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STUDIES ON FUNGI ASSOCIATED WITH HALOPHYTES FROM DELTA MARSH, MANITOBA

by

TAWFIK M. MUHSIN

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ABSTRACT

Six halophytic plants, Atriplex patula, Glaux maritima, Hordeum jubatum, Puccinellia nuttalliana, Salicornia europaea and Suaeda depressa, from Delta Marsh, Manitoba were studied for rhizoplane and cauloplane fungi. These plants showed diverse groups of mycota over the growing season. A total of 34 taxa were recovered during the course of this study. Morphological features and taxonomic disposition are given for each halophytic species. Among the studied plants, Salicornia europaea provided the majority of the fungal taxa.

Fungal community analyses demonstrated a similarity in the community parameters (i.e., similarity, diversity, dominance, spatial groups and life strategies) between Atriplex patula, Salicornia europaea and Suaeda depressa, and between Glaux maritima, Hordeum jubatum and Puccinellia nuttalliana. Dominance and diversity tended to be inversely related to each other over the collecting period. Differences in fungal assemblages over time were established on each of the halophytic species. The changes in fungal assemblages throughout the growing season demonstrated two successional patterns: seral and substrate succession. These types of

succession were attributed to the plant growth phases (vegetative and stationary) and chemical changes within plant tissue. The change in fungal seres over time is also discussed in response to the general plant osmotic strategies and phenological stages.

Additions of various treatments (sodium nitrate, sea salts and irrigation) to Salicornia europaea resulted in a noticeable change in growth habit, phenological stages, total salt content, ionic concentrations, and water content of the roots and shoots. Correlation between changes in the fungal communities on this halophyte and these parameters is presented. Sea salts-treated and untreated plants showed a similarity in dominant and subdominant fungi. A dissimilarity was also observed between sea salts-treated and irrigated plants.

Regression analysis correlated the total number of fungal isolates with the ionic levels of Salicornia europaea roots and shoots. The most strongly correlated ions were Na^{+}, Mg^{++} and $SO_4^{=}$. The correlations of total fungal isolates with total salts, root fungi with root salts, shoot fungi with shoot salts, total fungal isolates with the divalent/monovalent ratio of roots or shoots were also considered. Such correlations are suggested as a basis for a predictive tool for the assessment of salt content of halophytes.

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INTRODUCTION

Salt marshes are one of the most productive of all natural ecosystems (Odum 1971). The halophytic plants characteristic of these saline habitats may prove to be of some economic importance in the utilization of land which would otherwise be almost useless from an agricultural standpoint (Mudie 1974). The trophic significance of the food webs of salt marsh ecosystems is well established, with species such as Juncus, Salicornia, and Spartina contributing the greatest biomass to the detritus (Teal 1962).

While the vascular flora and ecology of salt marshes have been well studied, the role of the fungal communities is comparatively poorly known. A number of workers have compiled species lists of fungi inhabiting saline habitats (e.g., Gessner and Goos 1973a, 1973b; Pugh 1979; Kohlmeyer and Kohlmeyer 1979). The ecological role of fungi in the functioning of these ecosystems has been poorly studied.

It is known the microbial decomposition is a major cause of degradation of salt marsh detritus (Burkholder and Bornside 1957; Teal 1962), and recent studies have indicated that fungi also play an important role in detrital degrada-

tion (May 1974; Gessner 1977, 1980; Kohlmeyer and Kohlmeyer 1979). Recently Henderarto and Dickinson (1984) have suggested that salt marshes are very suitable ecosystems in which to study the microorganisms which are associated with halophytic plants.

This study was undertaken to investigate: (1) the taxonomy of fungi on six salt marsh halophytes (i.e., Atriplex patula L., Glaux maritima L., Hordeum jubatum L., Puccinellia nuttalliana (Schultes) Hitchc., Salicornia europaea agg., and Suaeda depressa (Pursh.) Wats.); (2) the fungal community structures (i.e., similarity, diversity, dominance, spatial groups and life spectra) on these six plants under control conditions; (3) differences in fungal assemblages over time on treated and untreated Salicornia europaea; (4) the relationship between fungal succession and plant growth strategies; and (5) physical and chemical (nutrient) changes in S. europaea roots and shoots and their possible influence on fungal communities.

LITERATURE REVIEW

Salt Marsh Halophytes

Salt marshes consist of plant communities occurring in saline habitats where the soil is wet or covered with water during part of the growing season (Waisel 1972). These habitats are widely distributed over the world and can be classified into various categories based on the nature of soils, type and level of the salts available in the soil, and the floral characteristics (Chapman 1960, 1974). The most fundamental division is between differentiation of coastal and inland salt marshes. The latter represent habitats in which soil salinity is related primarily to the nature of the groundwater.

