

For Legend See Fig. 3



Articulospora tetracladia Ing. Trans. Brit. Mycol. Soc. 25:376. 1942.

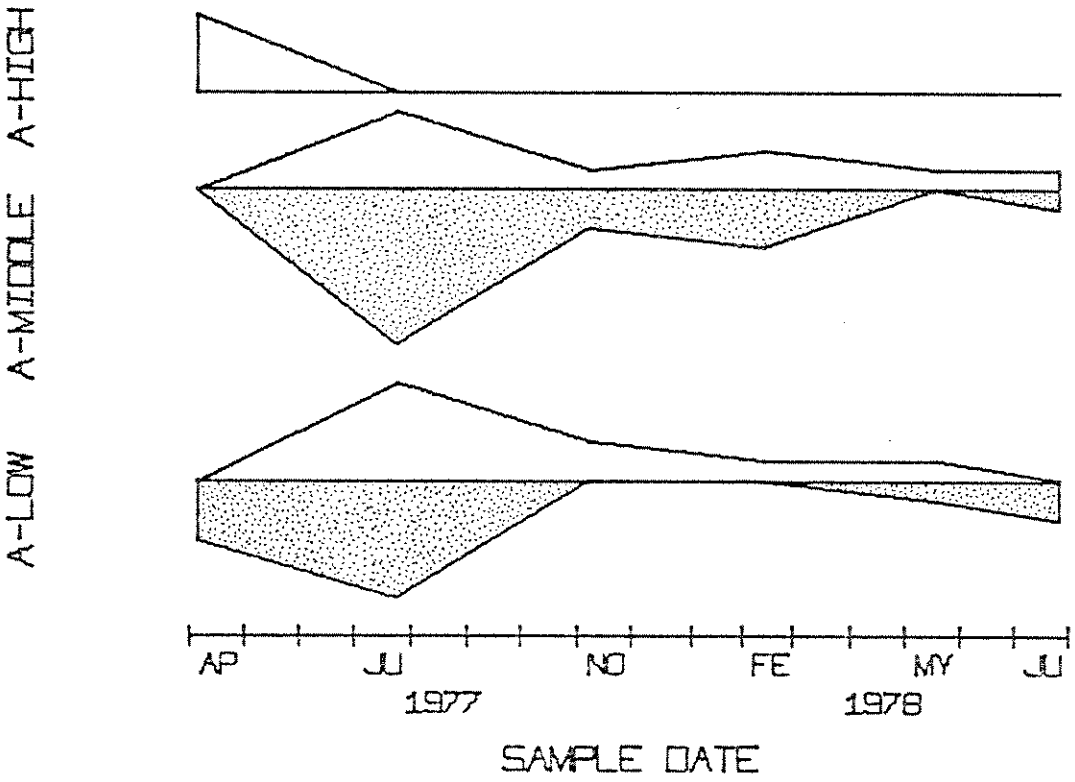
In culture, colonies are often pinkish, and appear wet on the surface, sometimes producing small rounded sclerotium-like structures of unknown function. This species is easily recognizable by its distinct tetraradiate spores, which are as long as 75 um.

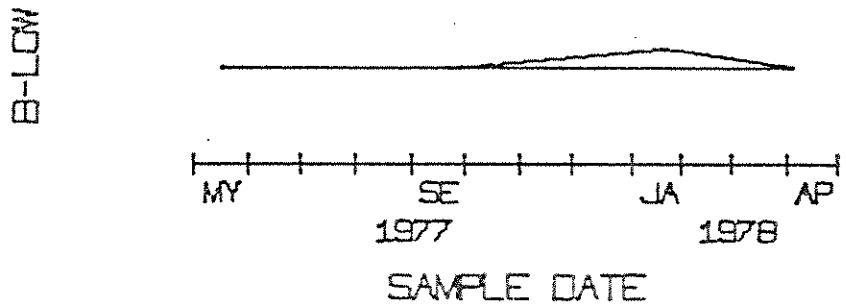
A. tetracladia was found predominantly at Site A. It occurred only once in Site B. It was isolated mostly from the lower and middle subsites, in both the L and F layers, but predominantly the F layer. It occurred in the greatest numbers at the first summer sample (Fig. 5). Temperature may be more important than precipitation in its seasonality, since later samples had more rain but lower temperatures, and the frequency was down. In culture, colony growth and sporulation decrease at lower (5° C) and higher (25° C) temperatures (Koske and Duncan, 1974). Moisture must still be important since its occurrence did not increase again at the second summer sample when the temperature rose, probably because there had been no rain for two weeks.

A. tetracladia is a member of the aquatic hyphomycetes, an artificial group usually found growing on debris in streams. It has often been reported from terrestrial situations (Bandoni, 1972, 1977; Sanders and Webster, 1978; Webster, 1977). Its occurrence in the F layer indicates its active role as a secondary colonizer in the decay of the terrestrial litter.

Figure 5. Seasonal Distribution - Number Of Isolates Of *Articulospora tetracladia*

For Legend See Fig. 3



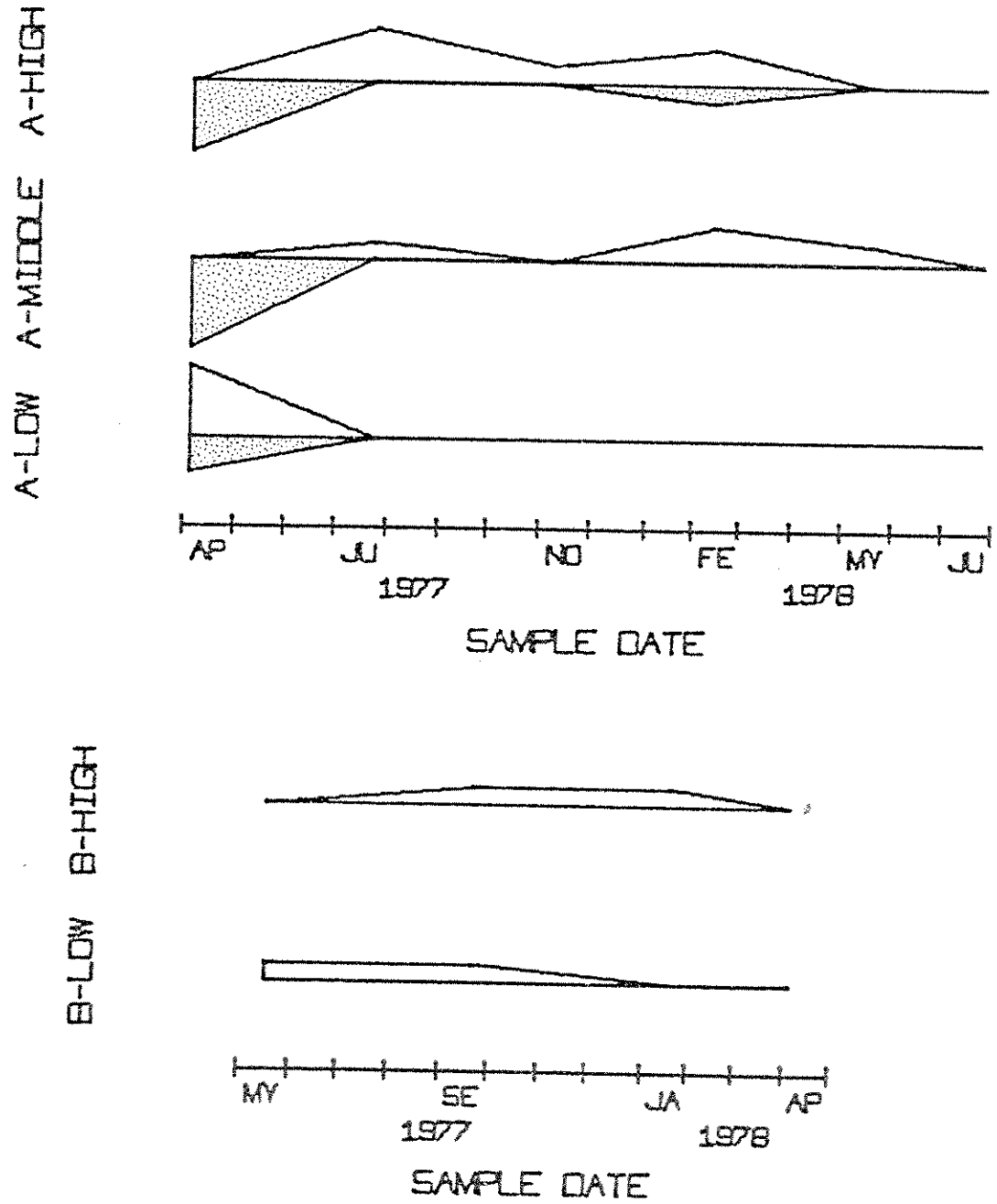
Chalara constricta Nag Raj and Kendrick. A Monograph of Chalara and Allied Genera. 103. 1975.

Cultures very slow growing, white to gray, sometimes with black patches; conidiophores usually funiculose; phialides often proliferating, sometimes slightly curved; spores hyaline, clavate, small, non-septate, 3.0 - 7.2 (10.8) x 1.0 - 1.8 um. This species was described by Nag Raj and Kendrick (1975) from leaves of Agathis australis from New Zealand. The present isolates differ from the original description in that the upper range of the spores is slightly higher in some cultures. Furthermore, in some isolates the conidiophores are more than 4 celled. These differences do not warrant exclusion from this species.

In Site A, C. constricta occurred most frequently in the first spring sample, where it occurred in all three subsites, mostly in the F layer. The frequency diminished in subsequent samples when it occurred only in the middle and high subsites, in the L layer. It occurred infrequently at Site B (Fig. 6). This species was isolated almost entirely from leaves in moist chambers. It occurred in the L layer during summer through winter and in the F layer during the spring. It did not occur at the final summer sample when the temperature was the highest and the rainfall the lowest.

Figure 6. Seasonal Distribution - Number Of Isolates Of Chalara constricta

For Legend See Fig. 3



Chalara cylindrosperma (Cda.)Hughes. Can. J. Bot. 36:747. 1958.

Colonies dark gray to black, restricted; conidiophores funiculose; phialides with a long collarette, 18.0 - 23.4 um; conidia cylindrical, hyaline, 7.2 - 14.4 x 1.8 um.

Nag Raj and Kendrick (1975) have reported this species from various angiosperm leaves and wood. C. cylindrosperma was restricted mainly to Site B, occurring most frequently during early fall in the F layer (Fig. 7).

Chalara longipes (Pr.)Cooke. Grevillea 10:50. 1881.

Colonies restricted, dark gray to black; conidiophores funiculose, dark; conidia cylindrical, 3.0 - 7.2 x 1.0 - 1.8 um. The type is on pine needles from Germany. The present isolates differ from the original description in that the spores are slightly larger.

In Site A, C. longipes occurred sporadically in most layers and subsites, with the highest occurrence in the low subsite, in the first spring sample (Fig. 8). This species was most prominent in the early fall at Site B, in the L layer. Overall, C. longipes was noticeably absent during the summers and therefore may not be active at times of high temperature and low precipitation. None of the preceding species of Chalara have been reported in studies on fungi from washed conifer litter.

Figure 7. Seasonal Distribution - Number Of Isolates Of *Chalara cylindrosperma*

For Legend See Fig. 3

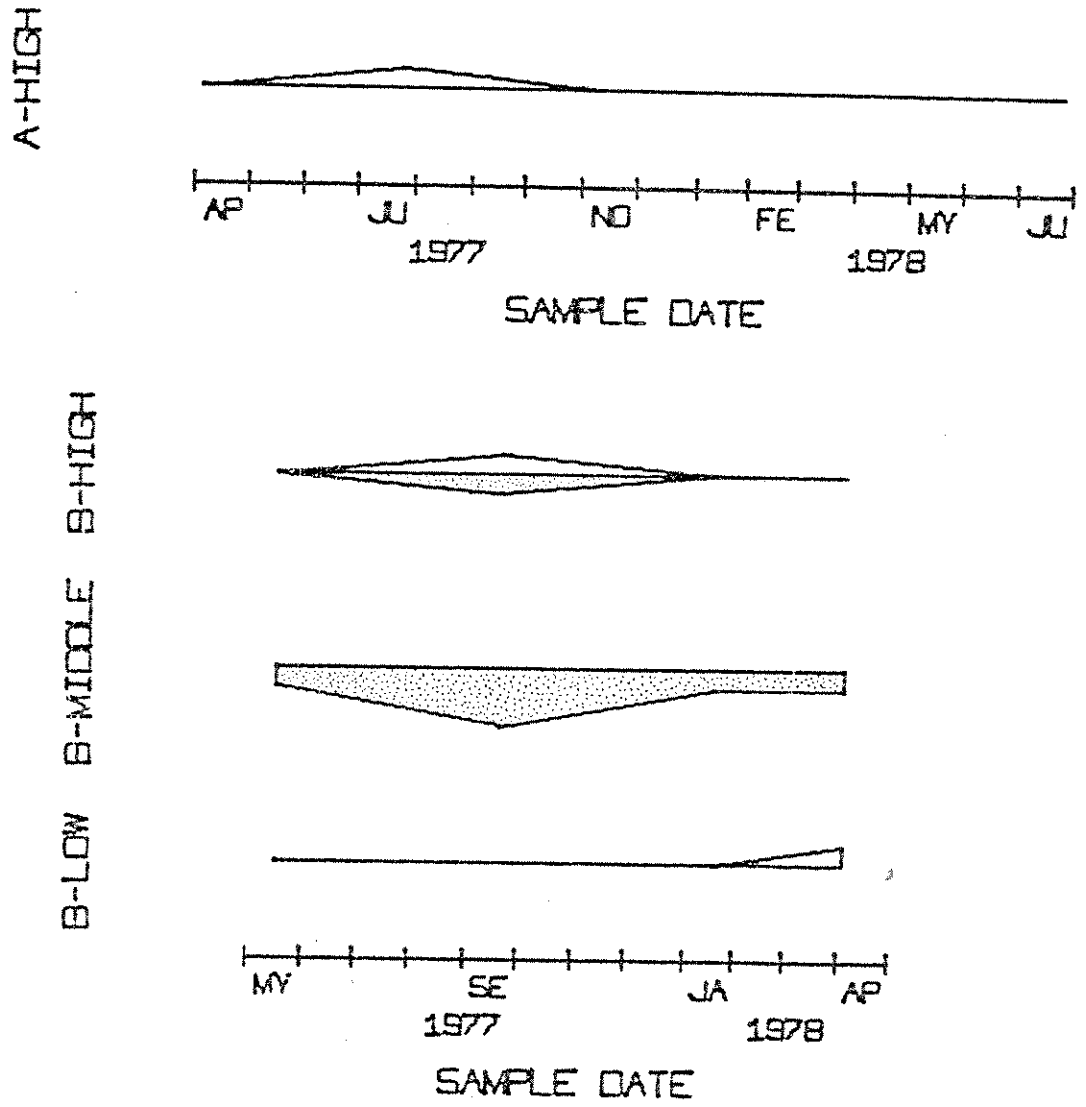
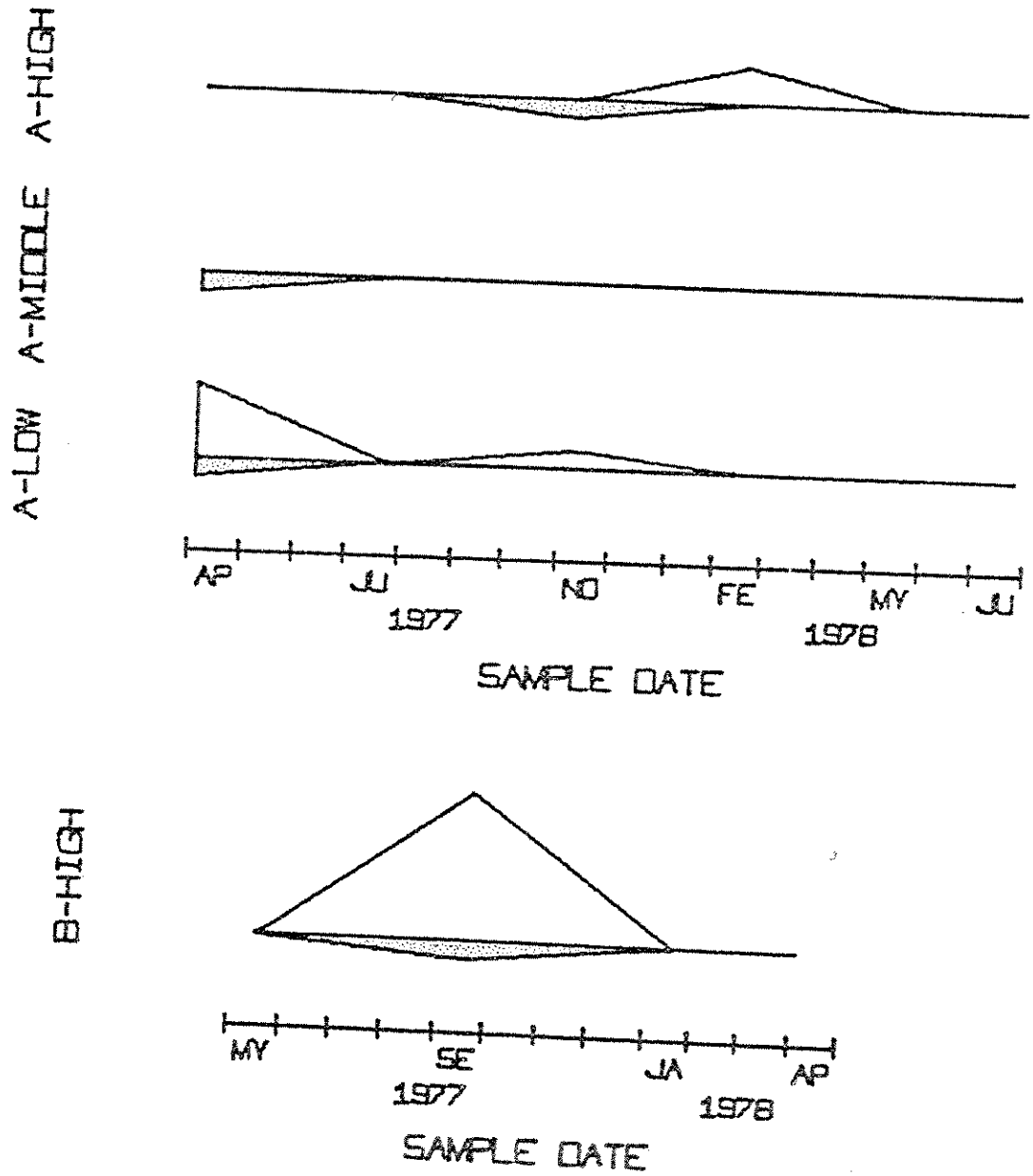


Figure 8. Seasonal Distribution - Number Of Isolates Of Chalara longipes

For Legend See Fig. 3



Chloridium virescens (Pers. ex Pers.)W. Gams & Hol.-Jech. var. chlamydosporum (Van Beyma)W. Gams & Hol.-Jech. Stud. Mycol. 13:21. 1976.

Colony growth restricted, producing abundant, brown chlamydospores, conidia 3.6 - 5.4 x 1.8 - 2.2 um. This species was isolated rarely, and only from the high subsite at Site B. It was prominent in the L layer during the spring, and the F layer during the winter (Fig. 9). C. virescens var. chlamydosporum has been reported previously from various soils and litters (Domsch and Gams, 1972; Gams and Holubova-Jechova, 1976).

Cladosporium cladosporioides (Fresen.)de Vries. Contribution to the Knowledge of the Genus Cladosporium Link ex Fr. 57. 1952.

This species is easily identified by the smooth, non-septate, lemon shaped blastospores. It was isolated frequently from both Site A and Site B. It occurred in all subsites, including the living leaves, in both L and F layers. Besides being one of the most common soil and litter fungi, this species has also been found repeatedly on the surfaces of living leaves (Baker et al., 1979; Gourbiere, 1975; Collins and Hayes, 1976). C. cladosporioides occurred largely during the spring and summer at Site A, and during the spring and winter at Site B (Fig. 10).

Figure 9. Seasonal Distribution - Number Of Isolates Of *Chloridium virescens* var. *chlamydosporum*

For Legend See Fig. 3

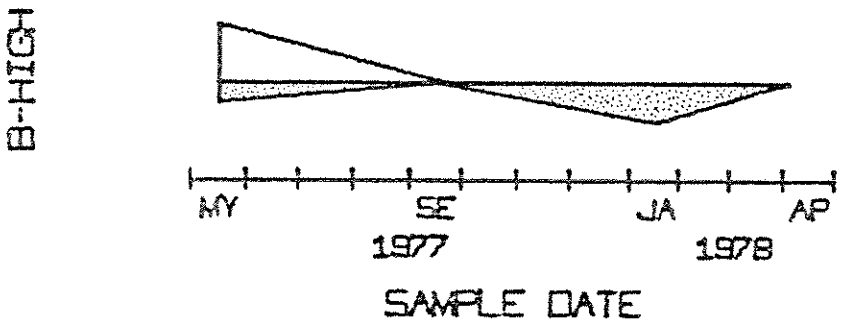
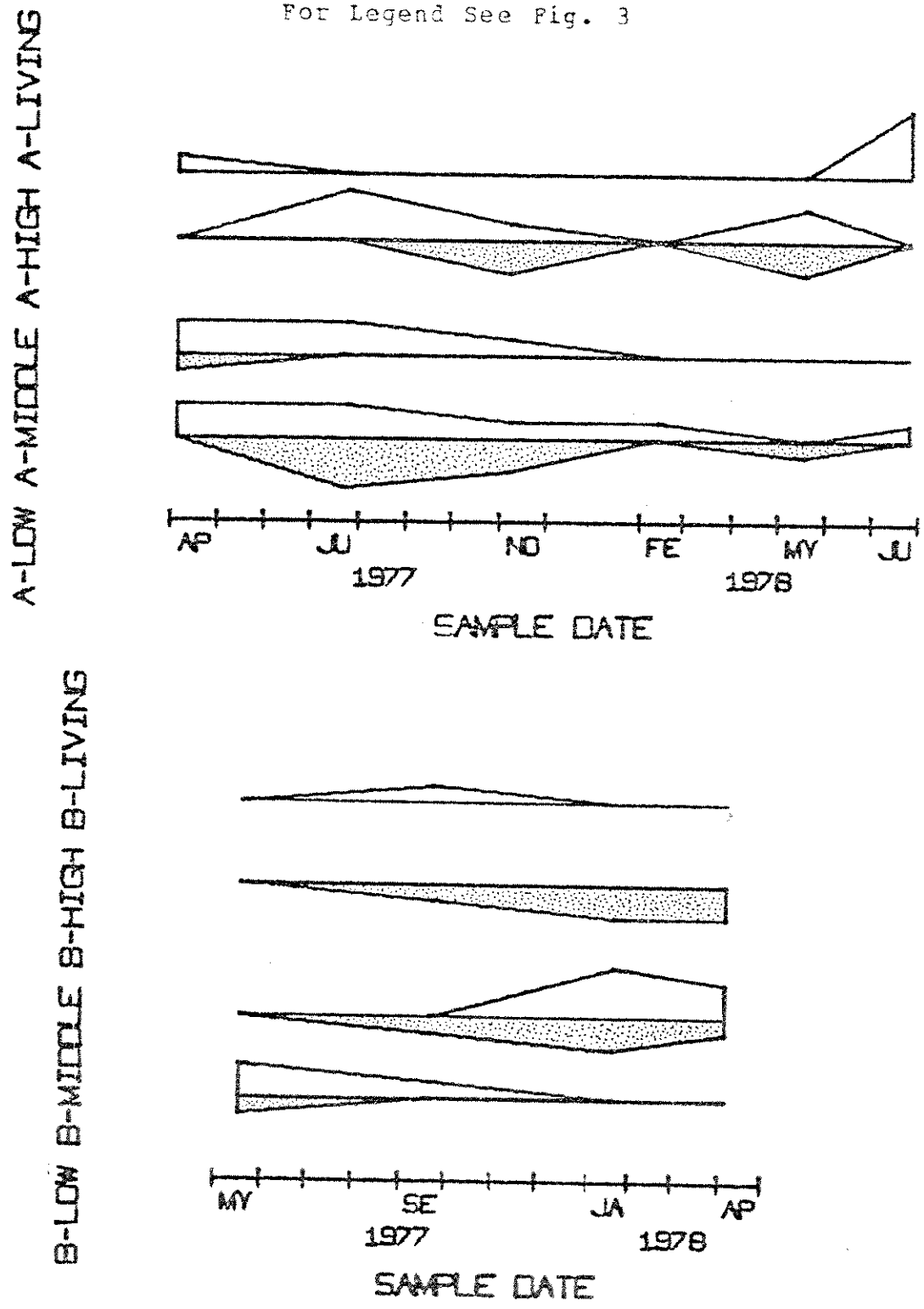


Figure 10. Seasonal Distribution - Number Of Isolates Of Cladosporium cladosporioides

For Legend See Fig. 3



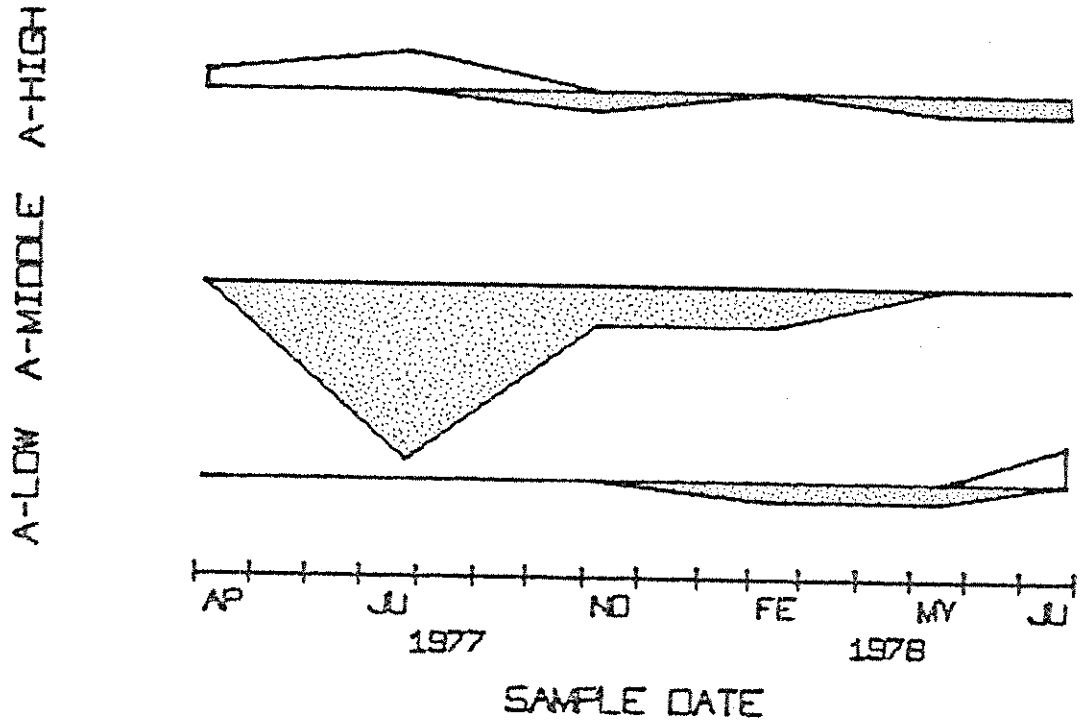
Cylindrocarpon didymum (Hortig)Wollenw. Fus. Autogr. Del. ed. 2. 650. 1926.

Colonies spreading relatively rapidly, white to off-white, sparse aerial hyphae, usually somewhat slimy; conidia produced in slimy masses, 0 - 3 septate, but usually 1 - 2, 18.0 - 35.0 x 3.6 - 6.0 um; chlamydospores present, brown. This species is easily recognized by the wide spores with somewhat non-symmetrical septa. Sometimes there were very small spores present, 5.4 - 7.2 x 1.0 - 1.8 um. These may be microconidia, or what Booth (1966) called primary conidia.

C. didymum was isolated only from Site A, mainly from the F layer. It occurred in all three subsites, most frequently occurring during the summer in the middle subsite (Fig. 11).

Figure 11. Seasonal Distribution - Number Of Isolates Of *Cylindrocarpon didymum*

For Legend See Fig. 3



Cylindrocarpon tenue Bugn. Encycl. Mycol. 11:175-178. 1939.

Colonies rapidly growing, aerial hyphae cottony, white to orange-brown, the latter color predominant in older cultures; conidia 0 - 1 septate, sometimes 2 - 3, 10.8 - 32.4 x 1.8 - 3.6 um; chlamydospores present, brown, usually in intercalary chains. These isolates fit the description of the species given by Booth (1966), but differ in that the spore size range is larger than that described. There is no other species with this combination of narrow spores and chlamydospores present. Sometimes smaller conidia are present, but these may just be immature types.

C. tenue was the most frequently isolated of all the fungi present. In Site A it was present at all sample dates, more often in the L layer, but also in the F layer. It seemed to occur under drier conditions, but not extremely dry. This is shown by the fact that it was present in the middle and low subsites, but not the high, when temperature was high and rainfall low. As the temperature fell and rainfall increased, it declined in the low and middle subsites, and rose in abundance in the high subsite. Conversely, when rainfall dropped drastically during the last summer sample at Site A, it was much less abundant (Fig. 12). In Site B it had much the same pattern except that it seemed to be more evenly distributed among the samples (Fig. 13).

Figure 12. Seasonal Distribution - Number Of Isolates Of *Cylindrocarpon tenue* --Site A.

For Legend See Fig. 3

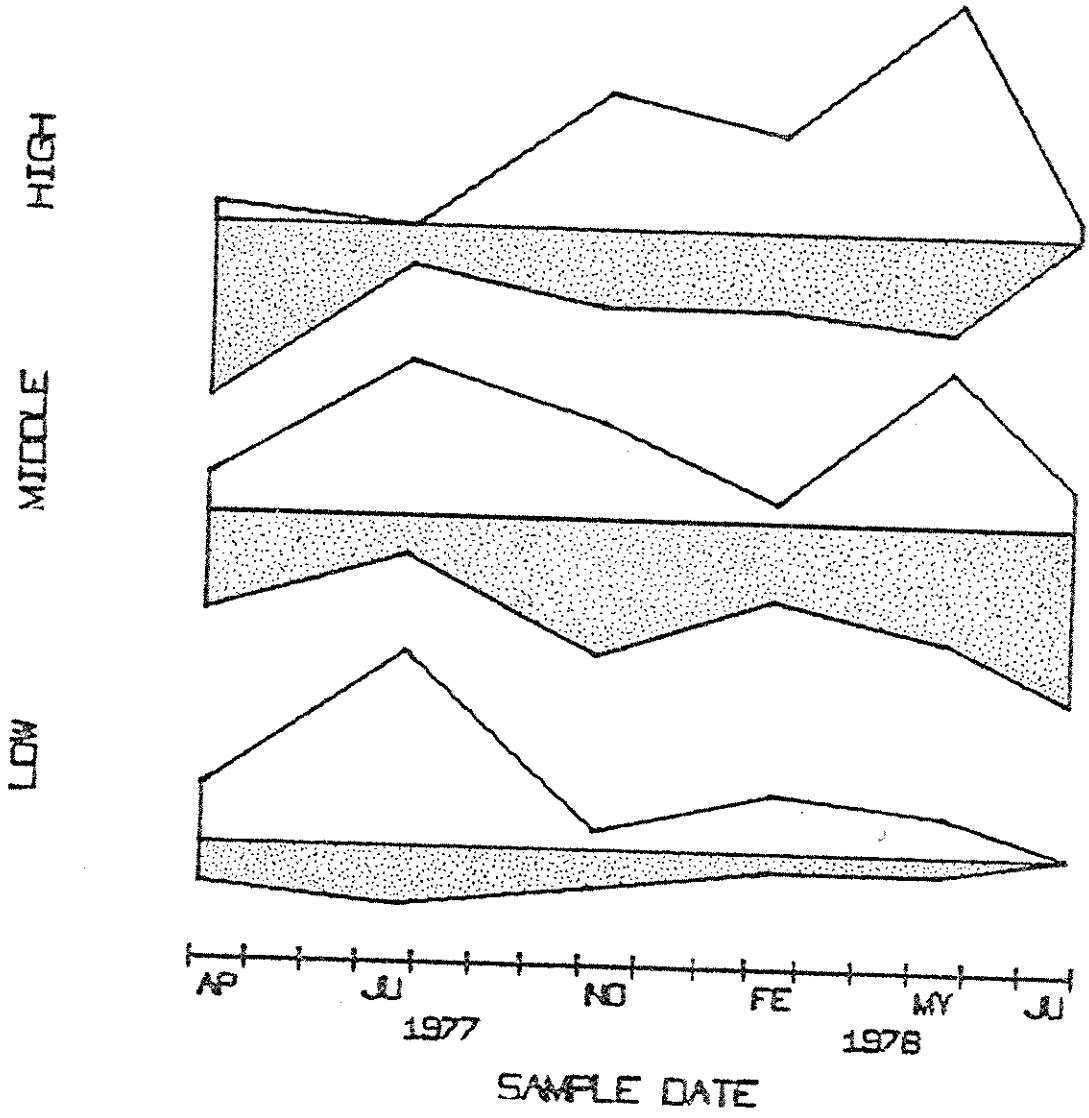
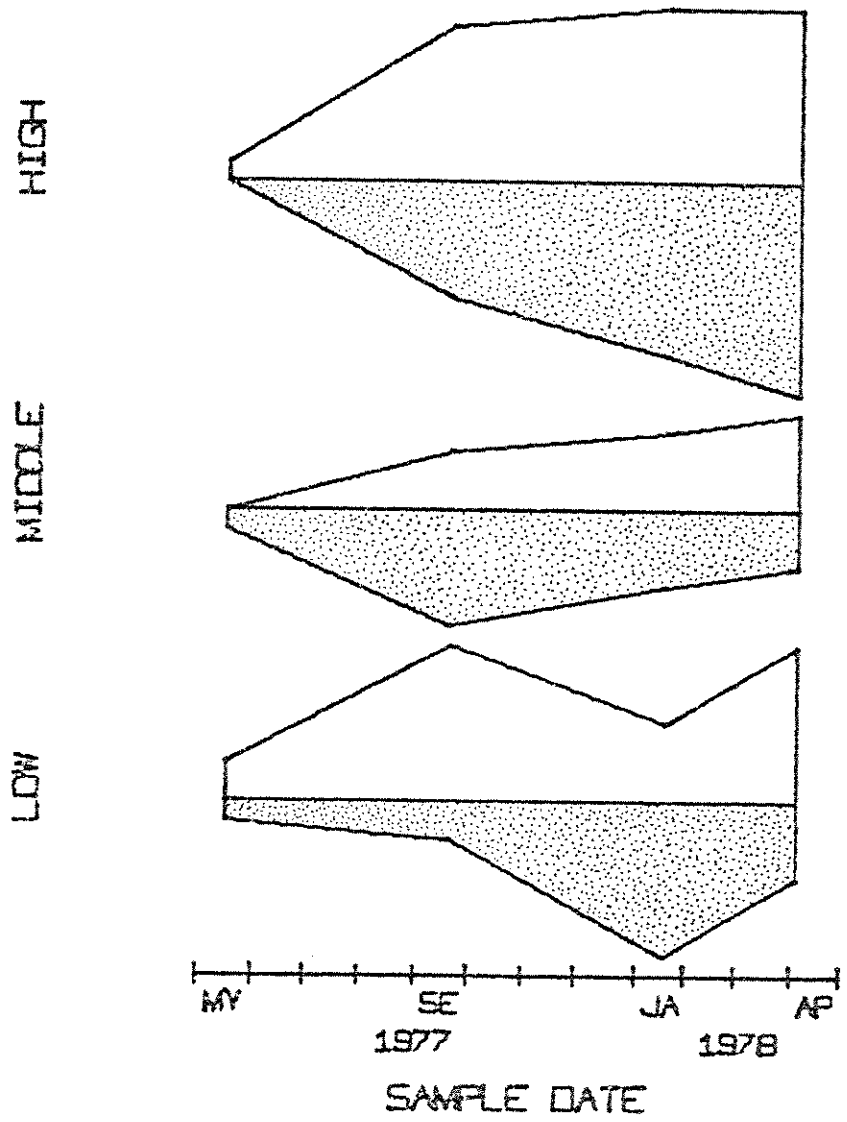


Figure 13. Seasonal Distribution - Number Of Isolates Of *Cylindrocarpon tenue* --Site B

For Legend See Fig. 3



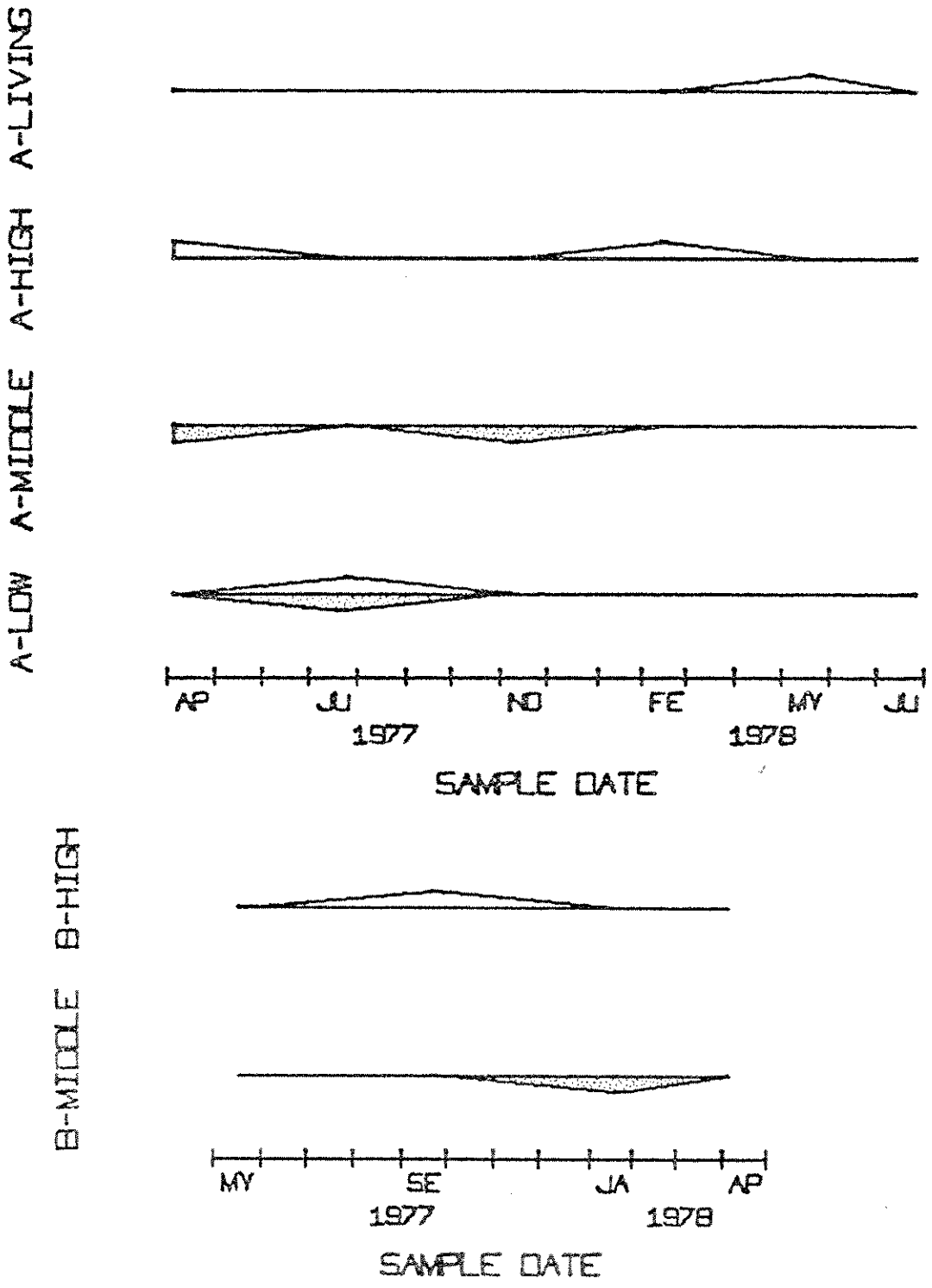
Endophragmia alternata Tubaki and Saito. Trans. Brit. Mycol. Soc. 52:477. 1969.

Colonies slow growing, mycelium black; conidiophores dark, short, producing only one or two dark, septate conidia. These isolates resemble that described by Tubaki and Saito (1969).

E. alternata was an extremely slow growing species in culture, and subsequently produced spores infrequently. Matsushima (1975) indicated this species to be infertile in culture. Some of the cultures designated as sterile dark mycelia, in this study, could have been isolates of E. alternata that had not sporulated. This species was isolated rarely, but occurred in all subsites at Site A and in the high and middle subsites at Site B (Fig. 14). Tubaki and Saito (1969) considered this species an important external colonizer of Pinus densiflora litter.

Figure 14. Seasonal Distribution - Number Of Isolates Of *Endophragmia alternata*

For Legend See Fig. 3



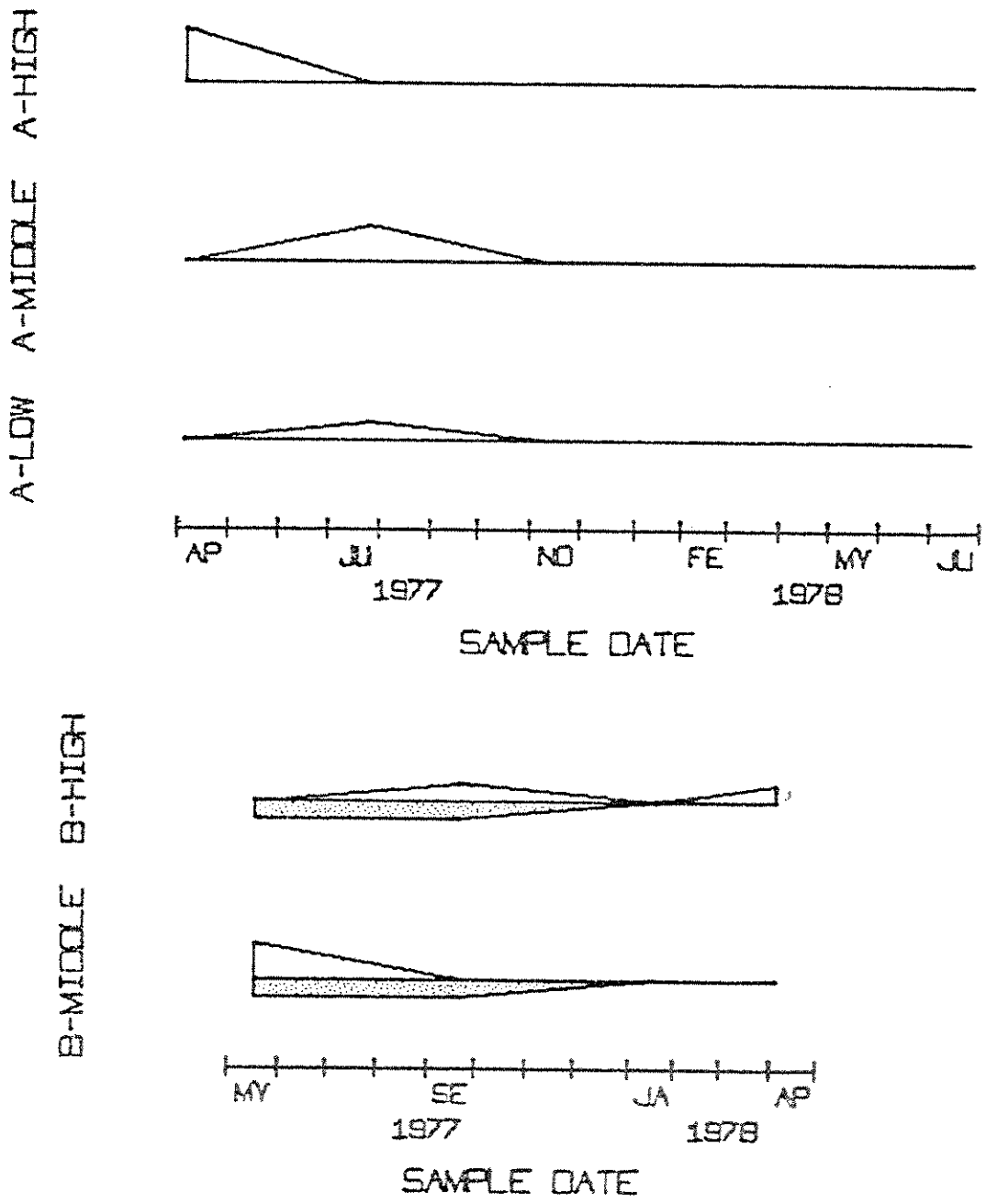
Flagellospora stricta S. Nilss. Bot. Not. 115:82. 1962.

Colonies with limited aerial mycelium, producing masses of slimy spores; conidia straight, 0 - 1 septate, tapered at both ends, 36.0 - 43.2 x 1.3 - 2.0 um. These isolates differ from the original description in sometimes having a septate spore.

F. stricta was found in both Site A and Site B, at the earlier sampling dates, spring and summer. It occurred more often in the high and middle subsites; confined to the L layer in Site A, in both layers at Site B (Fig. 15). It was not isolated frequently, and was rarely found on leaves in moist chambers.

Figure 15. Seasonal Distribution - Number Of Isolates Of *Flagellospora stricta*

For Legend See Fig. 3



Fusarium lateritium Nees. Syst. Pilze Schwamme. 31. 1817.

Cultures ranged from slimy and orange, to felty and vinaceous; the latter usually produced perithecia of its perfect stage, Gibberella baccata (Wallr.)Sacc.; conidia straight to falcate, 27.0 - 41.6 x 3.6 - 5.4 um. These isolates fit the description given by Booth (1971), who also reports perithecia of this species on Thuja, among other hosts. F. lateritium was isolated infrequently, occurring at both sites, but more frequently at Site B, where it was found during the fall (Fig. 16).

Gliocladium roseum (Link)Banier. Bull. Soc. Mycol. Fr. 23:111 - 112. 1907.

Colonies spreading, white; conidiophores tall; conidial mass in large droplets, 5.4 - 9.0 x 2.5 um. This species was easily recognizable by its slimy spore drops on penicilliate conidiophores. It occurs often as a parasite on other fungi (Barnett and Lilly, 1962). It was isolated from the litter in this study, but whether it occurred as a mycoparasite was not determined.

G. roseum occurred infrequently at Site A, but was more abundant at Site B. It was found most often in the F layer, especially during the winter and spring samples (Fig. 17). All isolates of this species were from leaves in moist chambers.

Figure 16. Seasonal Distribution - Number Of Isolates Of *Fusarium lateritium*

For Legend See Fig. 3

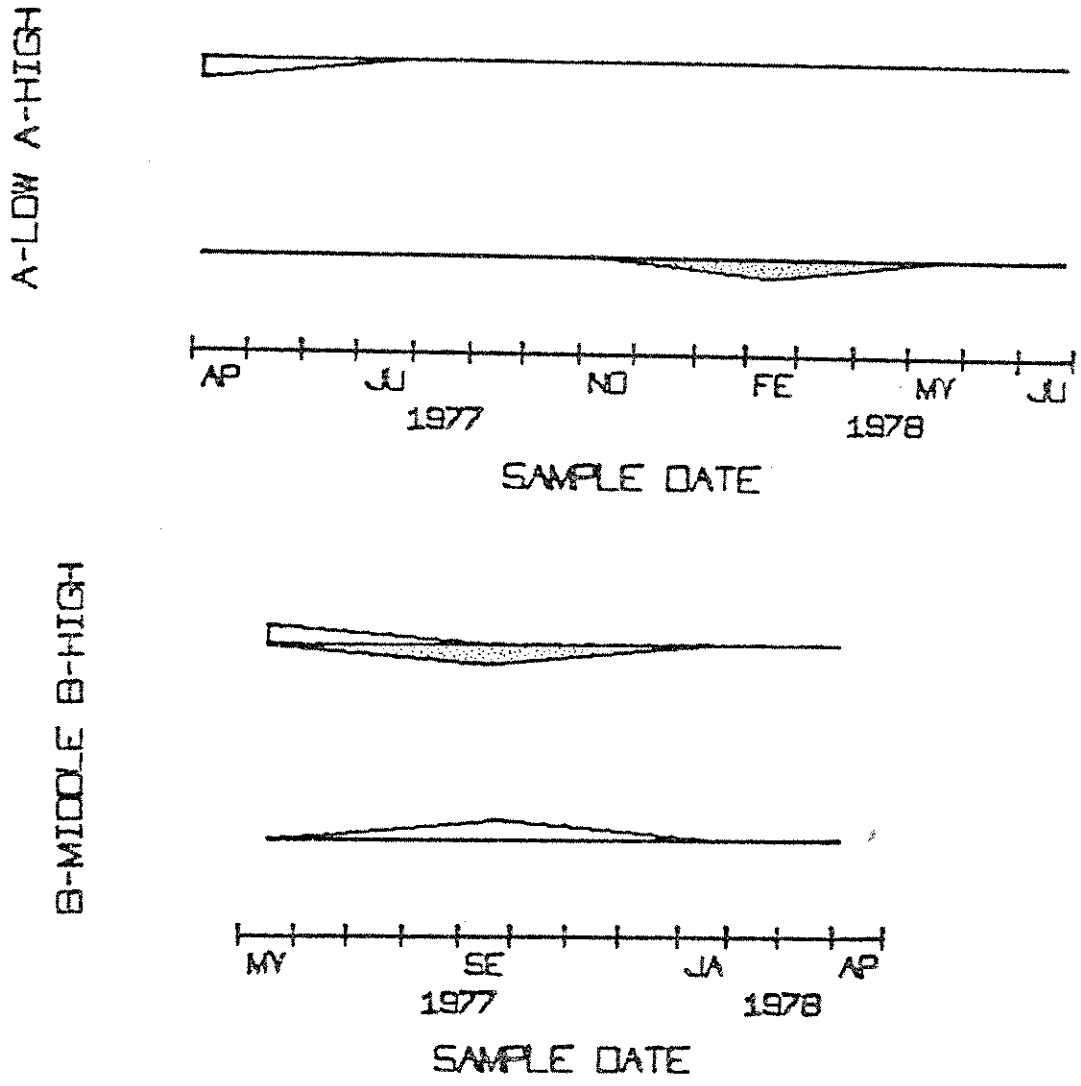
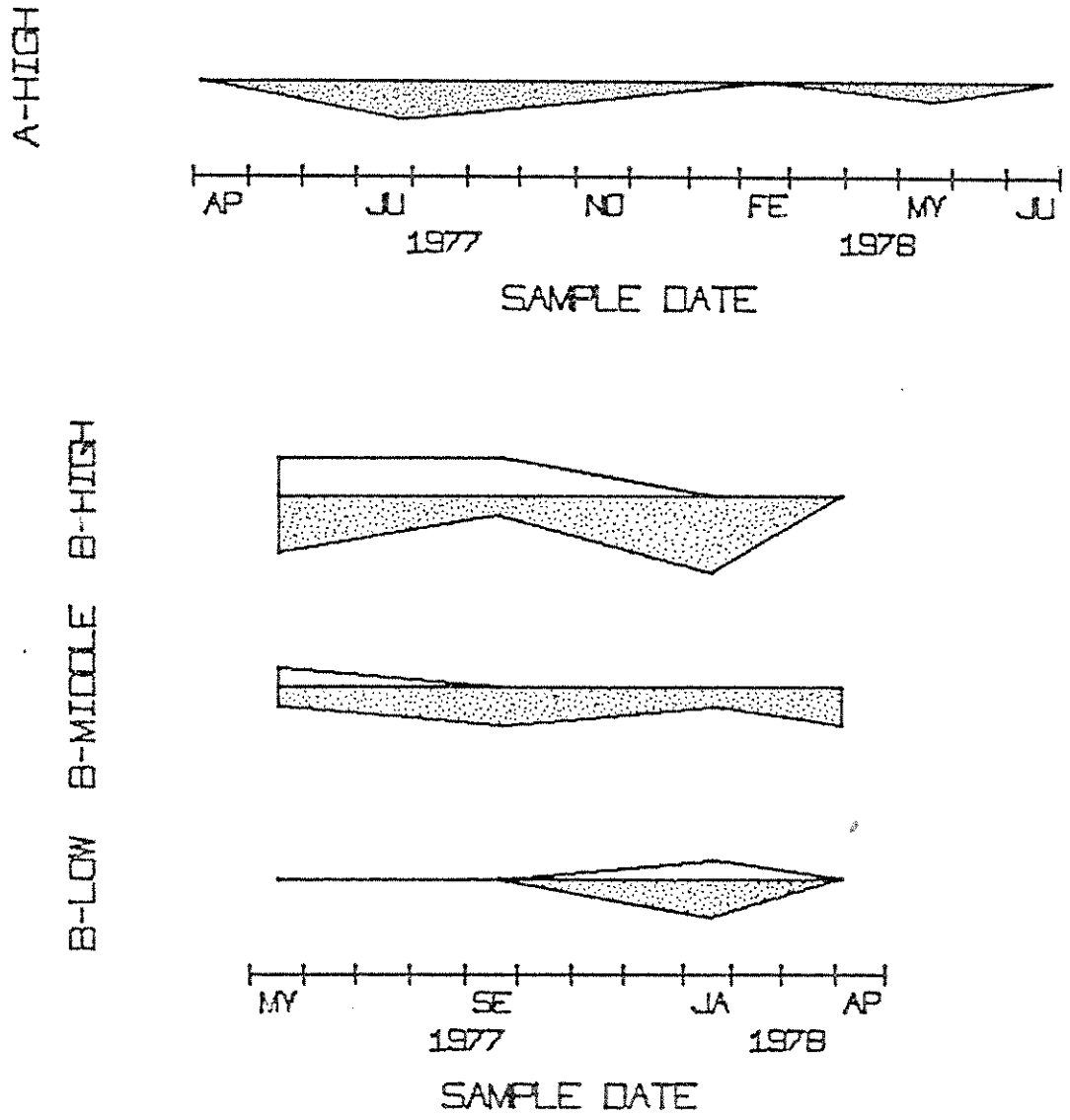


Figure 17. Seasonal Distribution - Number Of Isolates Of

Gliocladium roseum

For Legend See Fig. 3



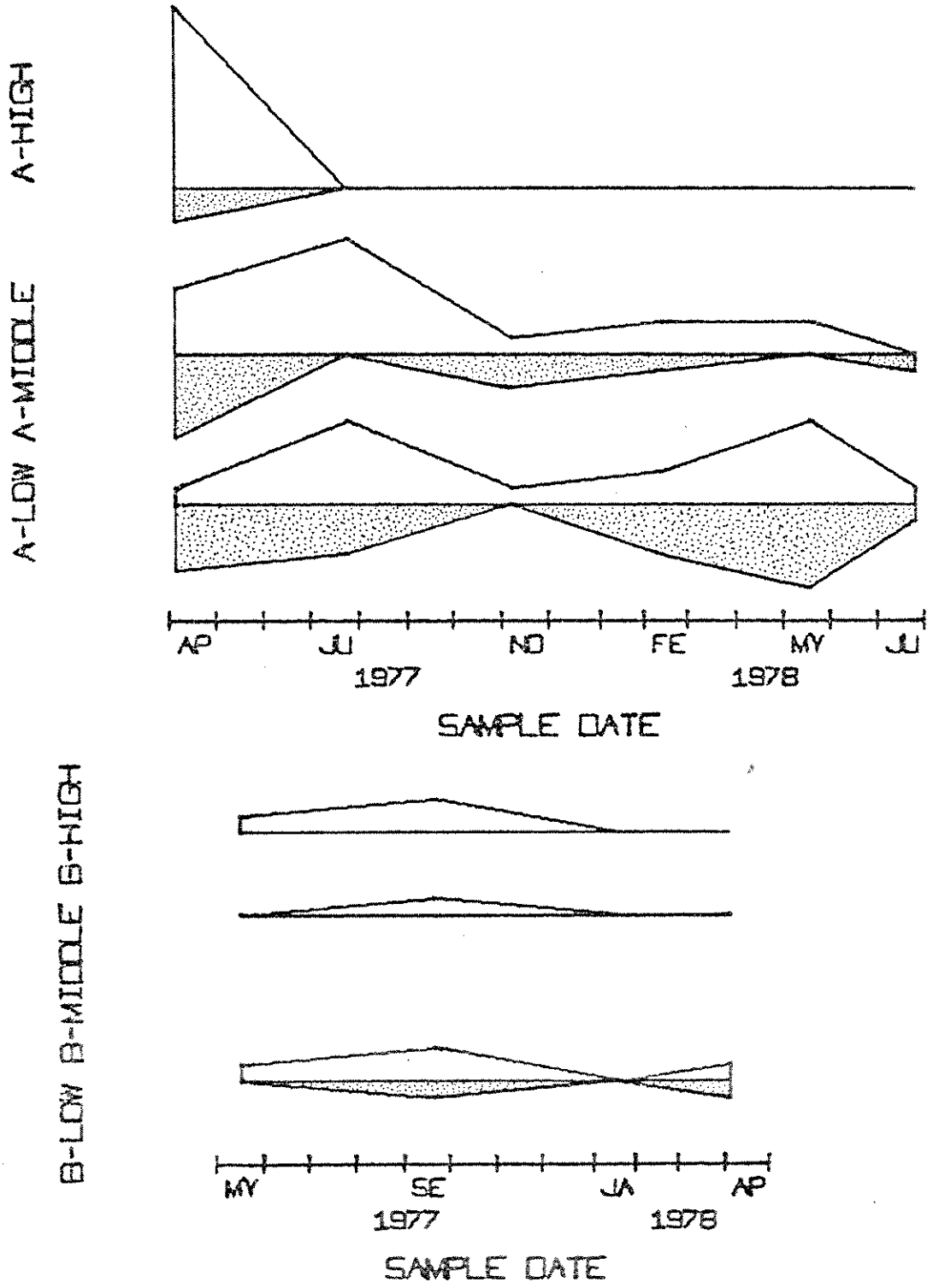
Helicodendron triglitziensis (Jaap)Linder. Ann. Mo. Bot. Gdn. 16:330. 1929.

Colonies spreading, white with abundant aerial mycelium; sporulating profusely, conidia 10.8 - 18.0 x 12.6 um, with 4-6 coils. This species is distinct in its production of chains of short-coiled spores.

H. triglitziensis was isolated mostly from Site A but did occur at Site B. It was present in all subsites but most often from the middle and low ones, in both L and F layers. It was found more commonly during the spring and summer samples (Fig. 18). This is one of the "aero-aquatic" fungi of Fisher (1977) and often has been reported on partially submerged litter. It is also known from angiosperm litter of this region (Goos and Bandoni, 1977).

Figure 18. Seasonal Distribution - Number Of Isolates Of *Helicodendron triglitziensis*

For Legend See Fig. 3



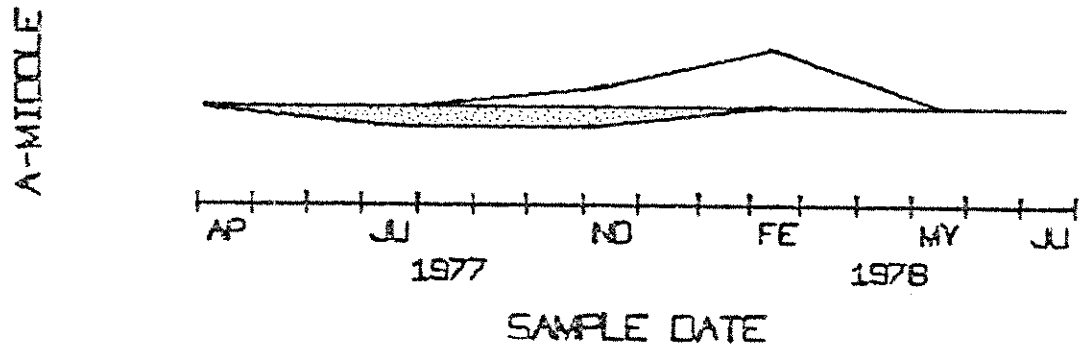
Helicoon fuscosporum Linder. Ann. Mo. Bot. Gard. 16:326. 1929.

Colonies moderately spreading; mycelium dark; conidiophores unbranched, 18.0 - 70.2 x 3.6 um; conidia fuscous, 30.6 - 66.6 x 21.6 - 32.4 um, coiled 9 - 15 times. This isolate resembles the description given by van Beverwijk (1953), except the conidiophores here are shorter and the conidia are larger, sometimes with more coils. These differences do not warrant exclusion from this species.

H. fuscosporum is another member of the "aero-aquatic" hyphomycetes (Fisher, 1977). It also has a relatively high cellulolytic ability (Fisher et al., 1977). It was isolated only from the middle subsite at Site A, in both layers, mostly during fall and winter (Fig. 19).

Figure 19. Seasonal Distribution - Number Of Isolates Of *Helicoon fuscosporum*

For Legend See Fig. 3



Hyalodendron lignicola Diddens. Zentralbl. Bakteriol., 2. Abt. 90:317-318. 1934.

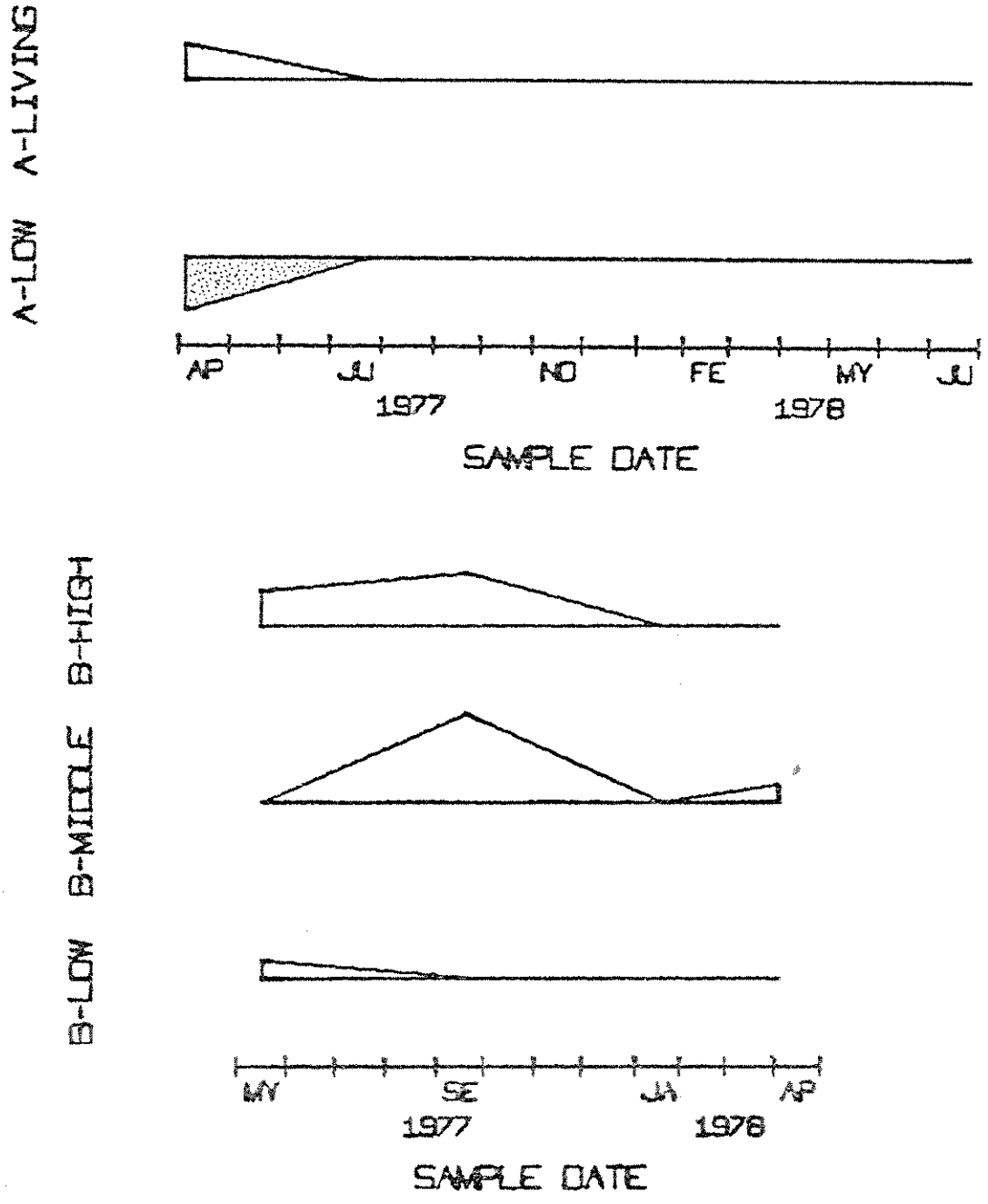
Colonies moderately spreading, submerged mycelium dark, aerial mycelium white, composed mostly of conidiophores and conidia; conidiophores often gathered in tufts; conidia in branched chains, hyaline, non-septate, lemon-shaped, 5.4 - 7.2 x 1.8 - 2.7 um. These isolates differ slightly from the original description in having a dark submerged mycelium. The method of spore production is the same, as is spore size. Hyalodendron is a confusing taxon in the literature; the most common interpretation is that it is a hyaline Cladosporium Link (Barron, 1968). There is also an affinity to Polyscytalum Riess, which has similar conidial production, but larger spores. A major investigation of these two genera would be helpful. Diddens (1934) isolated this species from decaying conifer woodpulp.

H. lignicola was isolated mainly from Site B but was found also at Site A. It was encountered more often in the L layer, in the middle and high subsites, and was also isolated from living leaves once (Fig. 20). This species was found in the spring and early fall samples, especially the latter, where it had the highest occurrence. H. lignicola has not been reported often in the literature; when found, it has usually been identified only to genus (Bhatt, 1970; Katz and Lieth, 1974; Sherwood and Carroll, 1974; Wicklow and Whittingham, 1974, 1978).

Figure 20. Seasonal Distribution - Number Of Isolates Of

Hyalodendron lignicola

For Legend See Fig. 3



Kriegeria seaveri (Rehm)Seaver. Mycol. 35:493. 1943.

This species was never actually isolated in culture, but readily formed apothecia on the leaves in moist chambers. The apothecia were small, gelatinous, greenish to yellow-green and fit the description provided by Seaver (1951). K. seaveri is known only from Thuja plicata foilage (Seaver, 1951; Shaw, 1973). It was found mainly at Site A, on living leaves and in the L layer, during the fall (Fig. 21).

Libertella sp.

Colonies moderately spreading, at first white, then turning light to darker brown, little aerial mycelium present; conidiophores branched, producing phialides, 4.5 - 12.6 x 1.0 - 2.7 um; conidia hyaline to pale brown in mass, U-shaped to sigmoid, produced in slime, 3 septate, 59.4 - 75.6 x 1.8 - 2.0 um.

Libertella sp. occurred in both Site A and Site B, mainly in the low and middle subsites, but was found in the high subsite in Site A during the spring. It occurred in both the L and F layers, with little change of frequency throughout the year (Fig. 22).

Figure 21. Seasonal Distribution - Number Of Isolates Of *Kriegeria seaveri*

For Legend See Fig. 3

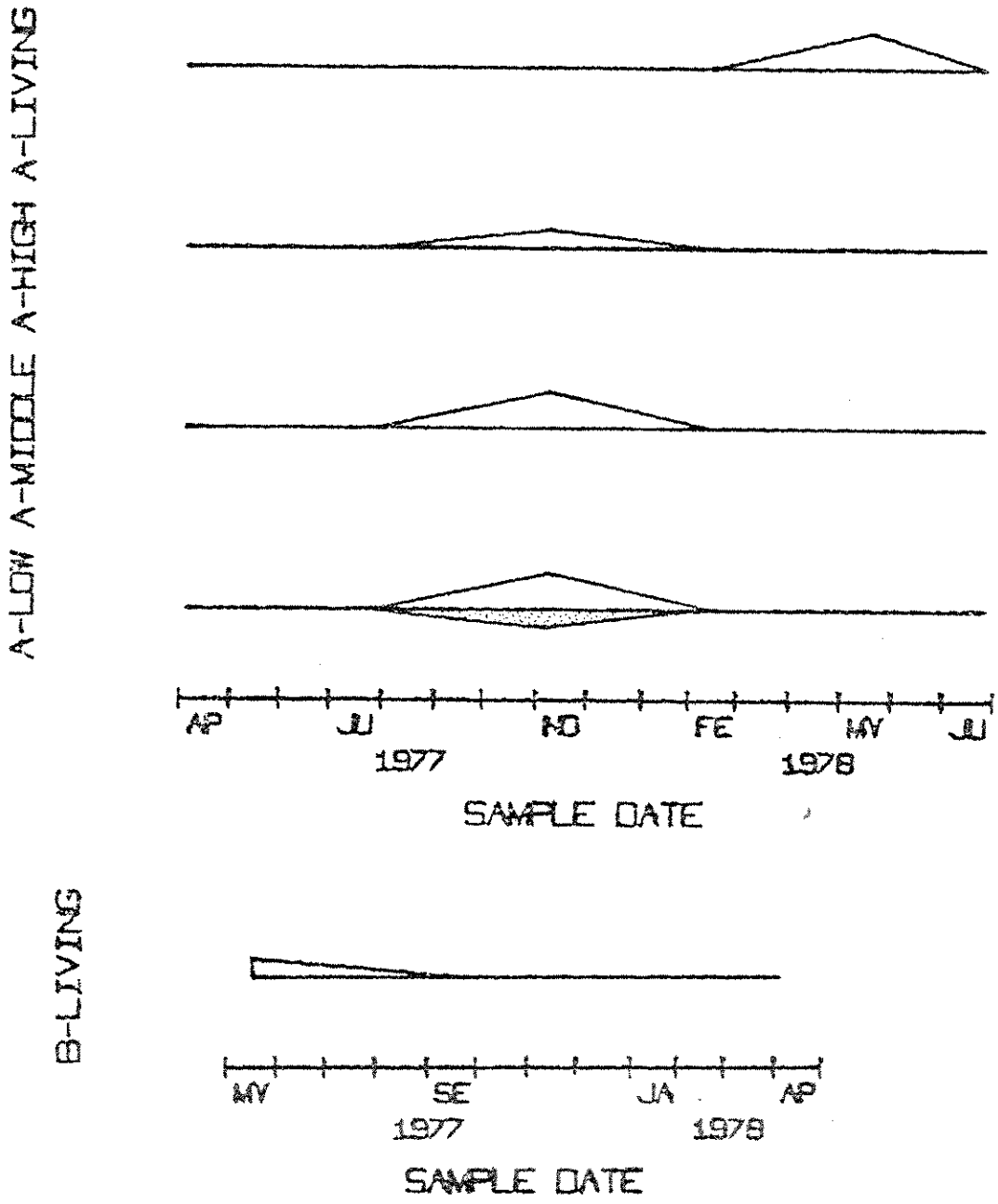
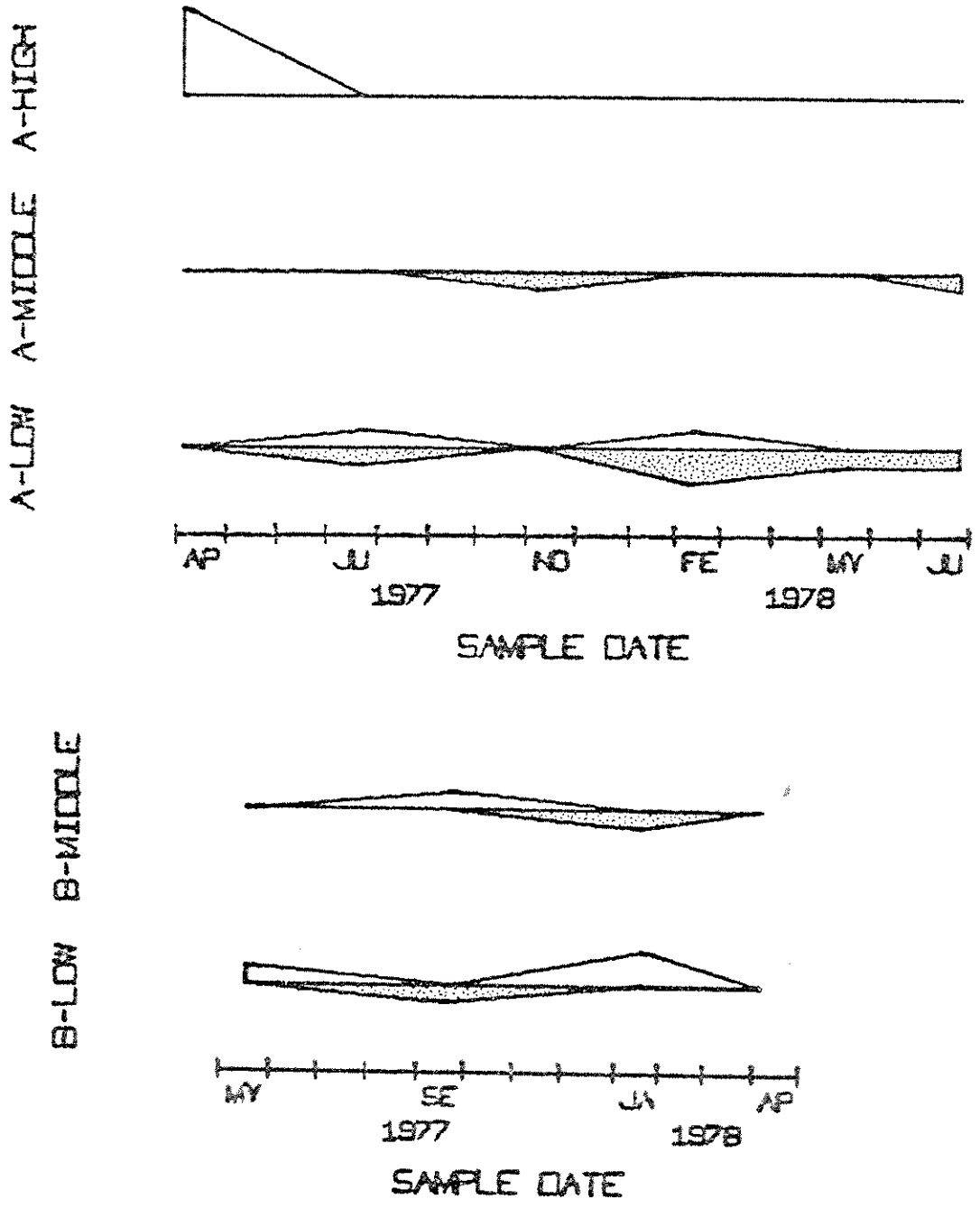


Figure 22. Seasonal Distribution - Number Of Isolates Of *Libertella* sp.

For Legend See Fig. 3

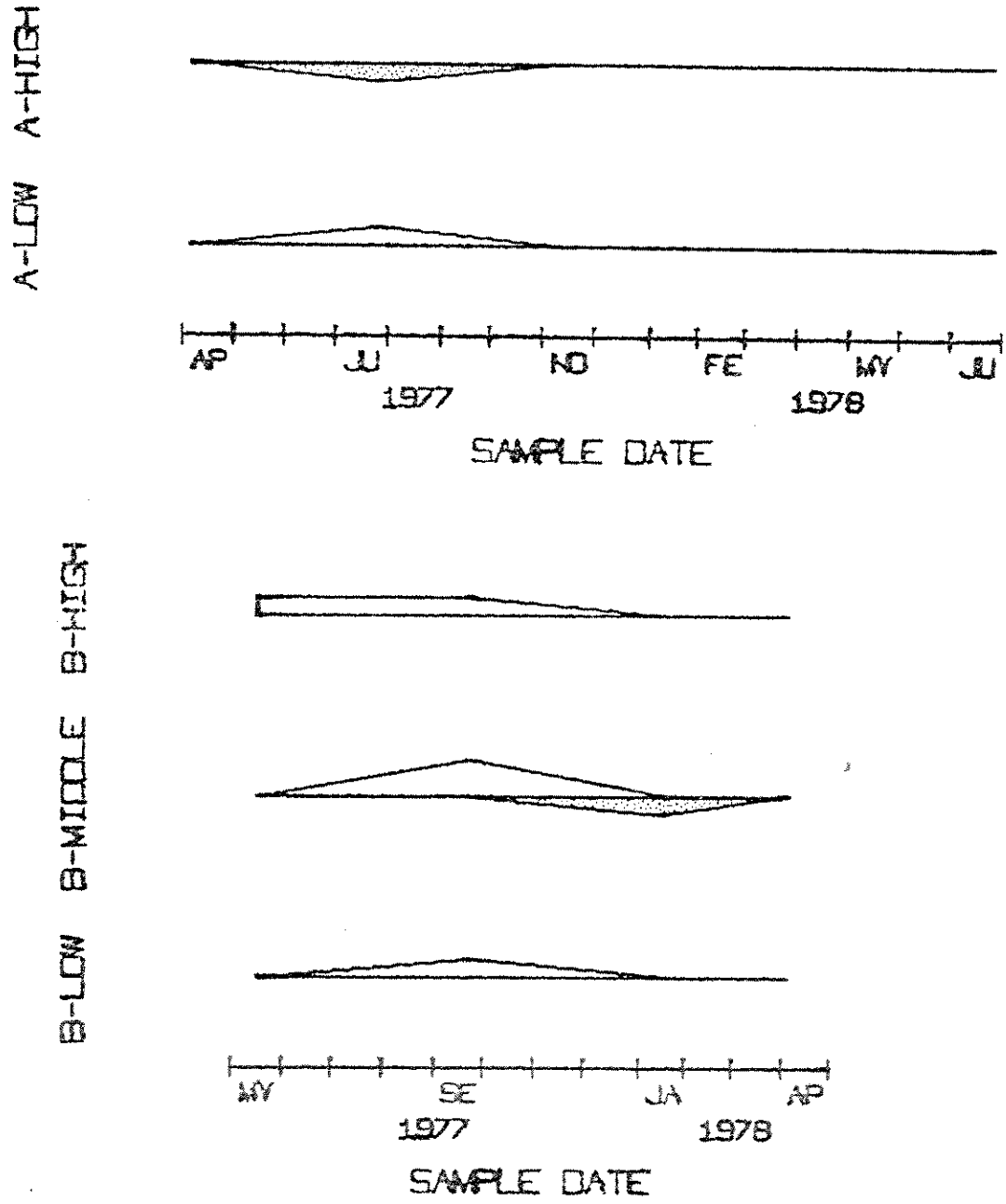


Mortierella ramanniana (Moller)Linnem. var. ramanniana Linnem. Pflanzenforschung, Jena. 23:19. 1941.

Colonies spreading rapidly; sporangiophores relatively short; sporangia reddish. This species was easily recognized through the above features. M. ramanniana var. ramanniana occurred twice at Site A, and six times at Site B, mostly in the L layer. It was usually isolated during the summer and early fall (Fig. 23). Mortierella species are heavily sporing and relatively slow growing, and are commonly found in the soil (Sewell, 1959).

Figure 23. Seasonal Distribution - Number Of Isolates Of *Mortierella ramanniana* var. *ramanniana*

For Legend See Fig. 3



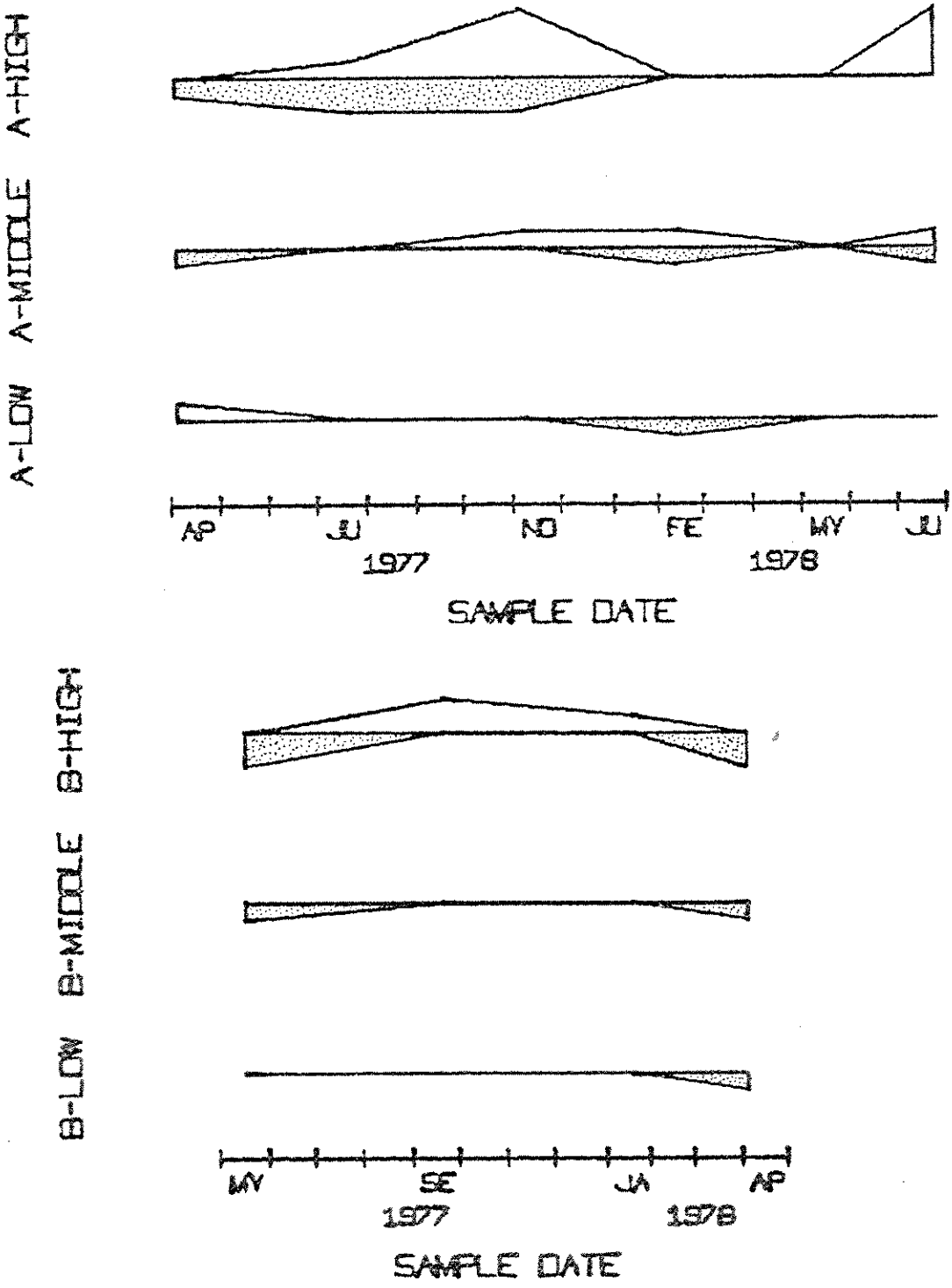
Mucor hiemalis Nehmer f. hiemalis Schipper. Stud. Mycol. 4:26. 1973.

Colonies fast growing; sporangiophores tall, with dark black sporangia; large columella present, 23.4 - 54.0 um in diameter, sometimes up to 100 um in diameter; spores irregular, globose to elongate 3.6 - 9.0 x 3.6 - 4.5 um. These isolates sometimes had a columella larger than that reported by Schipper (1973), but otherwise fit the description.

M. hiemalis f. hiemalis is widespread in soils and litter (Domsch and Gams, 1972), and was one of the most common fungi isolated from the SYT plates. It occurred at all sample times in both sites, in the L and F layers (Fig. 24). Although it was present in all three subsites, it was found more frequently in the high subsite.

Figure 24. Seasonal Distribution - Number Of Isolates Of Mucor hiemalis f. hiemalis

For Legend See Fig. 3



Penicillium brevi-compactum Dierckx. Soc. Scien. Brux. 25:88. 1901.

This species is a member of the Velutina subsection, according to Raper and Thom (1949). It is recognized by its short, tight penicillus, with somewhat swollen metulae. P. brevi-compactum was found more frequently in the middle and high subsites at Site A, and in the middle and low subsites at Site B. It was isolated from living leaves, but otherwise occurred mainly during the fall and winter (Fig. 25). It has been reported from a variety of soil types (Domsch and Gams, 1972).

Penicillium citrinum Thom. U.S.D.A. Bur. Anim. Ind. Bull. 118. 61-63. 1910.

This species is also a member of the sub-section Velutina (Raper and Thom, 1949). It is characterized by no branching below the level of metulae, and a bluish tint to the spore mass; conidia 1.5 - 2.0 um. P. citrinum was found mainly at Site A during the fall, but it occurred during the summer in the high subsite (Fig. 26). Its distribution is worldwide and common in soils (Domsch and Gams, 1972).

Figure 25. Seasonal Distribution - Number Of Isolates Of *Penicillium brevi-compactum*

For Legend See Fig. 3

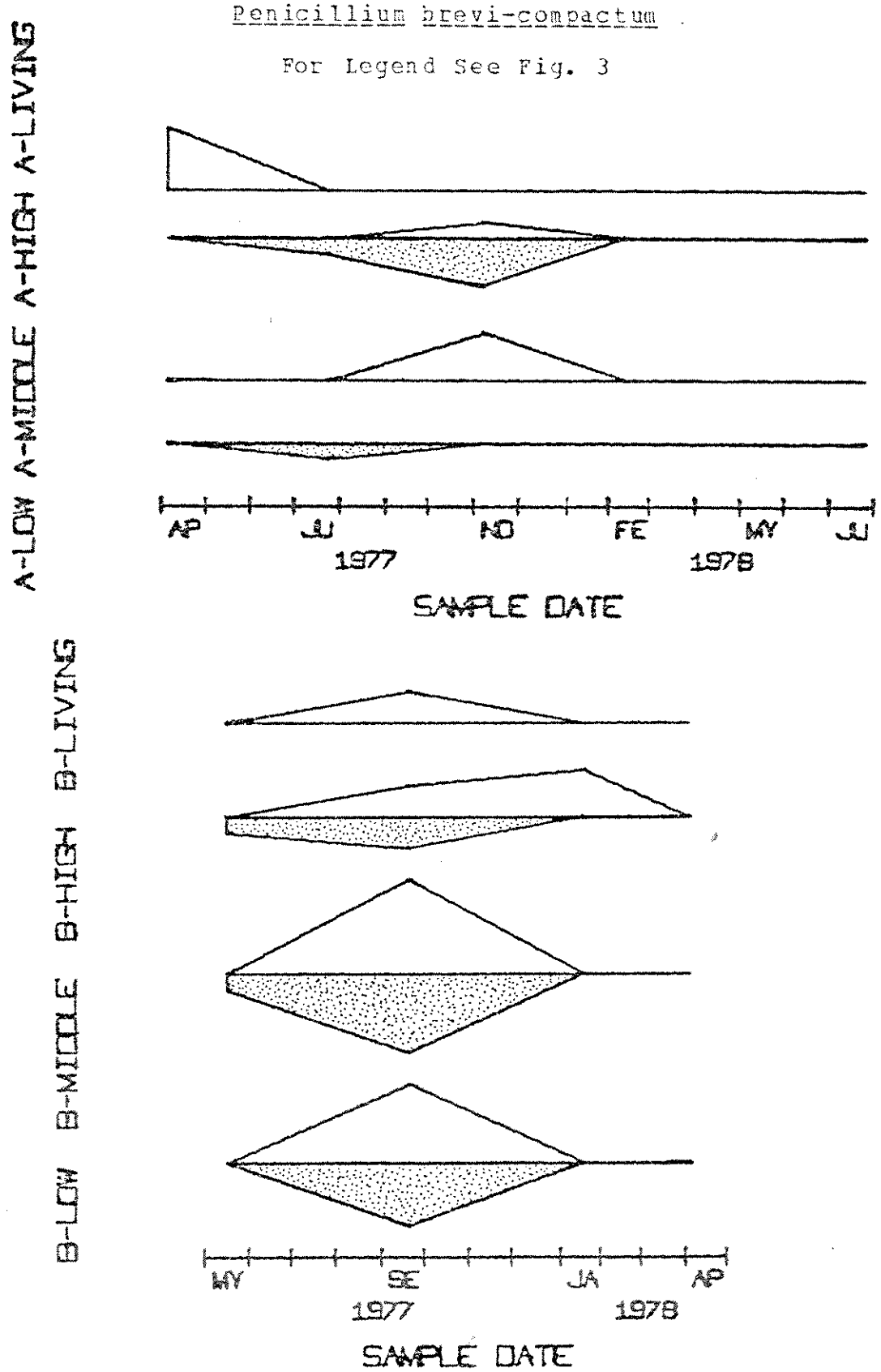
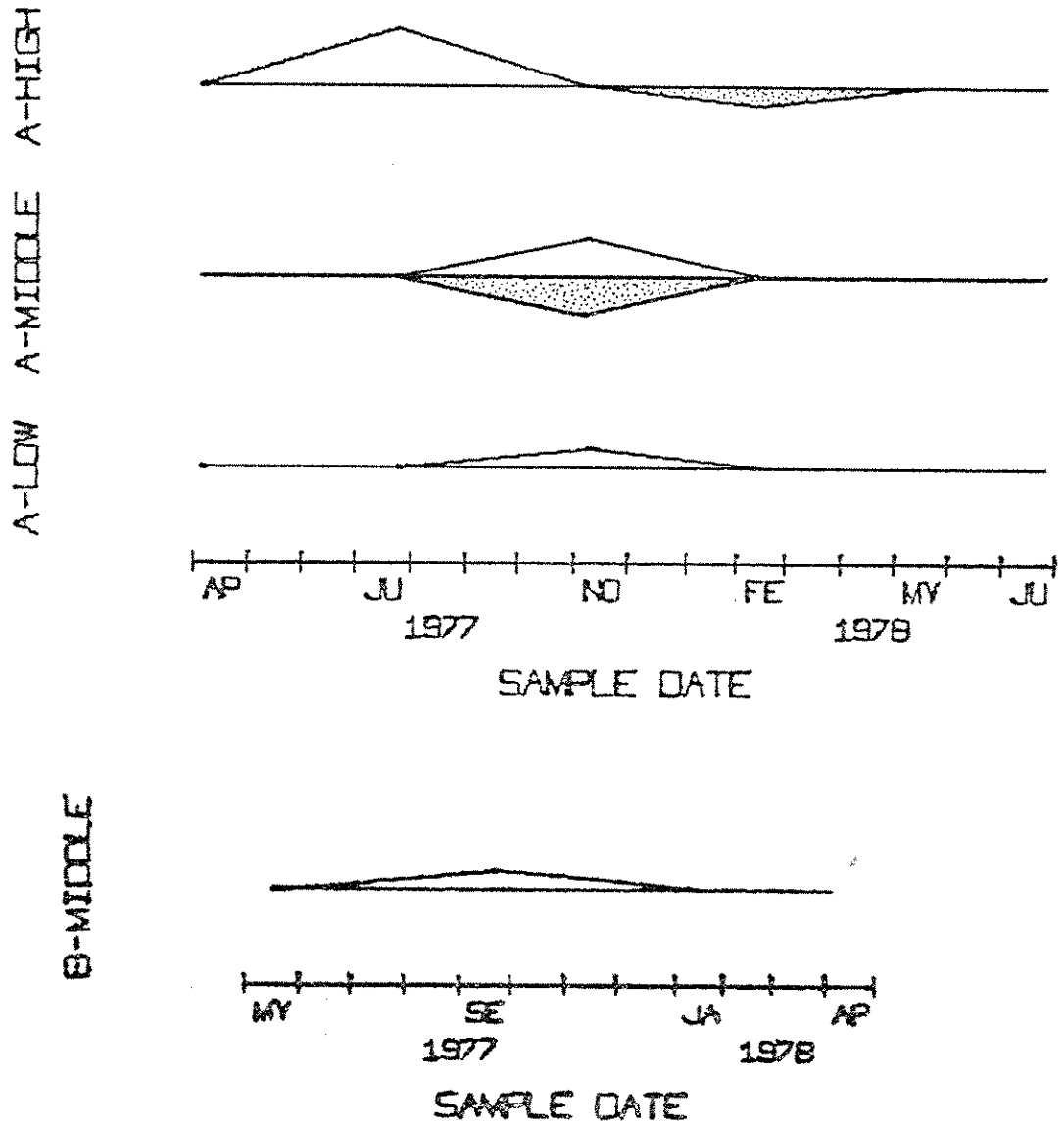


Figure 26. Seasonal Distribution - Number Of Isolates Of *Penicillium citrinum*

For Legend See Fig. 3



Penicillium frequentans Westling. Ark. Bot. 11:58. 133-134. 1911.

This species is a member of the Monoverticillata section, according to Raper and Thom (1949). It is recognized by its velvety colony, monoverticillate conidiophore and globose to subglobose conidia, 1.8 - 3.6 um in diameter, slightly roughened. P. frequentans was isolated mainly from Site B, in the F layer, during the fall and winter (Fig. 27). This is a common soil fungus, especially in forest soils and litter (Domsch and Gams, 1972).

Penicillium nigricans (Bainier)Thom. The Penicillia. 351-353. 1930.

P. nigricans belongs to the Divaricata subsection of Raper and Thom (1949). It is recognized by its somewhat roughened spores, 1.5 - 3.0 um in diameter, which impart a dull gray color to the colony, and a yellow reverse. It was isolated throughout the year at Site A, and only during the fall and winter at Site B (Fig. 28). In Site A the highest occurrences were during the summer samples, both of which were characterized by low precipitation and high temperature. This corresponds with the information reported by Domsch and Gams (1972) for this common soil fungus. Throughout the sampling, it was isolated more frequently from the high subsite and the F layer.

Figure 27. Seasonal Distribution - Number Of Isolates Of

Penicillium frequentans

For Legend See Fig. 3

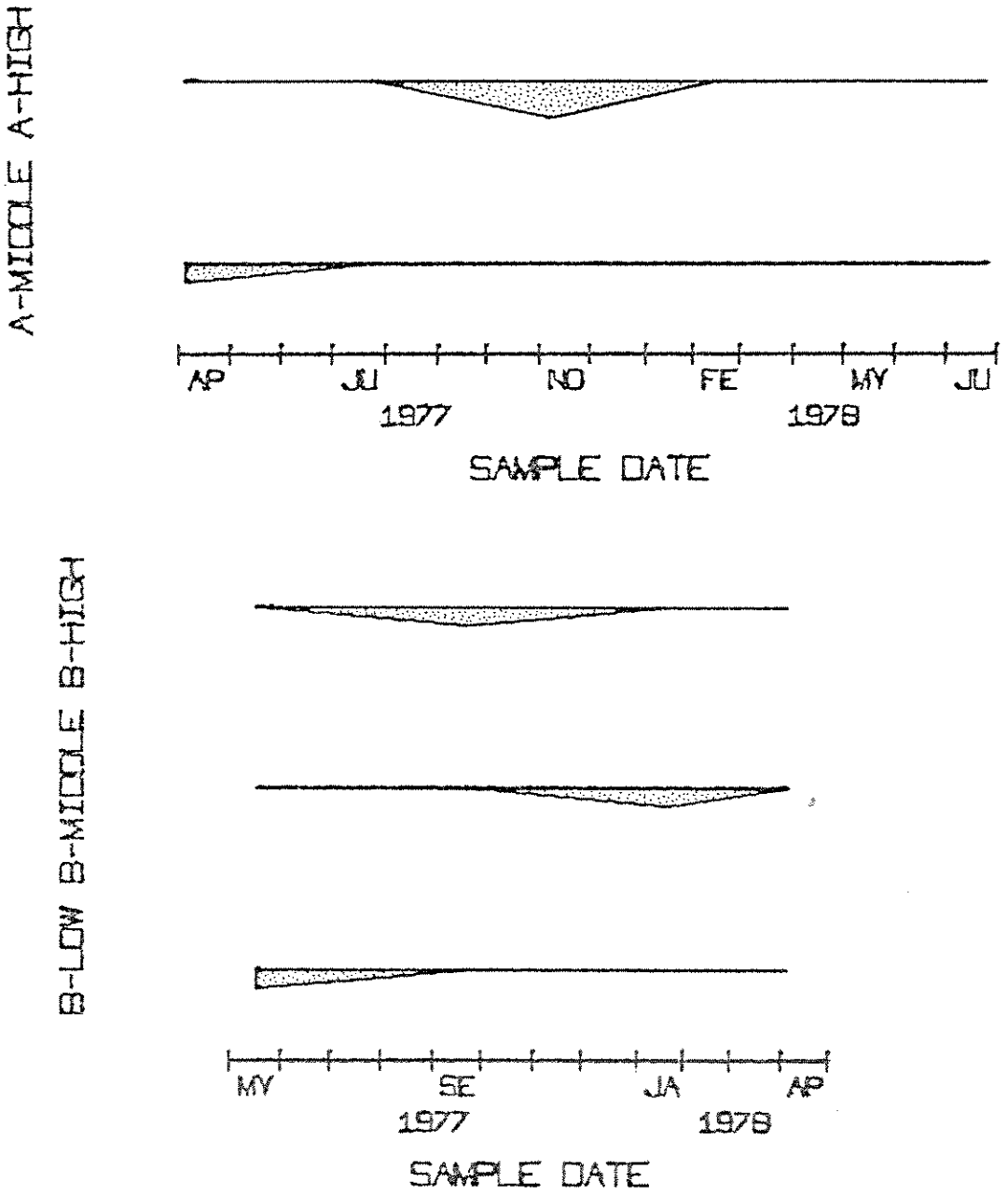
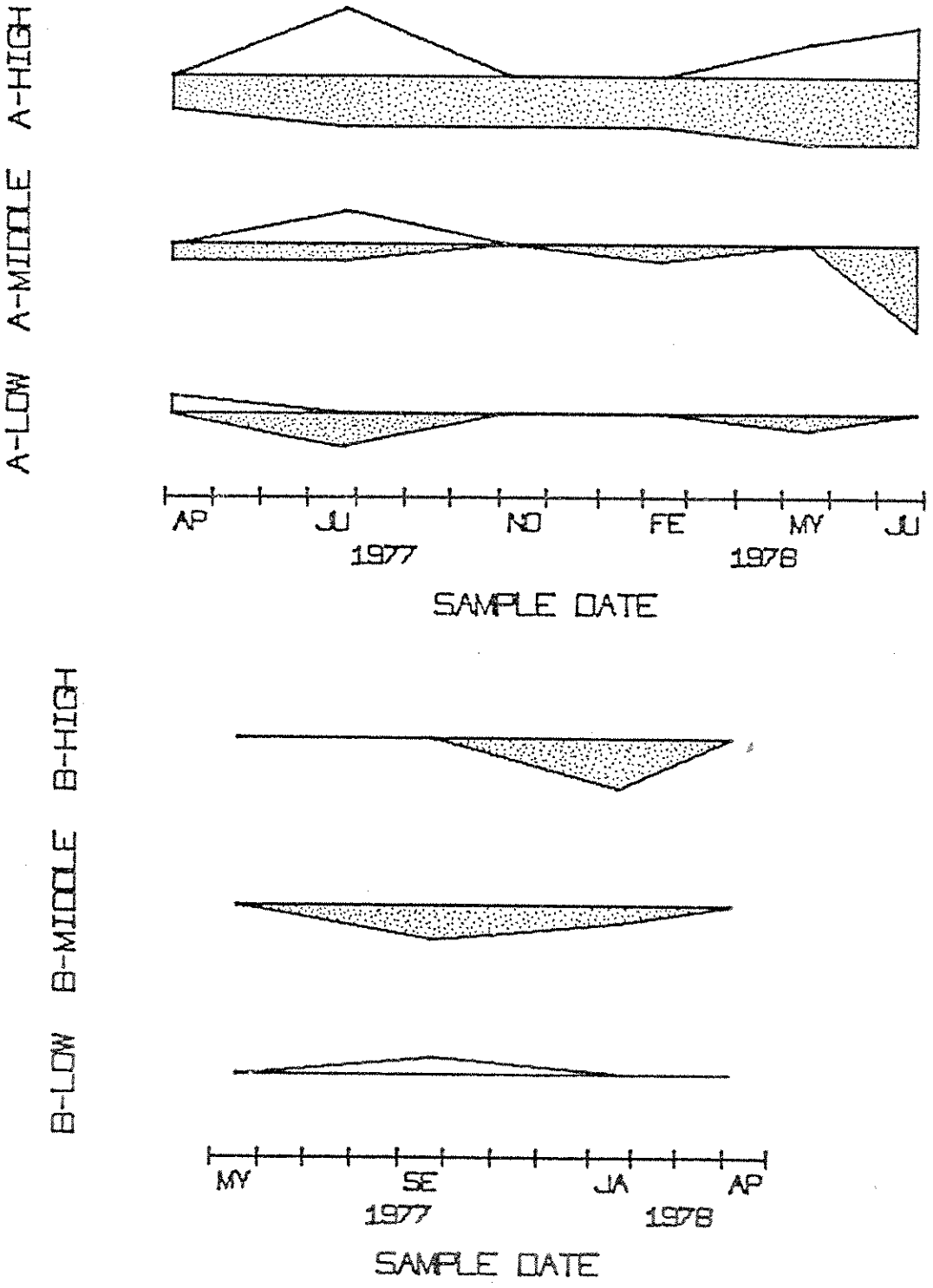


Figure 28. Seasonal Distribution - Number Of Isolates Of *Penicillium nigricans*

For Legend See Fig. 3



Penicillium notatum Westling. Ark. Bot. 11:55, 95-97. 1911.

This species is another member of the Velutina subsection of Penicillium (Raper and Thom, 1949). It is recognized by its blue-green color and subglobose to globose conidia, 2.0 - 3.6 um in diameter. P. notatum was found only at Site A, mainly in the F layer; it usually occurred during the fall and winter, but only in low numbers (Fig. 29). This is a common and widespread soil fungus (Domsch and Gams, 1972).

Penicillium raistrickii Smith. Trans. Brit. Mycol. Soc. 18:90. 1933.

This species is also a member of the subsection Divaricata (Raper and Thom, 1949). It is one of the easiest recognized Penicillia, in that it usually produces abundant sclerotia and relatively sparse conidiophores. The conidiophores are slightly roughened, and the aerial hyphae and the colony reverse are often yellow. P. raistrickii was found mainly during the summer samples at Site A; the early fall and spring samples at Site B (Fig. 30). It is similar to P. nigricans in occurring at times of low precipitation and high temperature.

Figure 29. Seasonal Distribution - Number Of Isolates Of *Penicillium notatum*

For Legend See Fig. 3

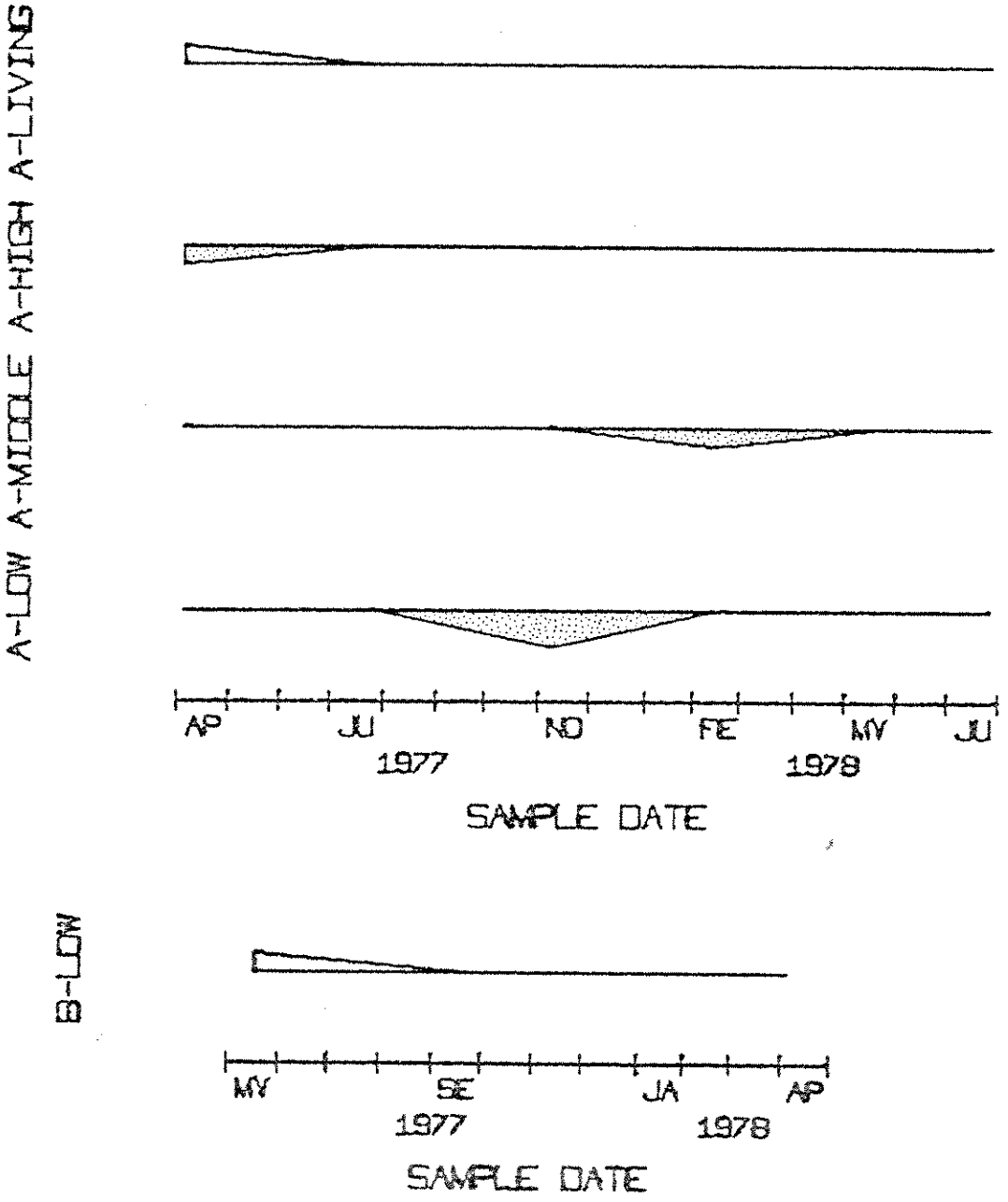
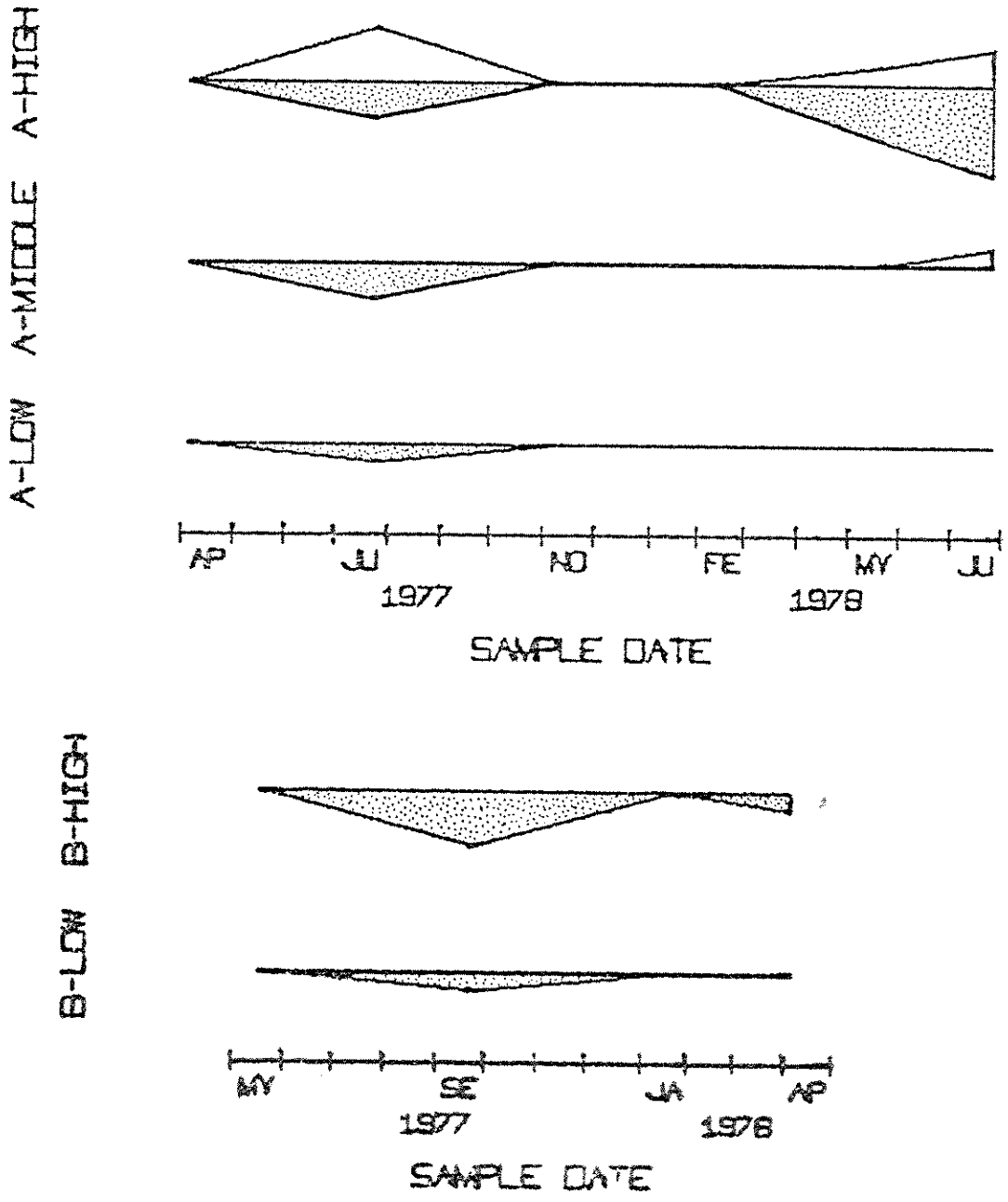


Figure 30. Seasonal Distribution - Number Of Isolates Of *Penicillium raistrickii*

For Legend See Fig. 3



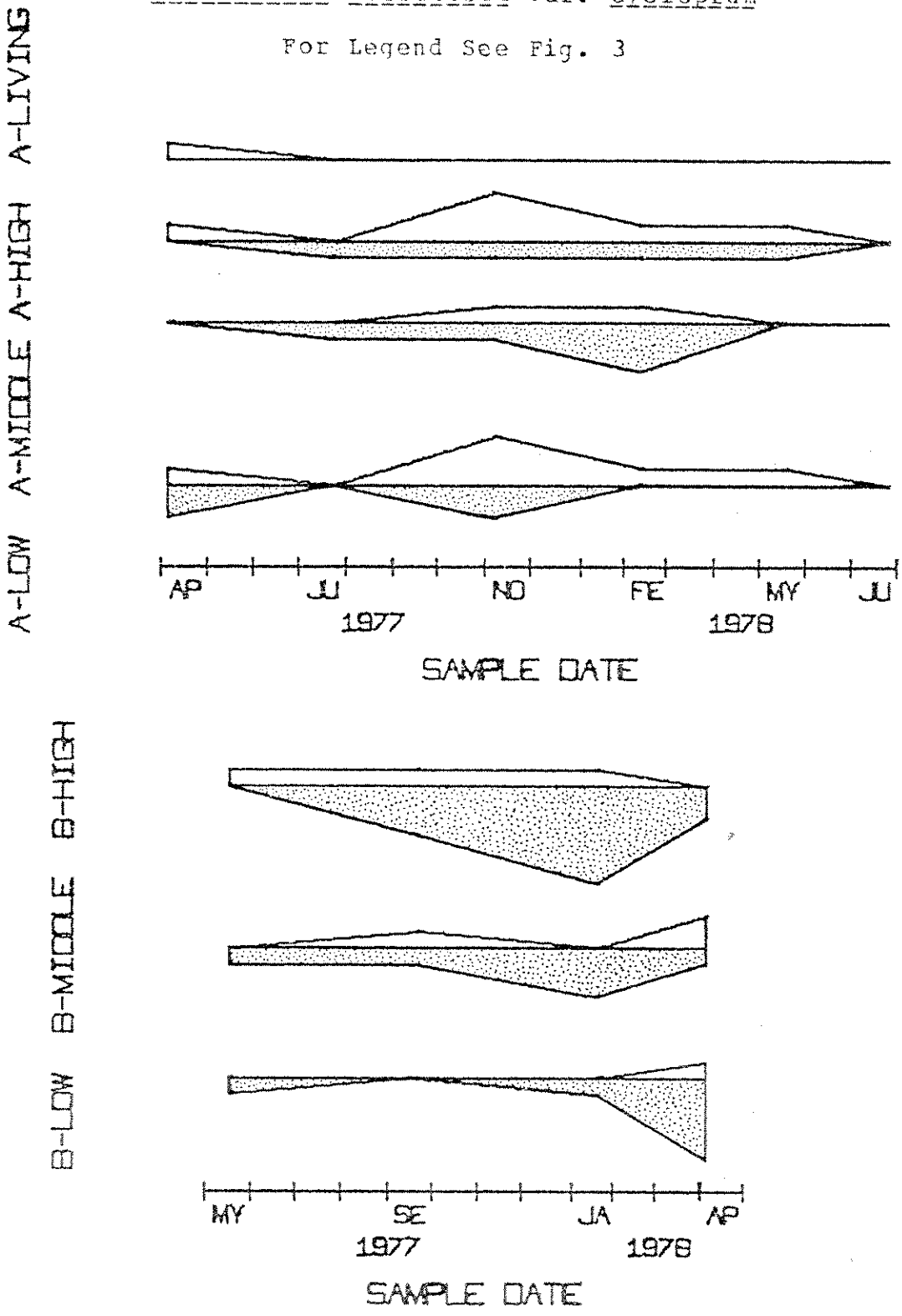
*Penicillium verrucosum* Dierckx. var. *cyclopium* (Westling) Sampson, Stolk & Hadlok. Stud. Mycol. 11:37-41. 1976.

According to Sampson *et al*. (1976), this species includes *P. cyclopium* and *P. martensii*, among other described species. These two species differ only slightly in the relative roughness of the conidiophore, therefore their combination under one species is warranted. This species is a member of the subsection *Fasciculata* of Raper and Thom (Sampson *et al*., 1976). It is characterized by somewhat fasiculate to mononematous conidiophores; usually with the conidia giving the culture a bluish shade; conidia 1.5 - 4.0 um in diameter; conidiophores fine to coarsely roughened.

*P. verrucosum* var. *cyclopium* was the most commonly occurring species of *Penicillium* in this study. It was present at all dates in both Site A and Site B, except for the last summer sample, and was more prevalent in the F layer when it was found (Fig. 31). It occurred mainly during the fall and winter samples, times characterized by low temperatures and high precipitation. Griffin (1963) has reported 81 - 84% relative humidity as the lower limit for growth for this species.

Figure 31. Seasonal Distribution - Number Of Isolates Of *Penicillium verrucosum* var. *cyclopium*

For Legend See Fig. 3

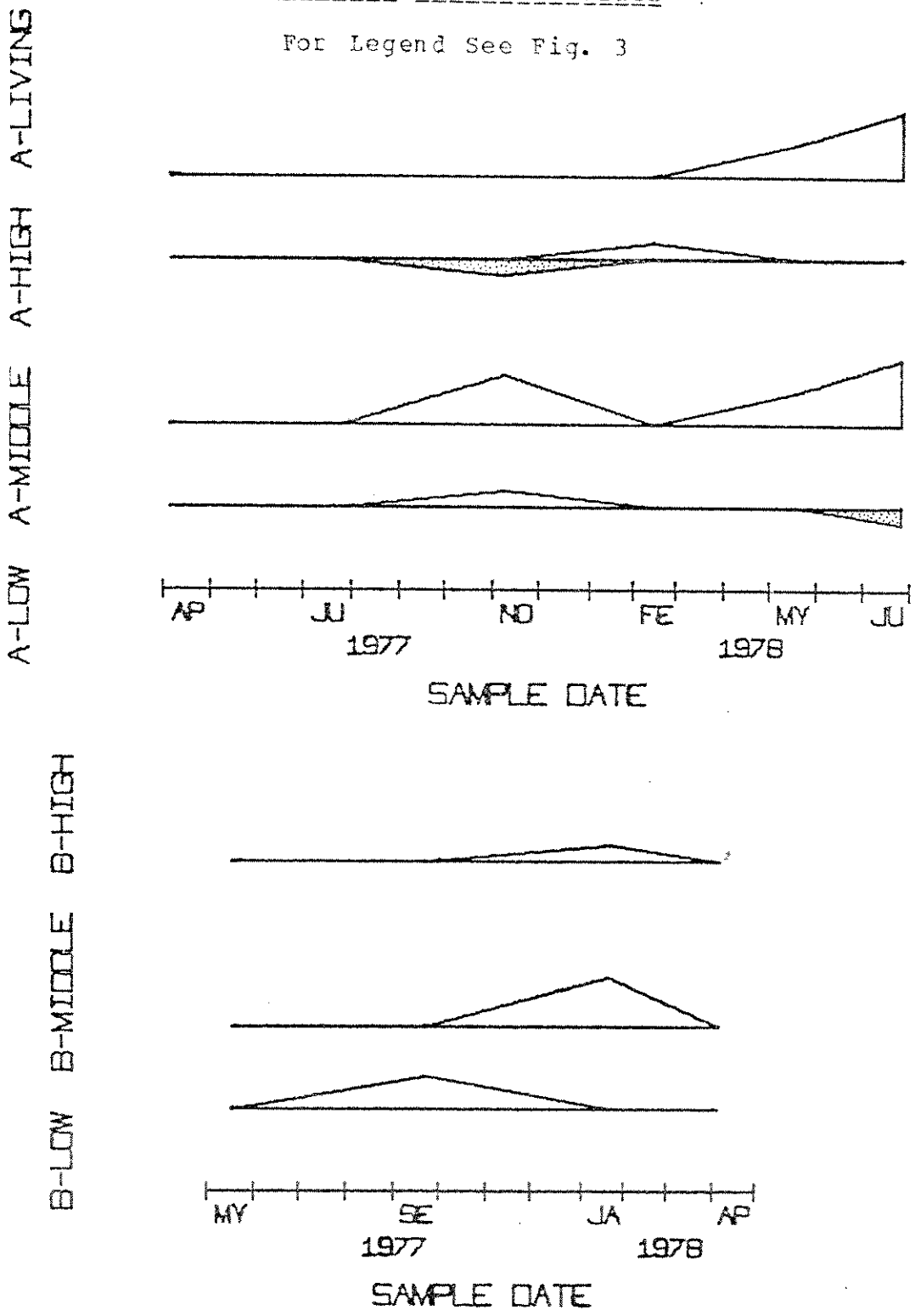


Pestalotia monochaetioides Doyer. Med. Phytopath. Lab. "Will. Comm. Schott." 9:24. 1925.

Colonies spreading rapidly; producing raised acervuli; conidia 5-celled, the middle three cells dark, the upper two cells slightly darker, the lower two cells often warty, 27.0 x 9.0 - 9.9 um; conidia with one seta, which is sometimes branched, up to 50.4 um long. Guba (1961) reports it from Chamaecyparis. P. monochaetioides was isolated mostly from the L layer at both sites, but also occurred on living leaves at Site A. It tended to be found during the fall and winter samples (Fig. 32).

Figure 32. Seasonal Distribution - Number Of Isolates Of *Pestalotia monochaetioides*

For Legend See Fig. 3



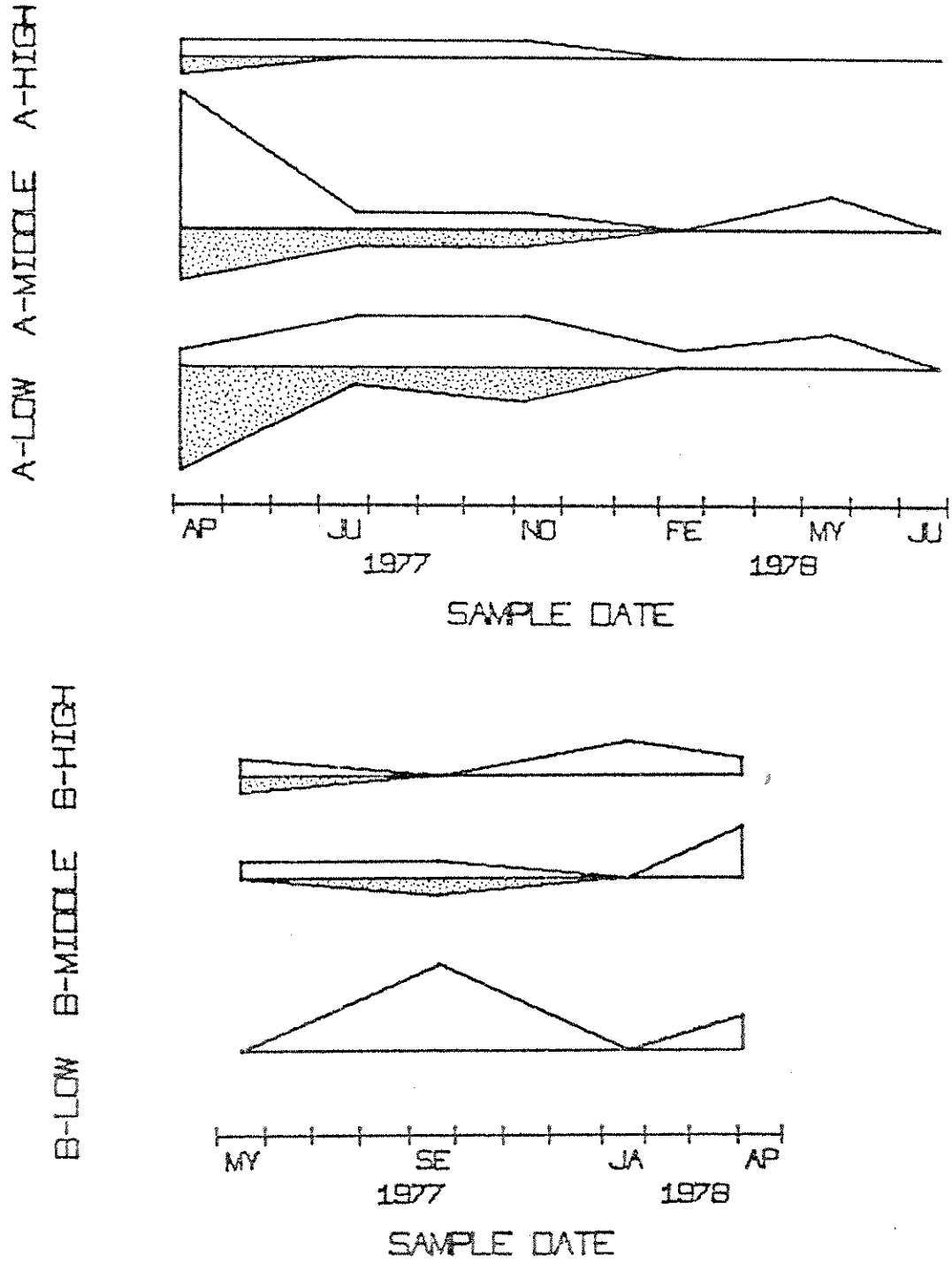
Polyscytalum fecundissimum Riess. Bot. Zeitung. 11:138-139. 1853.

Colonies moderately spreading, white to black in some areas; conidia produced in branched chains, sometimes gathered into tufts, 0-1 septate, 7.2 - 23.4 x 1.8 - 3.6 um. This species shows affinities with Hyalodendron lignicola Diddens, which it resembles. These two genera are baffling in the literature and are in need of major cultural and taxonomic analysis. P. fecundissimum was reported specifically by Hering (1965), but in other reports on litter fungi, it has been identified only to genus (Apinis et al., 1972; Hogg and Hudson, 1966; Katz and Lieth, 1974; Parkinson and Balasooriya, 1969; Tubaki and Yokoyama, 1971, 1973b; Yokoyama and Tubaki, 1973; Yokoyama et al., 1977).

P. fecundissimum was isolated frequently from both sites, in all subsites, but mainly the middle and low ones. It was more prominent in the L layer and occurred more frequently during the spring and fall. In Site A, as its occurrence tapered off in the middle subsite, it increased in the low subsite (Fig 33).

Figure 33. Seasonal Distribution - Number Of Isolates Of *Polyscytalum fecundissimum*

For Legend See Fig. 3



Ramichloridium subulatum de Hoog. Stud. Mycol. 15:83. 1977.

Colonies moderately spreading; aerial mycelium grayish; conidiophores dark, 22.5 - 40.5 x 3.6 - 4.5 um, elongating sympodially; conidia born on denticles, truncate, pale brown, 4.5 - 6.3 x 2.0 - 2.5 um. These isolates fit the description given by de Hoog (1977). R. subulatum was isolated only from Site A, mostly from the L layer. It was found infrequently, usually in the summer or winter (Fig. 34). This species has been reported from various soils (de Hoog, 1977).

Selenophoma sp.

Colonies moderately spreading; mycelium dark, producing dark pycnidia often grouped together, somewhat stromatic; conidia hyaline, allantoid, 9.0 - 10.8 x 2.7 um.

Selenophoma is a genus commonly found on grasses (Park and Sprague, 1953), but includes one species, S. drabae which is found on dicotyledons. No reports have been made of this genus on conifers, but Tubaki and Yokoyama (1973b) isolated it from sterilized leaves in angiosperm litter. Selenophoma sp. occurred at both sites, mostly in the L layer, but was isolated in larger numbers at Site B. At Site A it was prominent during the winter, while at Site B it occurred on living leaves in late summer, and in the other subsites in spring and winter (Fig. 35).

Figure 34. Seasonal Distribution - Number Of Isolates Of

Ramichloridium subulatum

For Legend See Fig. 3

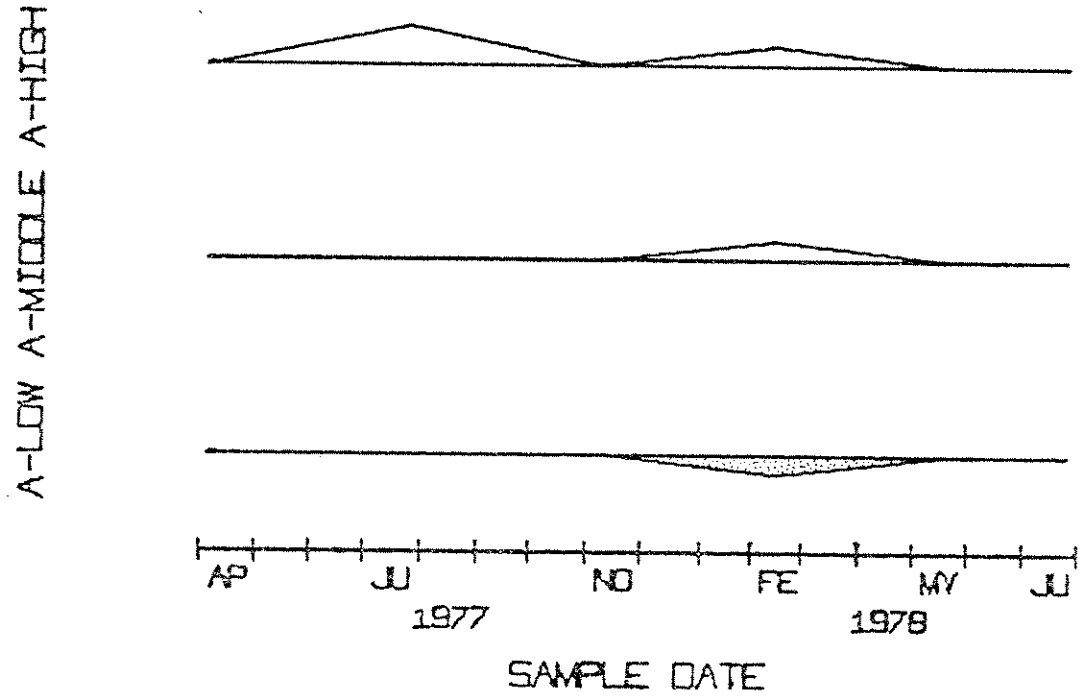
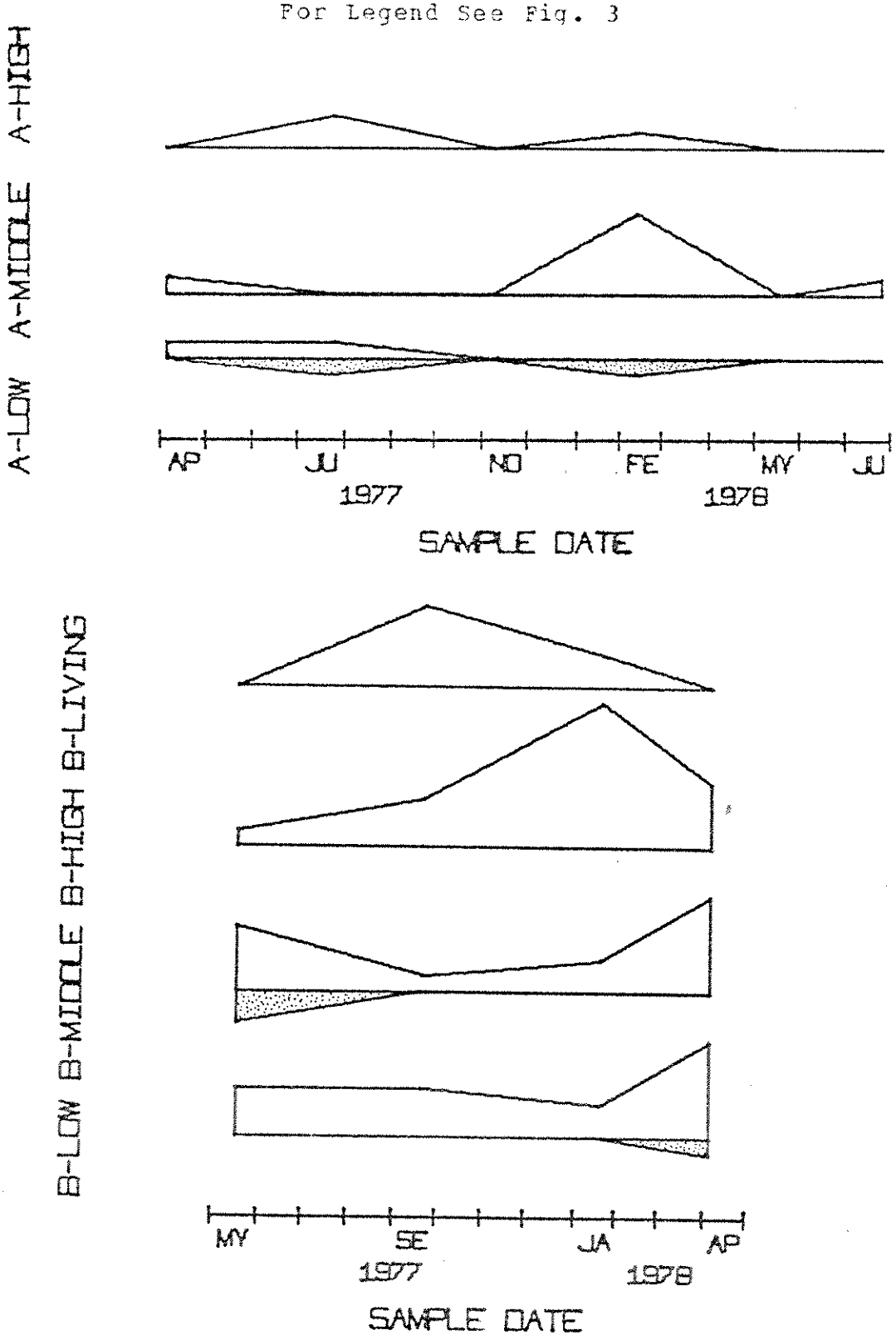


Figure 35. Seasonal Distribution - Number Of Isolates Of *Selenophoma* sp.

For Legend See Fig. 3



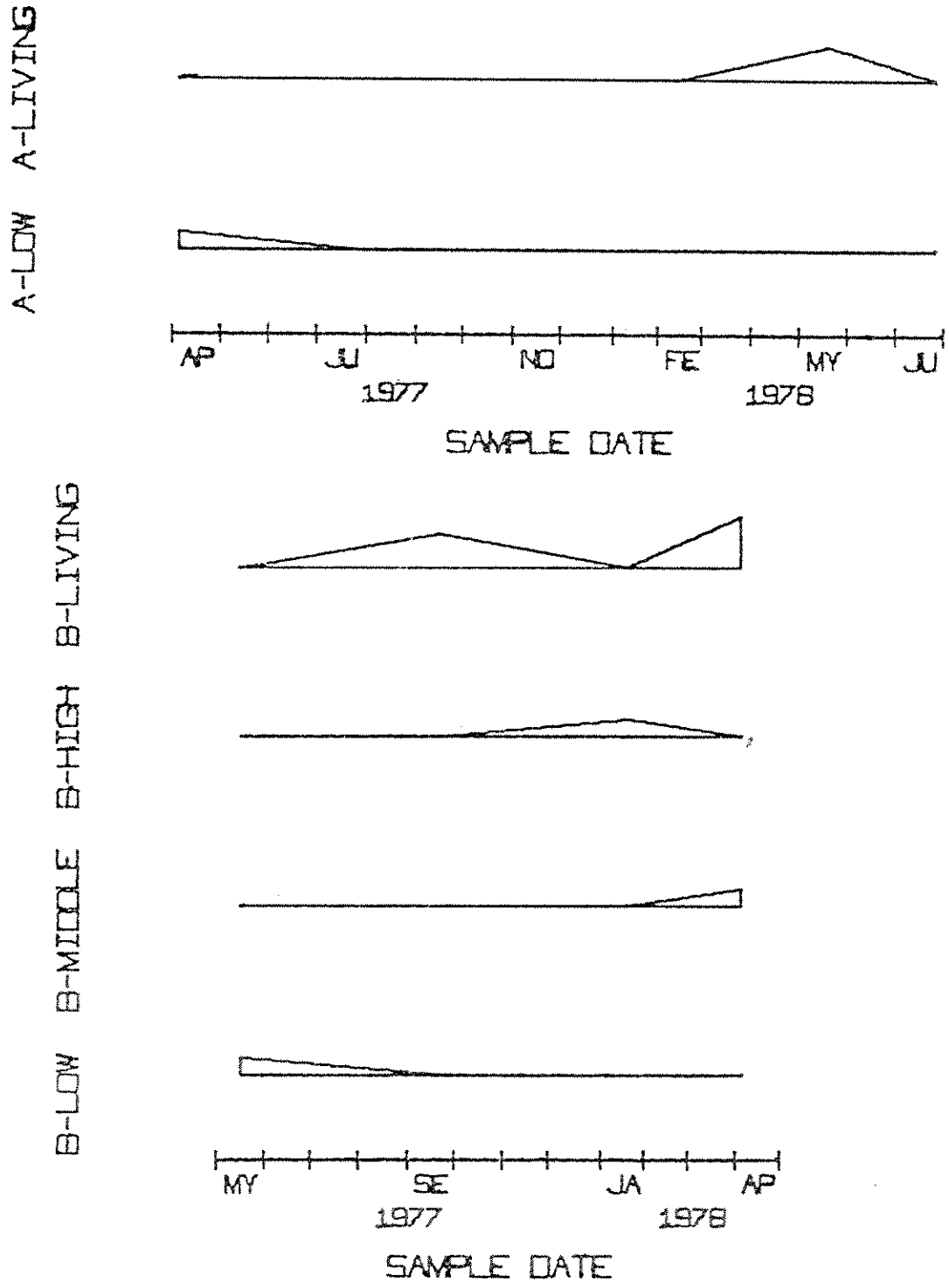
Septogloeum sp.

Colony growth moderate; mycelium white to gray: conidiophores in pustules, often brownish; conidia hyaline, at first continuous, but becoming 1-5 septate, mostly 3, base of conidium apiculate, 21.0 - 34.0 x 7.2 - 11.5 um. Sometimes the older conidia appear muriform, but this seems to be a result of plasmolysis.

Most of the species described in this genus occur on dicotyledonous plants. Septogloeum sp. was isolated at both sites, but more frequently at Site B. It was most frequently isolated from living leaves in late summer and fall (Fig. 36). Otherwise, it occurred mainly in the L layer.

Figure 36. Seasonal Distribution - Number Of Isolates Of *Septogloeum* sp.

For Legend See Fig. 3



Septonema chaetospira (Grove)Hughes. Naturalist. Jan.-Mar. 9-11. 1952.

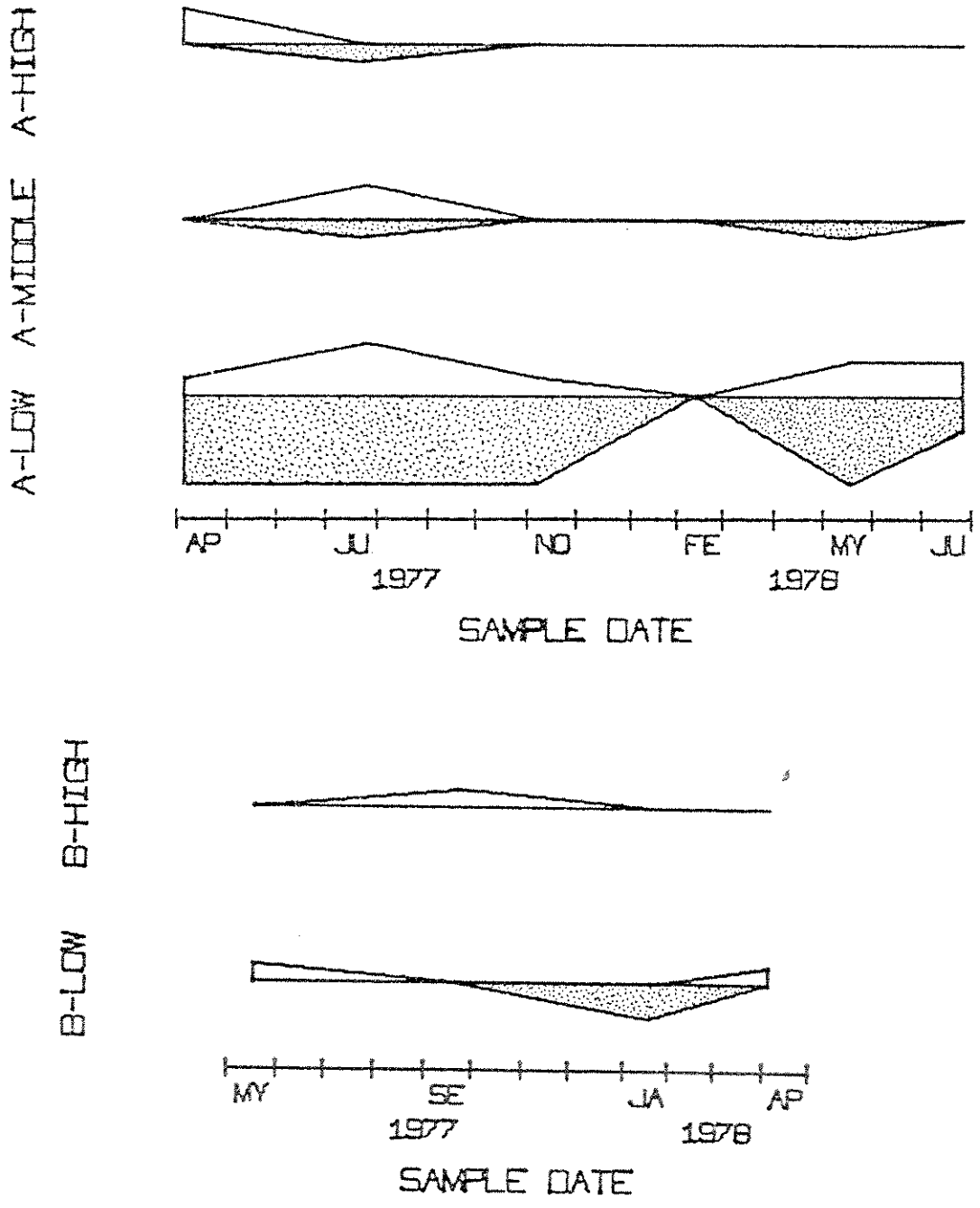
Colonies moderately spreading, dark brown to black with abundant aerial mycelium; conidia produced in long, branched chains, pale brown, 0-3 septate, 12.6 - 36.9 x 2.0 - 5.4 um. It is easily recognized by its characteristic septate blastospore. Ellis (1976) has placed this species in the genus Heteroconium Petrak .

S. chaetospira was relatively abundant, occurring in both Site A and Site B, more prominently in the low subsite, in both the L and F layers, but more often from the latter. It occurred in times of warmer temperatures, but not too dry, thus it is found more frequently in spring and summer (Fig. 37). The genus has been reported from soil (Ishii, 1970), living needles (Gourbiere, 1975) and needles in a stream (Barlocher and Kendrick, 1974). This particular species has been reported once from forest soil (Gochenaur and Woodwell, 1974) and agricultural soil (Domsch and Gams, 1972).

Figure 37. Seasonal Distribution - Number Of Isolates Of

Septonema chaetospira

For Legend See Fig. 3



Septonema chaetospira (Groves)Hughes var. pini Bourchier. Can. J. Bot. 39:1782-1784. 1961.

Colonies restricted, dark brown to black, little aerial mycelium present; conidia produced in branched chains, pale brown, 0-1 septate, 6.0 - 14.5 x 1.8 - 3.6 um. Bourchier (1961) described this species from the wood of Pinus contorta. S. chaetospira var. pini was isolated in low numbers from almost all samples in Site A and Site B. At Site A, it occurred in the low and middle subsites in the spring and summer, and in the high subsite in the winter. It was present inconsistently in both L and F layers (Fig. 38).

Sporodesmium flexum Matsushima. Icones Microfungorum Matsushima Lectorum. 137-138. 1975.

Colonies moderately spreading, aerial hyphae brown, bearing numerous spores; conidia flexuous, brown, 6 - 8 septate, tapering toward the apex. This species is identified easily by its characteristic spore. S. flexum was isolated only from leaves in moist chambers and from only Site A. It was found slightly more frequently in the F layer, and only in the middle and low subsites (Fig. 39). It occurred in spring and summer samples, especially the last two samples of the study, possibly indicating that it is more prevalent at times of high temperature but requiring a moderate amount of moisture.

Figure 38. Seasonal Distribution - Number Of Isolates Of *Septonema chaetospira* var. *pini*

For Legend See Fig. 3

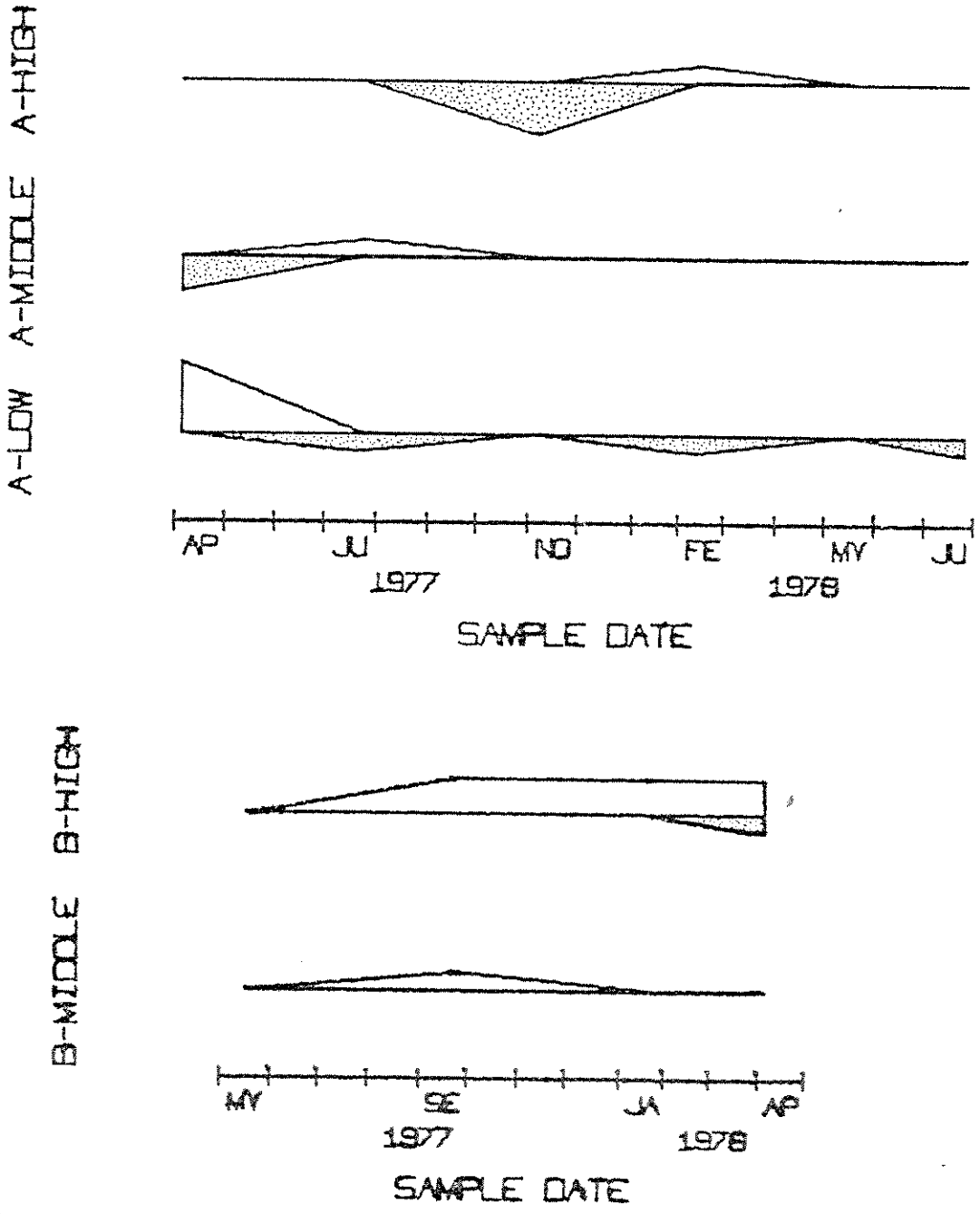
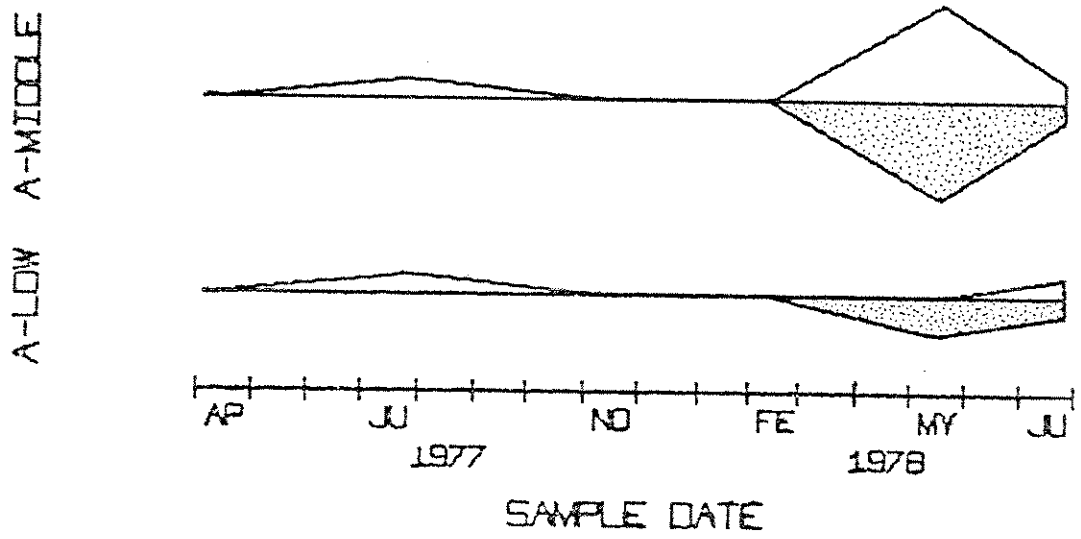


Figure 39. Seasonal Distribution - Number Of Isolates Of

Sporidesmium flexum

For Legend See Fig. 3



Trichoderma koningii Oud. apud Oud. et Koning. Archs. Neerl. Sci. II. 7:291. 1902.

Colonies spreading rapidly, producing loose spore masses with abundant aerial hyphae, spore clusters yellow-green; conidia ellipsoid, smooth, 3.6 - 5.4 x 2.0 - 3.0 um. T. koningii was isolated at both sites, but much more frequently at Site B. It was found in all three subsites, in both the L and F layers. It tended to occur more often in winter and spring (Fig. 40).

Trichoderma polysporum (Link ex Pers.)Rifai. Commonw. Mycol. Inst. Mycol. Pap. 116:19-22. 1969.

Colonies spreading rapidly, little or no aerial mycelium except for the spore clusters; conidia and conidiophores hyaline, conidiophores with apical sterile appendage, conidia small, 2.8 - 3.7 x 1.8 - 2.0 um. This common soil fungus is recognized easily by the white spores and sterile appendages. T. polysporum occurred mainly in the middle and low subsites, mostly in the F layer. It was more common during the spring and summer samples (Fig. 41).

Figure 40. Seasonal Distribution - Number Of Isolates Of *Trichoderma koningii*

For Legend See Fig. 3

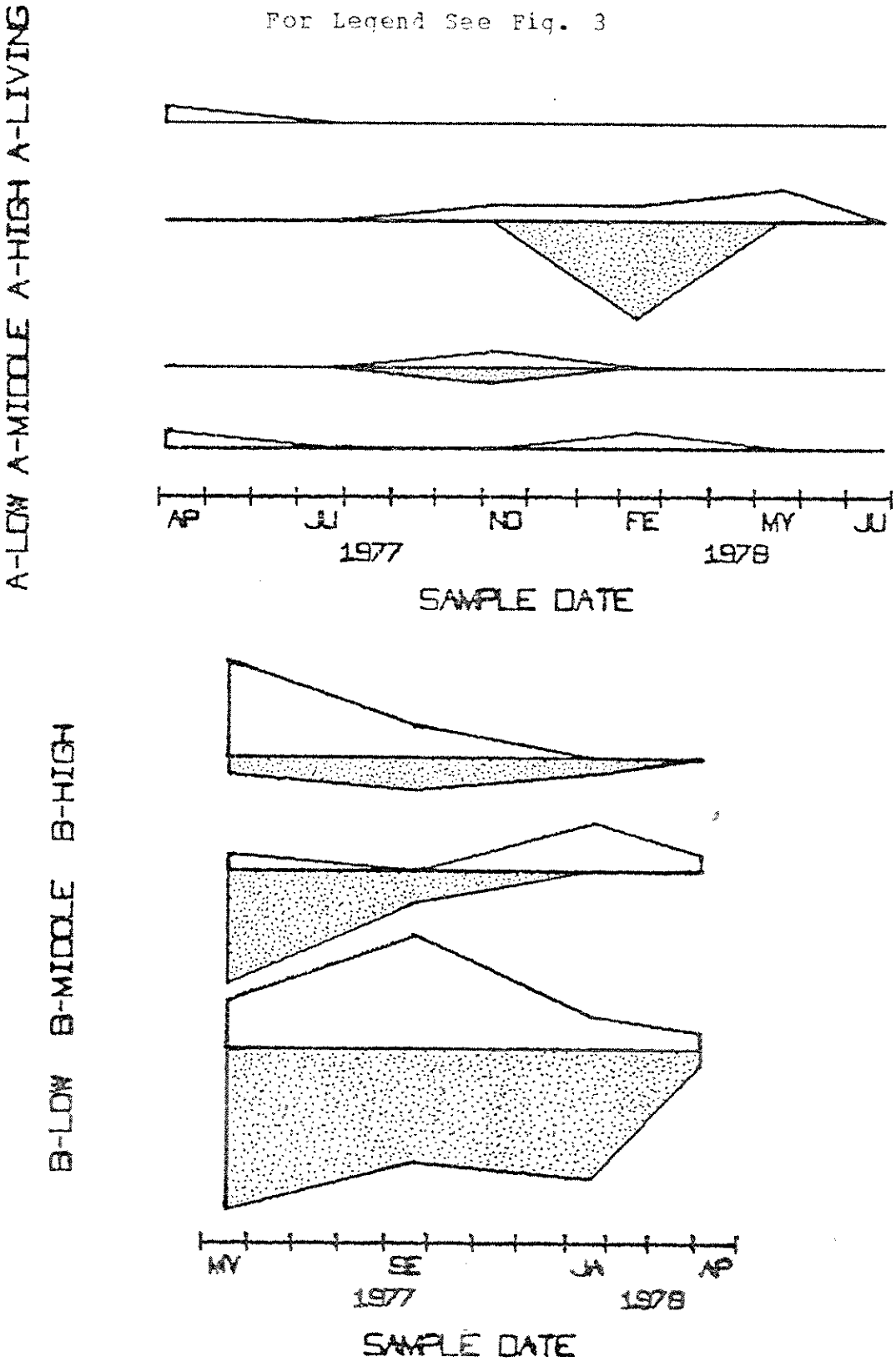
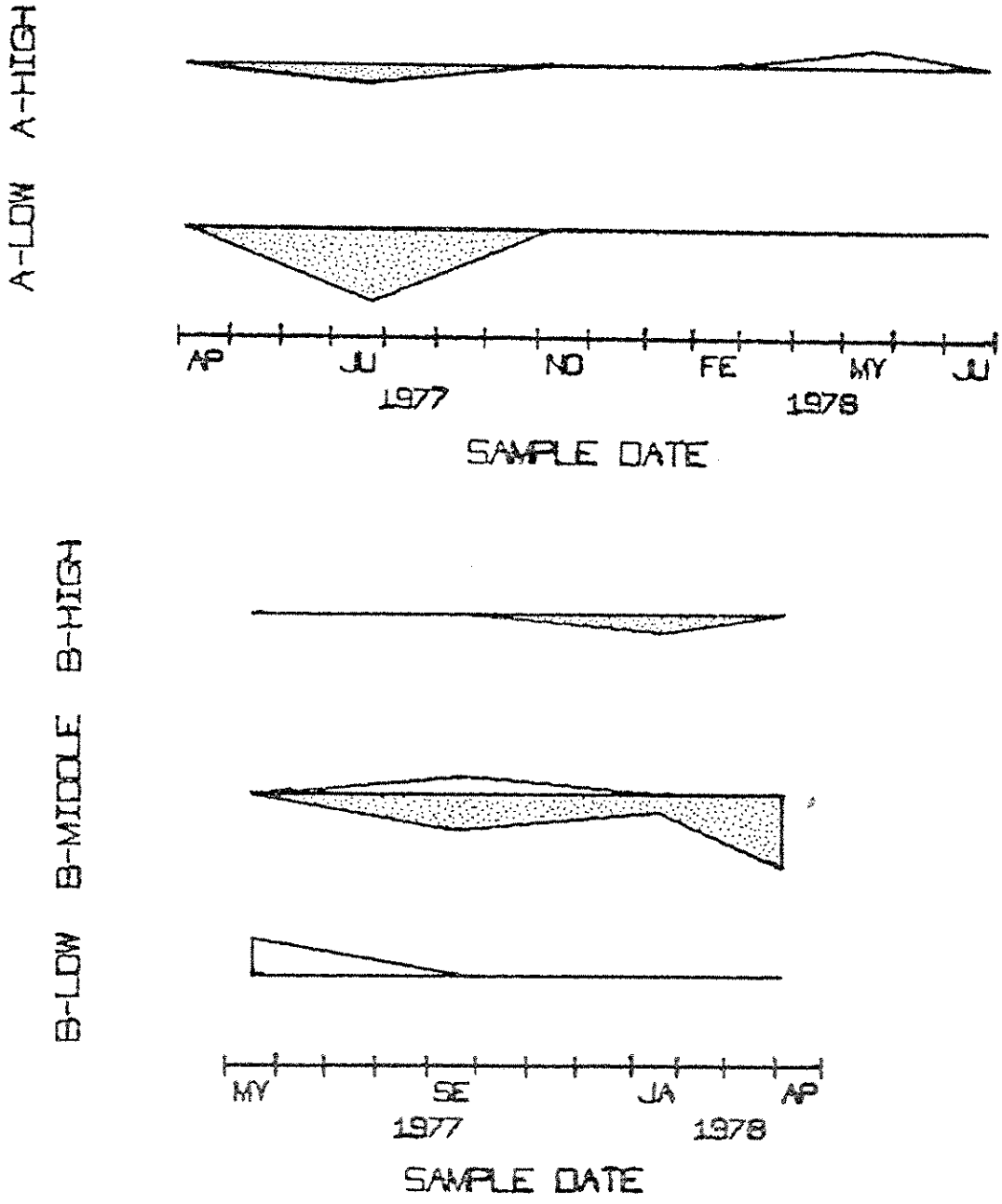


Figure 41. Seasonal Distribution - Number Of Isolates Of *Trichoderma polysporum*

For Legend See Fig. 3



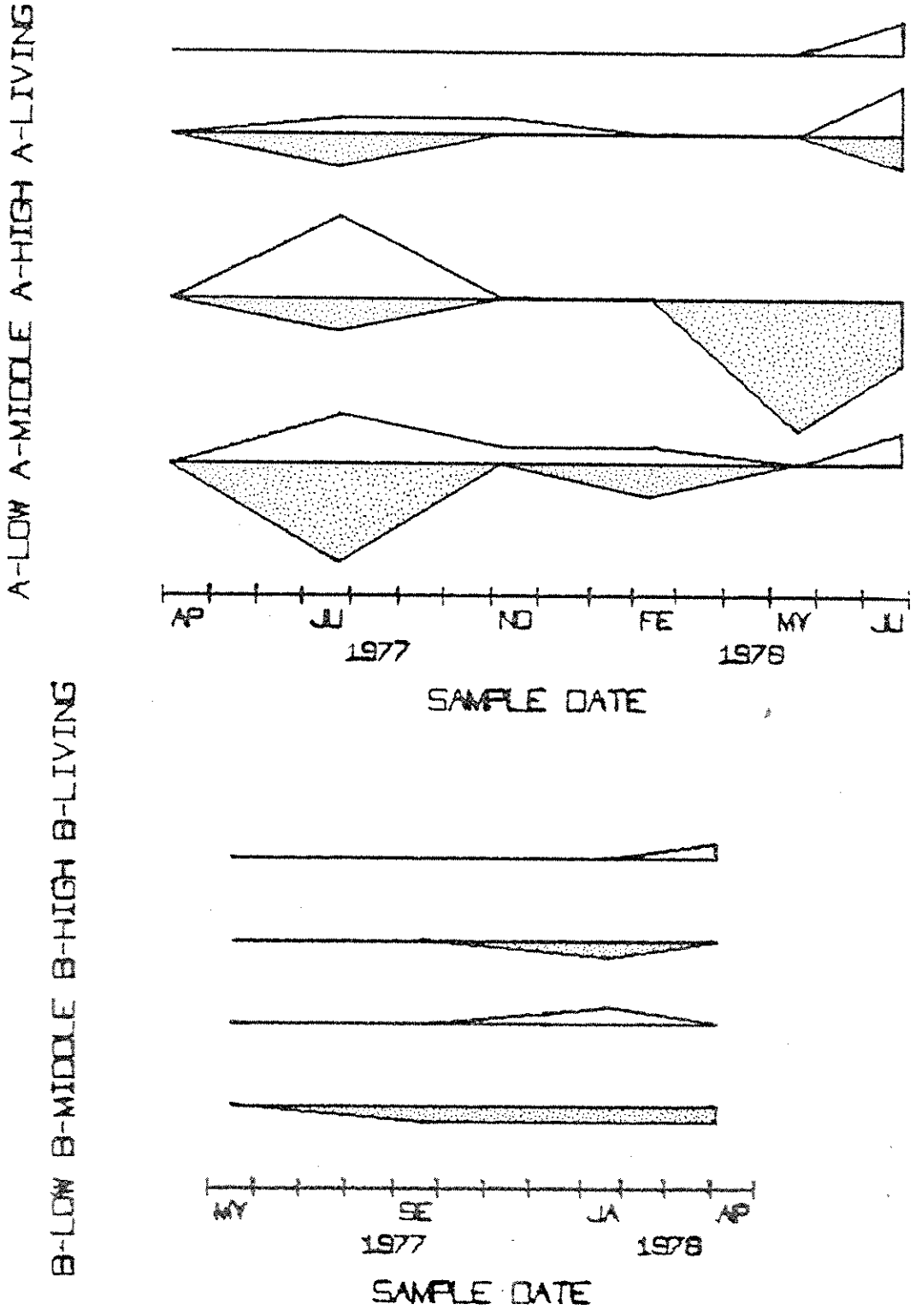
Trichoderma viride Pers. ex S.F. Gray. Nat. Arrang. Br. Pl. 1:560. 1821.

Colonies spreading rapidly, aerial mycelium sparse except in the spore clusters, conidia and conidiophores green, conidia very minutely to coarsely roughened, ovoid, 3.6 - 5.0 x 2.7 - 4.2 um. This species is identified easily by its characteristic rough spore. T. viride was found in all three subsites and on living leaves, at both sites, but much more frequently at Site A (Fig. 42). It occurred slightly more often in the F layer. The highest occurrences were during the summer samples, which were characterized by high temperatures and low precipitation. Griffin (1963) reported optimum growth at humidity of 91 - 96 %, which does not seem to reflect this pattern of occurrence. Before Rifai's treatment of the genus (1969), all green Trichodermas were referred commonly to T. viride. Griffin possibly could have been dealing with another species, which might explain this discrepancy. Possibly temperature is more important, as Sewell (1959) maintains that the mycelial activity is slowed in winter.

Figure 42. Seasonal Distribution - Number Of Isolates Of

Trichoderma viride

For Legend See Fig. 3



Tripospermum myrti (Lind)Hughes. Commonw. Mycol. Inst. Mycol. Pap. 46:17-18. 1951.

This species is recognized by its dark, somewhat restricted colony, producing irregularly tetraradiate conidia. T. myrti was isolated only at Site A, mostly from living leaves, but once in the L layer (Fig. 43). Gourbiere (1974a) has reported this species from living leaves of Abies.

Triposporium elegans Corda. Icon. Fung. 1:16. 1837.

Colonies somewhat restricted, white; aerial hyphae sparse; this species is recognized easily by its distinct dark tri- or tetraradiate spore, produced on erect, dark conidiophores. T. elegans was isolated only from Site B, mainly in the L layer. It occurred during the late summer, but was isolated in low numbers(Fig. 44).

Figure 43. Seasonal Distribution - Number Of Isolates Of

Trichospermum myrti

For Legend See Fig. 3

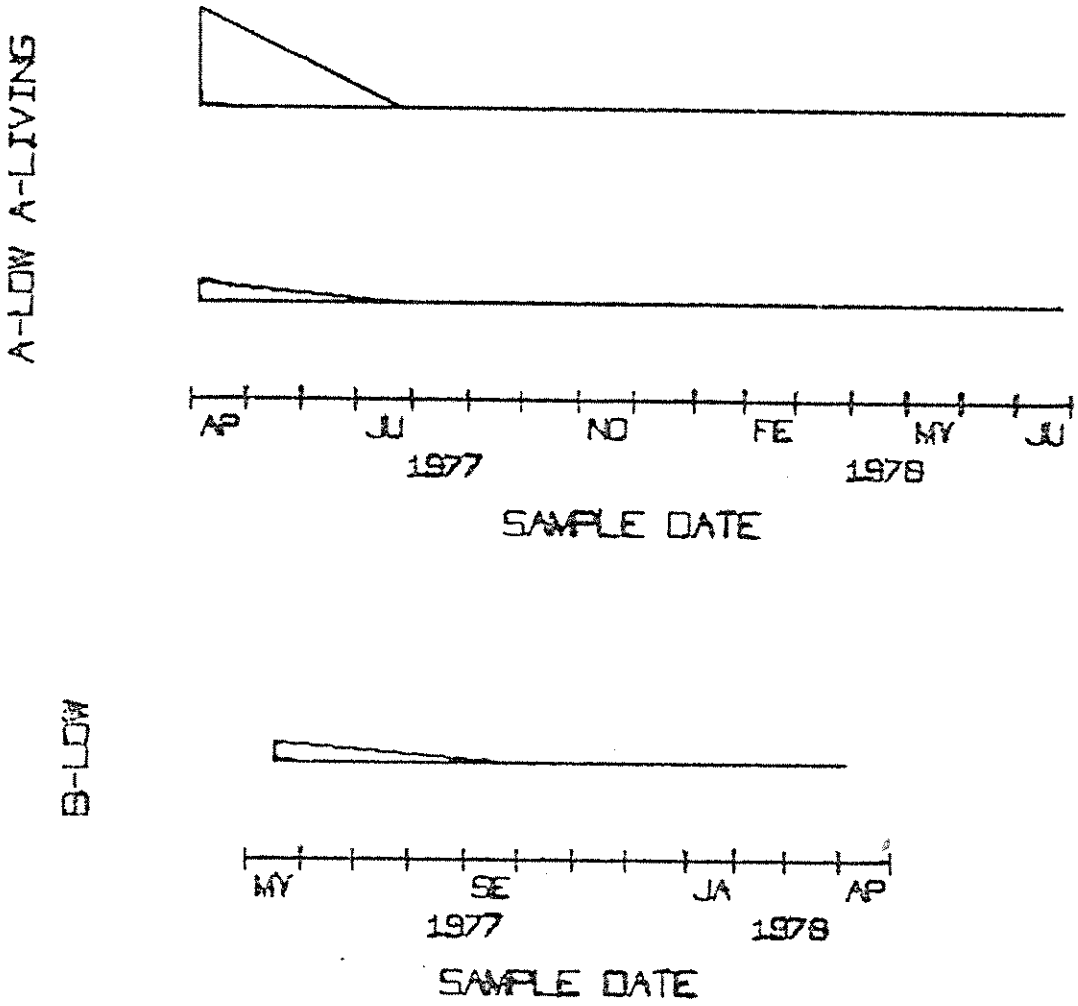
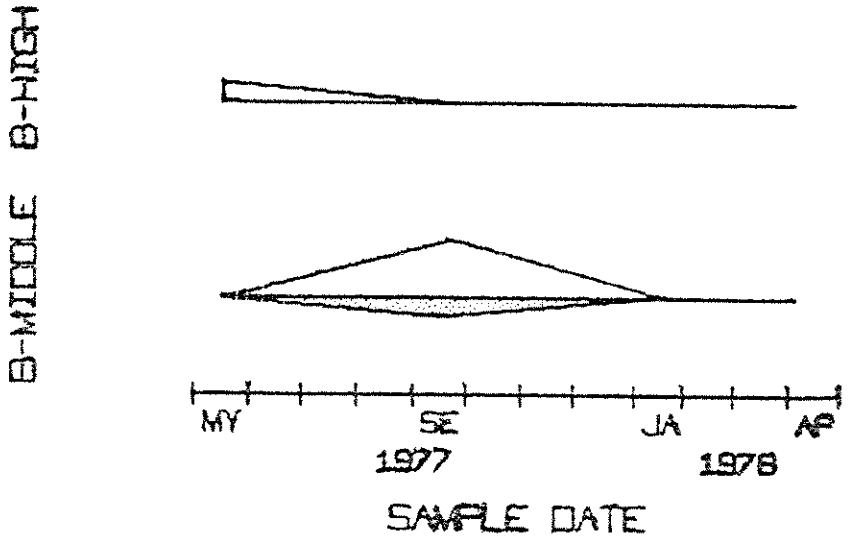


Figure 44. Seasonal Distribution - Number Of Isolates Of

Triposporium elegans

For Legend See Fig. 3



Varicosporium elodeae Kegel. Ber. Deutsch. Bot. Ges. 24:213-216. 1906.

Colonies moderately spreading, white, turning green in places; conidia characteristically branched and easily recognizable. This species was isolated only from Site A. V. elodeae occurred mostly in the low and middle subsites, and was more prevalent as precipitation decreased. It was most common in the low subsite where it was found more often in the F layer (Fig. 45). The occurrence of this species in both aquatic and terrestrial habitats has been well documented (Bandoni, 1972, 1977; Ingold, 1975; Park, 1974; Sanders and Webster, 1978; Webster, 1977).

Verticillium bulbillosum W. Gams and Malla. Cephalosporium-artige Schimmelpilze. 189-190. 1971.

Colonies moderately spreading, white with abundant aerial mycelium. This species was characterized by the presence of irregular shaped, unstalked chlamydospores, and conidia, 2.7 - 4.5 x 1.8 um. V. bulbillosum was infrequently isolated from Site A and Site B, but consistently from the F layer. It was more prevalent during the spring and summer (Fig. 46).

Figure 45. Seasonal Distribution - Number Of Isolates Of

Varicosporium elodeae

For Legend See Fig. 3

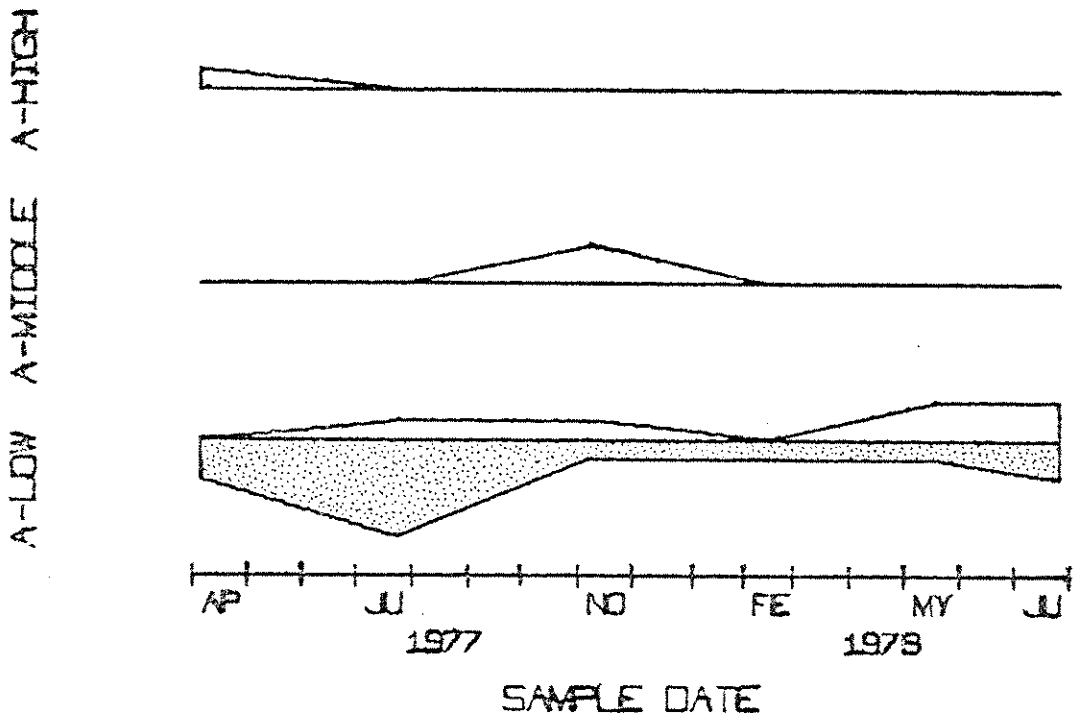
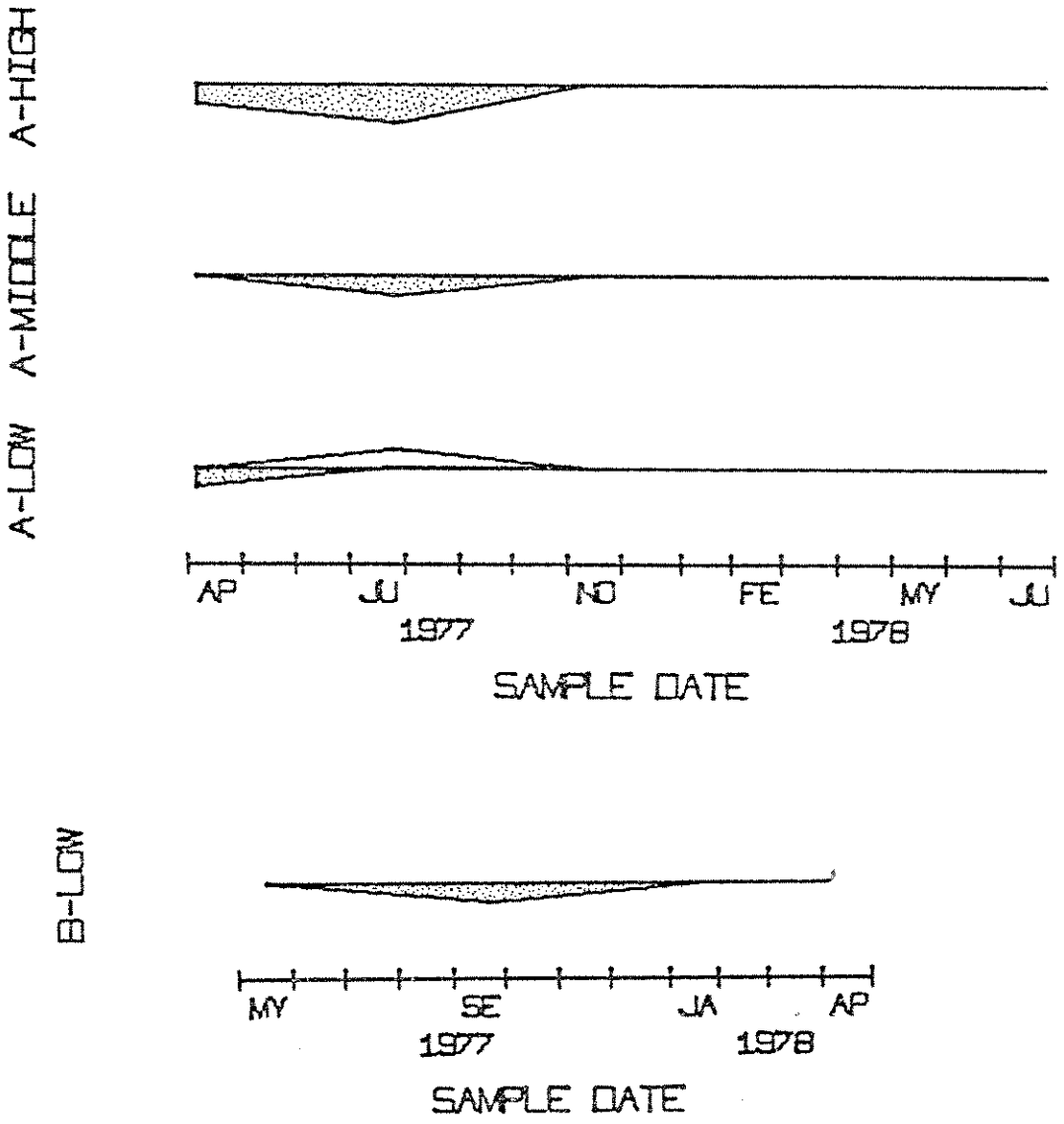


Figure 46. Seasonal Distribution - Number Of Isolates Of

Verticillium bulbillosum

For Legend See Fig. 3



## 6. Multivariate Analysis of the Data

The preceding sections have discussed separately the differences found between the separate layers, sites, subsites and seasons, with respect to species distribution. The data were complex and associations have been difficult to visualize. Certain trends could be shown when examining each aspect of the study separately but an overall integration of all the information was difficult. Therefore, an ordination of the samples was undertaken to provide a representation of their associations and differences, which could be used as a guide in interpreting the original data.

The species used to characterize the sites are given in Tables XXI and XXII, along with their frequencies of occurrence, means and variances. The complete distribution information on these species can be extracted from Tables III - IX or from the Figures for the corresponding species in the previous section.

Table XXI. Frequency And Variance Of The Most Common Species At Site A

| | TOTAL # ISOLATES | FREQUENCY % | MEAN | VARIANCE |
|---|---|---|---|---|
| Cylindrocarpon tenue | 139 | 14.57 | 3.46 | 9.52 |
| Helicodendron triglitziensis | 69 | 7.23 | 1.72 | 5.05 |
| Articulospora tetracladia | 48 | 5.03 | 1.23 | 3.70 |
| Trichoderma viride | 45 | 4.72 | 1.15 | 3.55 |
| Penicillium nigricans | 42 | 4.40 | 1.08 | 2.23 |
| Polyscytalum fecundissimum | 40 | 4.19 | 1.03 | 2.87 |
| Septonema chaetospira | 38 | 3.98 | 0.97 | 2.55 |
| Cladosporium cladosporioides | 34 | 3.56 | 0.87 | 1.17 |
| Penicillium verrucosum var. cyclopium | 28 | 2.94 | 0.72 | 0.79 |
| Chalara constricta | 26 | 2.73 | 0.67 | 1.70 |
| Cylindrocarpon didymum | 24 | 2.41 | 0.62 | 2.35 |
| Mucor hiemalis f. hiemalis | 22 | 2.31 | 0.56 | 0.99 |
| Varicosporium elodeae | 21 | 2.20 | 0.54 | 1.04 |
| Penicillium raistrickii | 20 | 2.10 | 0.51 | 1.26 |
| Pestalotia monochaetioides | 19 | 1.99 | 0.49 | 1.15 |
| Sporidesmium flexum | 19 | 1.99 | 0.49 | 1.36 |
| Trichoderma koningii | 15 | 1.57 | 0.38 | 1.08 |
| Selenophoma sp. | 14 | 1.47 | 0.36 | 0.82 |
| Septonema chaetospira var. pini | 14 | 1.47 | 0.36 | 0.76 |
| Libertella sp. | 14 | 1.47 | 0.36 | 0.82 |
| Penicillium brevi-compactum | 13 | 1.36 | 0.33 | 0.86 |
| Chalara longipes | 10 | 1.05 | 0.26 | 0.56 |
| Penicillium citrinum | 9 | 0.94 | 0.23 | 0.45 |
| Acrodontium crateriforme | 8 | 0.84 | 0.21 | 0.96 |
| Kriegeria seaveri | 8 | 0.84 | 0.21 | 0.33 |
| Endophragmia alternata | 6 | 0.63 | 0.15 | 0.13 |
| Acremonium strictum | 6 | 0.63 | 0.15 | 0.19 |
| Flagellospora stricta | 6 | 0.63 | 0.15 | 0.34 |
| Helicoon fuscosporum | 6 | 0.63 | 0.15 | 0.29 |
| Trichoderma polysporum | 6 | 0.63 | 0.15 | 0.45 |
| Tripospermum myrti | 6 | 0.63 | 0.15 | 0.66 |
| Verticillium bulbillosum | 6 | 0.63 | 0.15 | 0.19 |
| Hyalodendron lignicola | 5 | 0.52 | 0.13 | 0.33 |
| Penicillium notatum | 5 | 0.52 | 0.13 | 0.17 |
| Ramichloridium subulatum | 5 | 0.52 | 0.13 | 0.17 |

Table XXII. Frequency And Variance Of The Most Common Species At Site B

| | TOTAL # ISOLATES | FREQUENCY % | MEAN | VARIANCE |
|---|---|---|---|---|
| Cylindrocarpon tenue | 116 | 16.89 | 4.38 | 10.81 |
| Trichoderma koningii | 65 | 9.46 | 2.46 | 8.58 |
| Selenophoma sp. | 54 | 7.86 | 2.08 | 5.75 |
| Penicillium brevi-compactum | 31 | 4.51 | 1.19 | 3.52 |
| Penicillium verrucosum var. cyclopium | 31 | 4.51 | 1.19 | 2.40 |
| Gliocladium roseum | 22 | 3.20 | 0.85 | 1.26 |
| Cladosporium cladosporioides | 19 | 2.77 | 0.73 | 0.84 |
| Polyscytalum fecundissimum | 18 | 2.62 | 0.69 | 1.42 |
| Hyalodendron lignicola | 12 | 1.75 | 0.46 | 1.38 |
| Trichoderma polysporum | 11 | 1.60 | 0.42 | 0.89 |
| Helicodendron triglitziensis | 10 | 1.46 | 0.38 | 0.41 |
| Mucor hiemalis f. hiemalis | 10 | 1.46 | 0.38 | 0.49 |
| Chalara cylindrosperma | 9 | 1.31 | 0.35 | 0.48 |
| C. longipes | 9 | 1.31 | 0.35 | 2.48 |
| Flagellospora stricta | 8 | 1.16 | 0.31 | 0.30 |
| Septogloeum sp. | 8 | 1.16 | 0.31 | 0.54 |
| Septonema chaetospira var. pini | 8 | 1.16 | 0.31 | 0.46 |
| Penicillium nigricans | 7 | 1.02 | 0.27 | 0.52 |
| Acremonium strictum | 6 | 0.87 | 0.23 | 0.42 |
| Chloridium virescens var. chlamydosporum | 6 | 0.87 | 0.23 | 0.50 |
| Mortierella ramanniana var. ramanniana | 6 | 0.87 | 0.23 | 0.26 |
| Pestalotia monochaetioides | 6 | 0.87 | 0.23 | 0.50 |
| Libertella sp. | 6 | 0.87 | 0.23 | 0.26 |
| Trichoderma viride | 6 | 0.87 | 0.23 | 0.18 |
| Penicillium raistrickii | 5 | 0.73 | 0.19 | 0.40 |
| Septonema chaetospira | 5 | 0.73 | 0.19 | 0.24 |
| Triposporium elegans | 5 | 0.73 | 0.19 | 0.40 |
| Chalara constricta | 4 | 0.58 | 0.15 | 0.14 |
| Fusarium lateritium | 3 | 0.44 | 0.12 | 0.11 |
| Penicillium frequentans | 3 | 0.44 | 0.12 | 0.11 |

As mentioned previously, PCA was performed with both the unscaled and scaled options. Since the unscaled data emphasized mainly the most frequently isolated species, the ordinations tended to show some of the obvious groupings of species and did not show distinctive groupings of layers, subsites or samples.

With the Site A data, Cylindrocarpon tenue dominated the samples and had the highest variance. This meant that the ordination of samples showed very little in the way of groupings of samples possibly because this species was found everywhere. The cluster analysis was similar in its lack of distinction.

At Site B, the three most frequently isolated species, Cylindrocarpon tenue, Trichoderma koningii and Selenophoma sp., combined to influence the grouping of samples. This was because each of the three were found exclusive of the others. They represented the high subsite, F layer of the low subsite and the L layer, respectively. Because the species were mutually exclusive, these groups were relatively distinct, but were also obvious from the original data. Therefore, using unscaled data was helpful in verifying some of the major trends in associations but because they were dominated by the species with the highest frequencies, possibly the more subtle influence of the rest of the species isolated was overlooked.

When the data were scaled, all of the species were given essentially the same importance. This has the effect of reducing the influence of the most frequently isolated species, and increasing that of the rarer species. Thus, after first observing how the dominant species determined the ordinations with the unscaled data, it was instructive with the scaled data

to see what associations were apparent as a result of the less frequently occurring species.

In the Site A analysis using scaled data, a meaningful ordination of samples was obtained in the plot of principal component axis I vs. III (Fig. 47). The first principal component accounts for 12% of the total variance, and the third, 8%. Even though this is only 20% of the total variance, trends could be seen which shed light on the original data. There was a polarization between the first two spring and summer samples (2 and 3) and the last two spring and summer samples (6 and 7). These two groups overlapped slightly in the lower subsites, especially the F layer. Although these represented similar times of the year, they differed with respect to temperature and precipitation, and somewhat by species isolated (see Tables I, XVII and XIX). There was a grouping of the fall and winter samples (4 and 5), which were situated between the two sets of spring and summer samples, showing a temporal change from the initial sampling through to the last. An exception to this were the winter samples (5) in the high and middle subsites, L layer. These were associated more with the low subsite of the first spring sample (2) than the rest of the fall and winter samples. This illustrates the similarity of the low subsite in the spring to the high subsite in the winter, possibly because of similar precipitation and drainage conditions at these times of the year.

A species ordination at Site A was produced by plotting eigenvector I vs. eigenvector III (Fig. 48). There was a group toward the left of the plot represented by species 2, 28, 20, 3,

7, 13 and 26. These corresponded to Helicodendron triglitziensis, Flagellospora stricta, Libertella sp., Articulospora tetracladia, Septonema chaetospira, Varicosporium elodeae and Endophragmia alternata. These species represent the groups known as "aquatic" and "aero-aquatic" hyphomycetes, except for Libertella sp., S. chaetospira and E. alternata. The main characteristic of the "aquatic" and "aero-aquatic" hyphomycetes is the production of spores which are branched or otherwise adapted for dispersal in water. Libertella sp. produced curved scolecospores in slimy masses, which might be advantageous for dispersal in a moist environment. The other two species possessed quite different spores. S. chaetospira produced long chains of relatively dry spores. E. alternata also produced dry spores, but not in chains; this species was isolated in low numbers. All of these species were prominent in the lower subsites, and thus in close proximity to the stream.

Another grouping of species was in the lower right corner of the graph, species 14 and 5. These were Penicillium raistrickii and P. nigricans. They mainly represented the high subsite, occurring in the summer months. Possibly associated with this group were species 30, 16 and 4; Trichoderma polysporum, Sporidesmium flexum and T. viride respectively. These also tended to occur during the summer, but not during the extremely dry times when P. raistrickii and P. nigricans occurred. These two groups were separated from the aquatic and aero-aquatic group. This pattern contributed to the separation of the two sets of summer and spring samples in the ordination

of the samples previously mentioned.

The third group of species was represented by Selenophoma sp., Chalara longipes and C. constricta (10, 22 and 18). All of these tended to occur during the fall and winter samples, mostly in the L layer, and were characteristic of the winter samples segregated out above. In describing the ordination it appears that eigenvector III polarized the winter and fall species from the summer and spring ones, and eigenvector I seemed to separate the species occurring in moister subsites from those occurring in drier ones. In comparing this ordination to that produced with the unscaled data, the same basic groups composed of the more frequently isolated species could be seen, but added to these groups with the scaled data were some of the less frequently isolated species.

Figure 47. Ordination Of Samples At Site A. Axis I vs. III (Scaled)

2 - 7 = Sample Dates (see Table I)

○ ● = High Subsite

△ ▲ = Middle Subsite

□ ■ = Low Subsite

○ △ □ = L Layer

● ▲ ■ = F Layer

x = Living Leaves

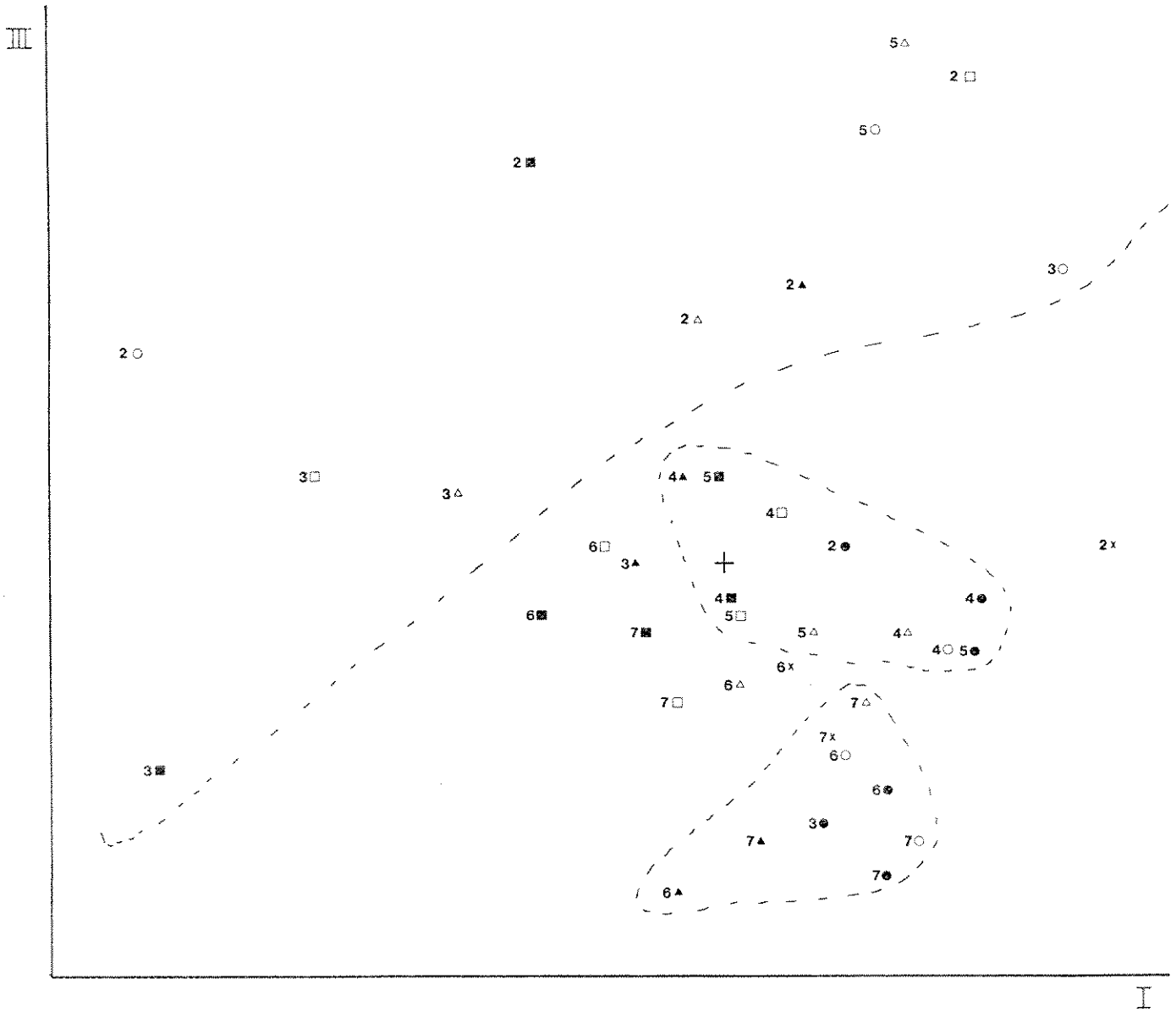
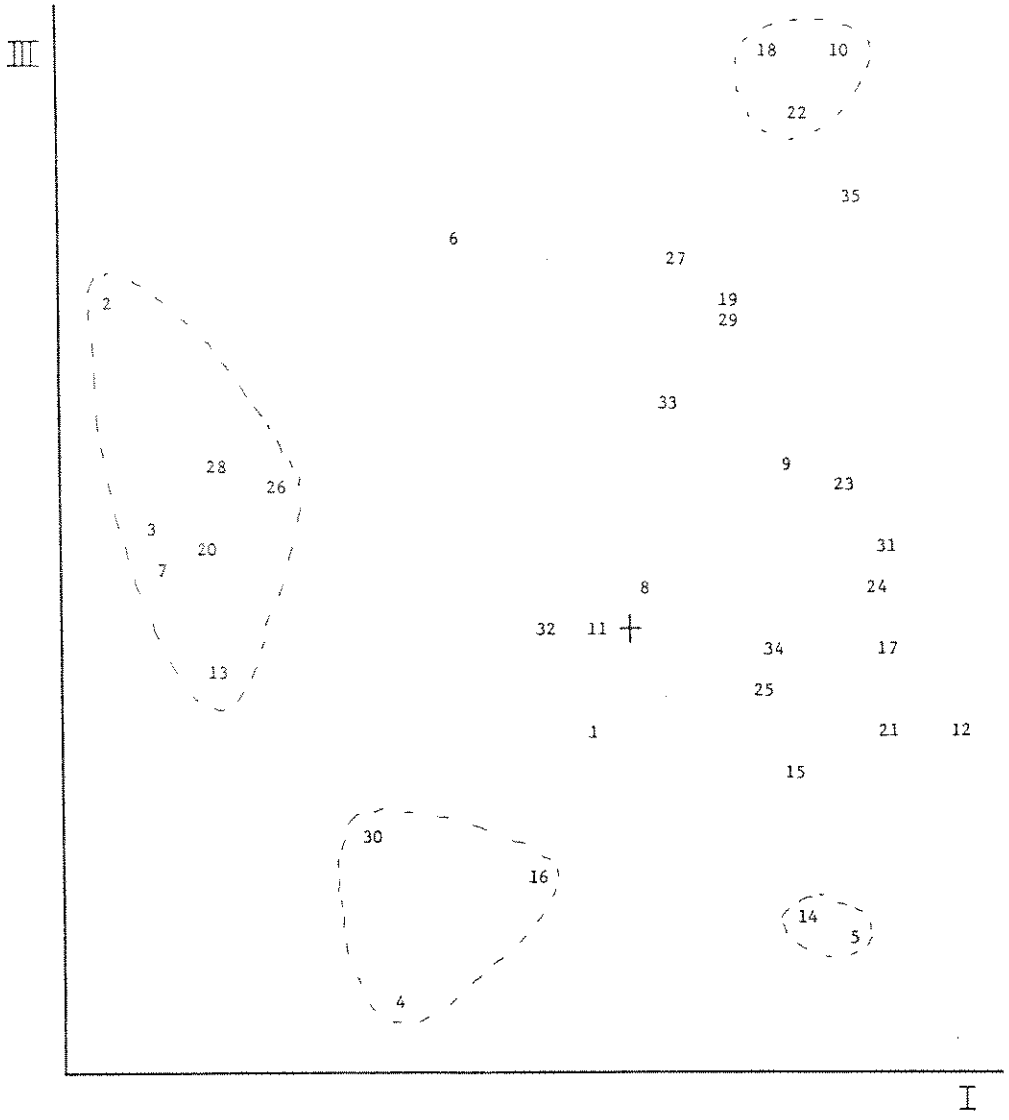


Figure 48


III
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Site B was characterized by many of the same fungi as were present at Site A, but in different frequencies. The species utilized in the PCA at Site B are listed in Table XXII. The plot of axis II vs. axis III (Fig. 49) was considered to give the most meaningful ordination of samples using scaled data. These components account for 12% and 10% of the total variance, respectively. Although this plot only accounts for a small amount of the total variance (22%), it does indicate trends and associations which are helpful with respect to the original isolation data. Within the F layer, the high and middle subsites appear similar, especially among the fall and winter samples (2 and 3); however, in the L layer, the high subsite is separated from the low and middle subsites. Also, the samples of living leaves tend to associate with those of the L layer. This is expected since the leaves on the tree, after falling, would initially be found in the L layer.

The plot of eigenvectors II vs. III (Fig. 50) provided an interpretable species ordination. There was a four cornered polarization of the species found at this site. In the upper right hand corner, species 6, 13, 18 and 5 tended to group together. These points represented Gliocladium roseum, Chalara cylindrosperma, Penicillium nigricans and P. verrucosum var. cyclopium respectively. These species were representative of the F layer, during the fall and winter, thus distinguishing these samples in the above ordination. Opposite this group, in the lower left of the diagram, was a group of species including Selenophoma sp., Polyscytalum fecundissimum, Pestalotia monochaetioides and Septogloeum sp. (3, 8, 22 and 16,

respectively). These species seemed to characterize the L layer and also the living leaves, and were found mainly during the fall and winter. This group corresponds with the samples from living leaves and the L layer, as shown in the ordination of the samples. In the lower right corner, there were three species forming a group, 23, 29 and 27; they were Libertella sp., Fusarium lateritium and Tripospórium elegans. They represented the first spring and early fall samples in the high and middle subsites, L layer. In fact these samples were found in the same position in Fig. 49 as the species in Fig. 50. Opposite to these were also species which occurred in the early fall; Mucor hiemalis f. hiemalis, Cylindrocarpon tenue, Chalara longipes and Flagellospora stricta (12, 1, 14 and 15). They were more representative of the high subsite, in the L layer. They also seemed to represent the fall samples and thus contributed to their grouping together. In comparison with the unscaled data, this ordination shows the association of many other species with two of the three most frequently isolated species, Cylindrocarpon tenue and Selenophoma sp.. Trichoderma koningii was centered in the plot and thus associations were not obvious.

In summing up the relative worth of PCA as used in this study, I found that it was useful as a descriptive means of viewing the data and thus possibly pointing out associations which lend themselves to interpretation through the original data.

Figure 49. Ordination Of Samples At Site B. Axis II vs. III (Scaled)

1 - 4 = Sample Dates (see Table I)

○ ● = High Subsite

△ ▲ = Middle Subsite

□ ▩ = Low Subsite

○ △ □ = L Layer

● ▲ ▩ = F Layer

x = Living Leaves

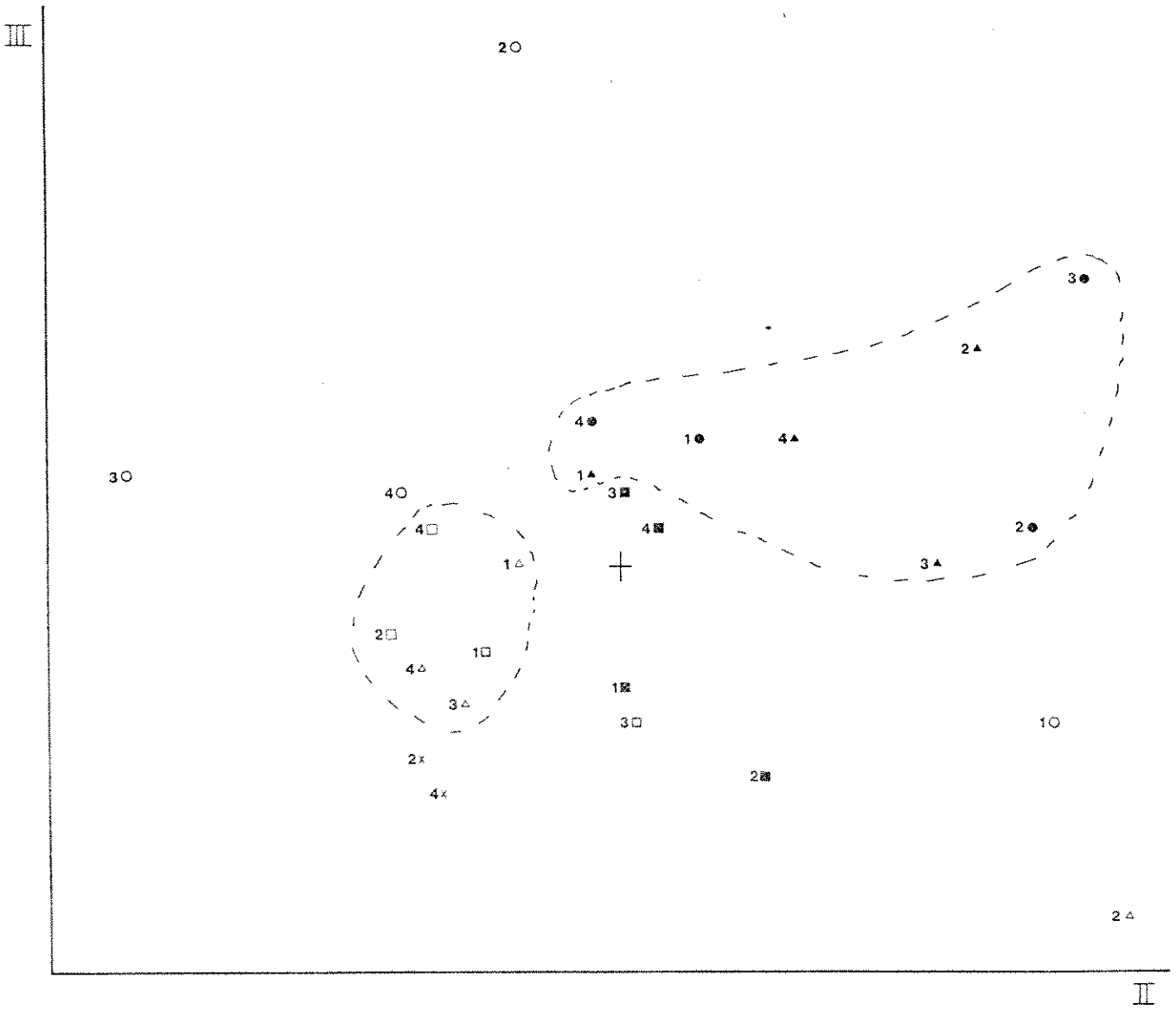
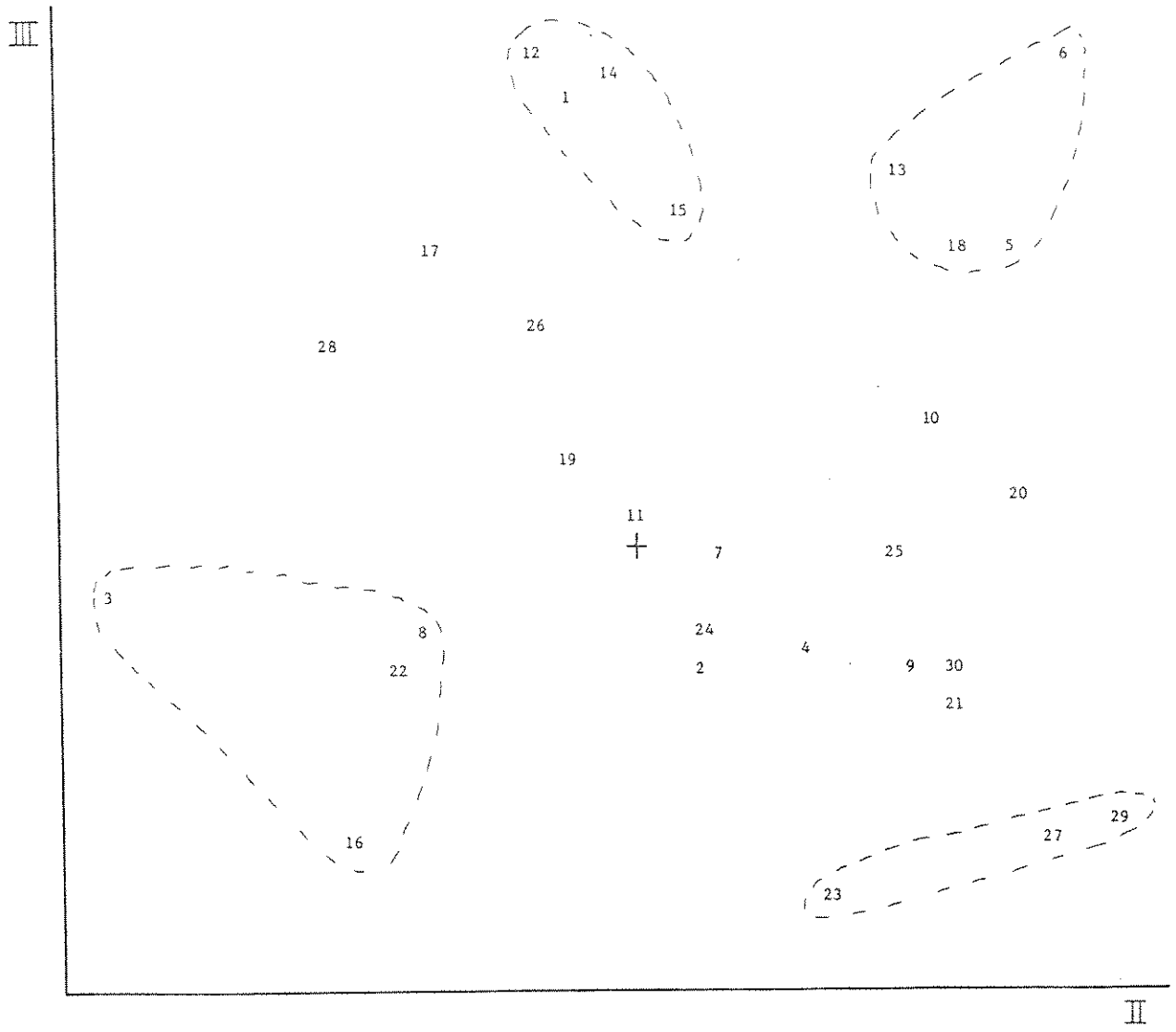


Figure 50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# IV. Discussion and Conclusions

In the present study, fungi involved in the decay of red cedar litter were examined. The frequency of isolation of fungi from the branchlets in the litter layers has been taken as an indication of their relative involvement in decay. Granted that this indirect measure of activity is subject to a number of variables, such as isolation technique and media employed, it nonetheless provides a basis for some general indications of the associations of these fungi. The influence of moisture upon the distribution of species was only indirectly examined. That is, precipitation data was obtained relative to collection dates.

## 1. Discussion of the Subsites

As mentioned previously, the study sites were divided into three subsites, indicating their relative position in relation to a nearby stream. The divisions were artificial and subjective, but were employed to see if there were differences in the mycobiota with slight positional changes in relation to the stream.

The species isolated were used to characterize each sample, and the samples were grouped through a PCA ordination. The results of this analysis have been presented in the foregoing section. In the analysis of the data, the subsites were not associated in the same exact groups in each of the main sites.

The subsites represented a gradation away from the stream and thus toward somewhat drier conditions. It seemed reasonable to expect the two extreme subsites, low and high, to be more distinct, with the middle subsite associated at times with one or the other. In some respects this was the case, as shown by the cluster analysis and PCA of the data from both sites. Samples from the high and low subsites were more or less distinguished as separate groups, with samples from the middle subsite distributed between these two. At Site A, the middle subsite was more frequently grouped with the high. At Site B, the middle subsite was associated equally between the low and high.

## 2. Discussion of the Litter Layers

In an attempt to determine what effect spatial differences had on the fungal population, the species composition in the L and F layers was also examined. The fungi present on litter in these layers were representative of their position in the time sequence of decay; the L layer species being mostly early colonizers, and the F layer species representing those colonizing at later stages of decay.

In examining the ordinations discussed previously, the relative separation of the samples into these two layers was determined. At Site A, separation of layers was not very strong; there was a grouping of the F layer in the spring and summer samples. There were other scattered groupings of samples from

the same layer, but nothing very distinctive. The incomplete separation of the two layers was even more evident in the cluster analysis. On the other hand, at Site B, both the unscaled and scaled data, and also the cluster analysis, depicted a reasonable separation of the two layers.

When investigating litter decay fungi, most workers have found the division into the L and F layers represented units distinguishable by the fungal species present (Borowska, 1966; Brandsberg, 1969; Kendrick, 1963; Kendrick and Burges, 1962; Verona and Rambelli, 1972; Visser and Parkinson, 1975; Watson et al., 1974; Wicklow and Whittingham, 1974, 1978; Widden and Parkinson, 1973). In the present study, the species characteristic of the different layers are listed in Tables XVII and XVIII. Many of these species have not been reported previously from litter studies; of those that have, occurrence in the respective layers is consistent with what has been reported.

Some of the species found in the L layer at one site, were found in the F layer at the other site. This was true of Hyalodendron lignicola, Mucor hiemalis f. hiemalis and Acremonium strictum. It is probable that these represent species which can be considered to occur equally in both layers. The differences may reflect the basic differences between the sites. For the most part, this division of species between the layers represents a definite ecological tendency; some species are found predominantly in the L layer, while others are found predominantly in the F layer. Since many of the species have not been reported previously from litter, their inclusion here adds

more information to the ecology of these species.

## 3. Discussion of Seasonality

The samples were analyzed regularly throughout the study in order to determine the seasonal differences among them. In the ordinations already presented, some of the samples were often clustered seasonally, regardless of their layer or subsite. This was especially true with the fall and winter samples, and the spring and summer samples. The grouping together of these seasons seemed reasonable as they represent major climatic differences during the year.

Many of the species isolated can also be grouped together on the basis of their seasonal occurrences. The groupings have been listed in the previous section on seasonality in the L and F layers. Other workers have reported some of the species to show the same seasonal distribution. Species occurring during spring were Acremonium strictum, Trichoderma viride and Polyscytalum fecundissimum (Katz and Lieth, 1974). The summer group included Cylindrocarpon didymum (Badurowa and Badura, 1967), Trichoderma viride (Gourbiere, 1979; Ruscoe, 1971; Visser and Parkinson, 1975), Penicillium nigricans (Martinez and Ramirez, 1972) and P. raistrickii (Gourbiere, 1979). The species found during the fall and winter were Mucor hiemalis f. hiemalis (Hering, 1965; Gourbiere, 1979; Martinez and Ramirez, 1972), Penicillium brevi-compactum and P. notatum (Badura and Badurowa, 1964; Badurowa and Badura, 1967; Martinez and Ramirez, 1972),

P. citrinum (Yokoyama et al., 1977), P. frequentans and Mortierella ramanniana var. ramanniana (Badurowa and Badura, 1967; Gourbiere, 1979), Chalara cylindrosperma (Hogg and Hudson, 1966) and Hyalodendron lignicola (Katz and Lieth, 1974; Tubaki and Yokoyama, 1971). Some of these workers have reported different seasonalities for a few of the species, but this may reflect only differences in climates and substrata.

Since most of the species isolated in this study have not been reported previously from litter, their occurrences with respect to seasons has not been discussed previously. Of these species, those isolated during the spring and summer were Articulospora tetracladia, Septonema chaetospira, Flagellospora stricta, Sporidesmium flexum, Helicodendron triglitziensis, Varicosporium elodeae and Verticillium bulbillosum. Species present in the fall and winter were Pestalotia monochaetioides and Triposporium elegans. One species, Chalara constricta, was found in the fall and winter in the L layer, and in the spring in the F layer.

## 4. Species Associations

In the process of analyzing the data to determine the associations of the samples, an ordination was also made of the species used to characterize the samples. The groups of species, mentioned in the previous section, were based on similar distributions of the species in the subsites and layers. At Site A, unscaled data, the group of Cylindrocarpon didymum,

Penicillium nigricans, P. raistrickii and Articulospora tetracladia, represented the summer species group that were also found predominantly in the F layer. These species form a biological unit indicative of, and favored by, dry conditions. P. nigricans, P. raistrickii and C. didymum have often been found under low moisture conditions (Bissett and Parkinson, 1979a; Gochenaur and Backus, 1967). A. tetracladia is usually thought of as an inhabitor of aquatic environments, but it has also been found to survive well in terrestrial situations (Bandoni, 1972, 1977; Sanders and Webster, 1978; Webster, 1977). Another group of species, Helicodendron triglitziensis, Polyscytalum fecundissimum and Chalara constricta, were spring and summer species in the L layer. Thus a combination of characteristics has been utilized to provide species associations, particularly, seasonality and occurrence in one or the other layer. The third major group at this site was strictly the product of position, occurring in the F layer, in the low subsite. The species involved were Septonema chaetospira, Varicosporium elodeae and Trichoderma polysporum. V. elodeae, like A. tetracladia, is considered a member of the aquatic hyphomycetes, but it too has been shown to exist in dry terrestrial conditions (Bandoni, 1972, 1977; Bessey, 1939; Gourley, 1969; Sanders and Webster, 1978; Waid, 1954; Webster, 1961, 1977; Williams and Schmitthenner, 1956).

When the ordination was performed using scaled data, the groups of species were based again on different parameters. One group was separated because of a high frequency of occurrence in the low subsite. Another represented summer species, and this

group was divided into the extreme dry times (sample 7; Penicillium nigricans and P. raistrickii) and the less extreme (sample 3; Trichoderma polysporum, T. viride and Sporidesmium flexum). This group was similarly distinguished as such in the unscaled ordination. The last group in this ordination was of fall and winter occurring species, in the L layer, represented by Chalara constricta, C. longipes and Selenophoma sp. It follows that Selenophoma sp. would be found more frequently in the fall and winter since it is pycnidial, thus an early colonizer, and much of the leaf fall is during the fall of the year (Dimock, 1958; Kendrick, 1959).

As already stated, Site B was slightly different from Site A in species isolated. Therefore the ordination of species at Site B did not provide the same associations of species as at Site A. With the data unscaled, two of the groups were seasonally distinct. These were Penicillium brevi-compactum and Polyscytalum fecundissimum, in the low subsites during the fall, and Penicillium verrucosum var. cyclopium and Gliocladium roseum, in the F layer during the winter. Although these species are not reported frequently in litter decay studies, the information available tends to support these distributions (Badura and Badurowa, 1964; Hogg and Hudson, 1966; Widden and Parkinson, 1973). The other species were separated on positional grounds; Trichoderma koningii, an F layer species in the low subsite, and Selenophoma sp., an L layer species in the high subsite.

When the data were scaled, the groups remained much the same, but more species were added. The winter group above gained

species (Chalara cylindrosperma and Penicillium nigricans), and were representative of fall and winter species in the F layer. It is interesting that P. nigricans was isolated more frequently in the fall and winter at this site and not in the summer, as was the case at Site A. This anomaly may be simply the result of overemphasizing the importance of this species at Site B, since it occurred in relatively low numbers there. The fall group lost one species (Penicillium brevi-compactum) and combined with Selenophoma sp. and other species (Septogloeum sp. and Pestalotia monochaetioides) to represent fall and winter species in the L layer. These species all represent primary colonizers of leaves, and thus this grouping is not unexpected. The other two associations were not shown in the PCA of the unscaled data. These were species from the first spring and fall samples in the L layer of the high and middle subsites (Libertella sp., Fusarium lateritium and Triposporium elegans), and fall species in the L layer of the high subsite (Mucor hiemalis f. hiemalis, Cylindrocarpon tenue, Chalara longipes and Flagellospora stricta). The species in the first group were found in low frequencies and their emphasis may have been a result of the increased importance given them by standardizing the data. The latter group represents species more frequently encountered in the high subsite, and may be good indicators of that area.

In an overall view of species associations based on similarities of distribution in the various layers, subsites and seasons, the ordination method (PCA) provides indications of groups that can be pursued through the raw data. By combining the information from both major sites, several groups of species

emerge which appear to represent possible ecological units.

The first group of species are representative of low subsites and thus moist conditions. These include Helicodendron triglitziensis, Articulospora tetracladia, Varicosporium elodeae, Flagellospora stricta, Polyscytalum fecundissimum, Septonema chaetospira and Endophragmia alternata. As mentioned previously, the first four species represent aquatic-type hyphomycetes, although they are not unknown from terrestrial situations. The last three species have not been reported frequently in litter studies, and their inclusion here is new.

A second group includes Trichoderma viride, Penicillium nigricans, P. raistrickii, T. polysporum and Sporidesmium flexum. These species were indicative of summer conditions, and P. nigricans and P. raistrickii were both prominant during extremely dry periods.

Another association of species included Selenophoma sp., Pestalotia monochaetioides, Septogloeum sp., Penicillium brevi-compactum, Mucor hiemalis f. hiemalis, Chalara constricta and C. longipes. These were representative of the L layers. The first three are pycnidial and thus important primary colonizers. P. brevi-compactum and M. hiemalis f. hiemalis are common litter fungi. C. constricta and C. longipes have not previously been reported in litter studies.

A final group did not include many species, but they did tend to occur under similar circumstances, usually in the F layer. They were Penicillium verrucosum var. cyclopium, Gliocladium roseum and Chalara cylindrosperma. The latter species was not reported from litter before, and the former two

are common soil and litter fungi.

## 5. Summary

In conclusion, this study has provided further insight into the complex process of litter decay and the fungi involved, in a unique environment dominated by Thuja plicata Donn. The standard technique for determining this has been to examine the occurrence and distribution of species, using various isolation techniques (Lindsey, 1973; Parkinson, 1973). The fungi involved in the decay were isolated and identified. Many of these species have not been reported previously in soil and litter studies. Their occurrence here may be a result of the techniques employed. Studies on litter fungi using the modified dilution plate technique, have resulted in a predominance of species of Penicillium, Mucor and Trichoderma (Brandsberg, 1969; Verona and Rambelli, 1972). A combination of washing litter and then using the dilution plate method, as used by Visser and Parkinson (1975), resulted in a predominance of Penicillium spp., Trichoderma spp. and Phoma spp. Other workers who utilized washing techniques and cultured the washed litter on selective media or in moist chambers, reported a reduced involvement of Penicillium spp., with Trichoderma spp., Mortierella spp., Mucor spp. and primary colonizers such as pycnidial species, predominanting (Gourbiere, 1979; Kendrick and Burges, 1962; Watson et al., 1974). In the present study the predominant species was Cylindrocarpon tenue, which has not been reported

often from litter studies. Trichoderma spp. (T. viride and T. koningii) and Penicillium spp. (P. nigricans, P. verrucosum var. cyclopium and P. brevi-compactum) were also found to occur with high frequencies. A pycnidial species, Selenophoma sp., was also isolated as a primary colonizer. Two species, Helicodendron triglitziensis and Articulospora tetracladia, were isolated with high frequencies. These species have been reported occasionally as occurring on litter, but have never been found in studies on litter decay fungi. Their occurrence here indicates their probable active involvement in the decay process. Many of the remaining species have not been isolated before in litter decay studies.

The techniques used in this study (i.e. washing litter and then putting it on SYT plates or in moist chambers) probably give a good indication of the fungi involved in the decay. Since isolates were taken from the first two spots in the SYT plates and mainly after the first week of incubation of the moist chambers, the fungi could be considered actively growing in the litter.

The differences between the various subsites were slight, but did tend to represent a gradient between the low and high subsites. The L and F layers were often more distinct in the species isolated, and represent differences in the involvement of fungi in the different stages of decay. As with spatial differences, seasonal changes in the occurrence of species were slight but represented a gradient between fall and winter, and spring and summer. The differences in the summer were often extreme. The common denominator among all these differences

seems to be moisture although supportative data are not available. The slight differences in distance from, and elevation above a stream, or seasonal differences in precipitation, are deemed to be responsible for slight but discernible changes in the occurrence of species.

The associations of species, shown through PCA,suggest a number of starting points for experimental research into the nature of interactions among species involved in the decay process. While these associations do not characterize specific differences in subsites, seasons or layers, they do represent a combination of these factors. As a result, the species associations represent groups which probably function together in the environment.

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