Despite variation in edaphic factors, distinct community zonation is often found in salt marsh ecosystems (Ungar 1974). Salt marsh plants which are capable of tolerating 0.5% or more NaCl (Waisel 1972) are called halophytes. Various halophytic plant groups, based on degree of salt tolerance, have been recognized (Steiner 1935; Aderiani 1956; Chapman 1960; Waisel 1972). Many halophytic species are distributed in inland salt marshes of North America and Canada and are mostly dominated by graminoid, shrub and succulent plants (Chapman 1974; Ungar 1974).

Salinity and soil moisture are the major factors affecting the distribution and growth of halophytic species (S. Flowers 1934; Chapman 1960, 1974; Waisel 1972; Ungar 1974, 1978). Soil salinity values vary throughout the season according to precipitation and evaporation levels (Mahall and Park 1976; Ungar et al. 1979).

Salt marsh soils are dominated by sodium chloride, sulphate and carbonate compounds (Waisel 1972; Ungar 1970, 1974). Ungar et al. (1979) reported that the salinity gradient varies from the central to the peripherial zones, i.e., from the low marsh to the high marsh. The latter phenomenon is a feature of inland salt marshes. Annual succulent plants, e.g., Salicornia and Suaeda, often invade the central areas which have highest soil salinities, while the perennial plants, mostly grasses, occupy the lower salinity soils (Ungar 1974).

One of the most critical stages in the life cycle of halophytes is the period of seed germination. Studies by Ungar (1962, 1967, 1974, 1978), Macke and Ungar (1971), Williams and Ungar (1972) and Chapman (1974) indicated that seeds of many halophytic species germinate best under freshwater conditions. Consequently seed germination of salt marsh plants often occurs during times of high precipitation and low salt stress.

Growth of halophytes, unlike the germination of their

seeds, is usually stimulated under higher salinity conditions (Jennings 1968; T.J. Flowers et al. 1977). In salt marshes, the growth strategies of halophytic plants in relation to salinity, climatic and edaphic factors have been reviewed by Jefferies et al. (1979). Growth of these plants is often determined by the interaction of soil moisture and salinity, which are codeterminants of soil water potential (Waisel 1972).

Tiku (1976) and Ungar (1978) reported that the optimum salinity for growth of some halophytic species ranges between 1% and 2% NaCl. As the salinity exceeds this limit, the growth of most plants is considerably diminished (Williams and Ungar 1972; T.J. Flowers 1975).

Maas and Nieman (1978) reported that NaCl generally stimulates the growth of most halophytic plants. Species which are highly tolerant to NaCl may not be tolerant to another salt compound. Futhermore, plant age and growth phase may show different response to the salinity (Bernstein and Hayward 1958; Chatterton and McKel 1969).

Growth response to salinity level has been studied for many halophytic species. Ashby and Beadle (1957) observed that growth of Atriplex is enhanced by the addition of salts. They also showed that the presence of salts in the soil influences the flowering and fruiting formation of this halophyte. On the other hand, growth of perennial

halophytes such as Hordeum jubatum L. and Puccinellia nuttalliana (Schutt.) Hitch. is better in areas where salinity is low (Macke and Ungar 1971; Ungar 1974). Other studies investigating the influence of salinity on growth of various halophytic plants, including Atriplex, Salicornia and Suaeda, are: Blumenthal-Goldschmidt and Poljakoff-Mayber (1968), Ungar (1970), Gale and Poljakoff-Mayber (1970), Williams and Ungar (1972), McMahon and Ungar (1978) and Yeo and Flowers (1980).

Among all the inland salt marsh halophytes, Salicornia is considered as a typical obligate succulent halophyte (Flowers 1934; Ungar 1974). It dominates soils of high salinity. This has stimulated several researchers to investigate growth habit and salt resistance under field and experimental conditions (Hill 1908; Webb 1966; Austenfeld 1974; Chapman 1974; Tiku 1976; Grouzis et al. 1977; Jefferies et al. 1979; Ungar et al. 1979; McGraw and Ungar 1981; Cooper 1982; Pearcy and Ustin 1984).

Pomeroy (1970) considered salt marshes to be nutrient sinks in which an excess of the essential elements are available. However, it has been observed that these habitats may contain limiting amounts of particular nutrients such as nitrogenous compounds. Stewart et al. (1972, 1973) and Jefferies (1977) suggested that nitrogen availability in salt marsh soils may limit the distribution of halophytes.

Valiela and Teal (1974) and Jefferies and Perkins (1977) found that the growth of various species in salt marshes can be increased by application of nitrogenous compounds.

Waterlogging may also affect the growth and distribution of salt marsh plants (Brereton 1971). It has been observed that dry weight of some halophytic species is reduced in waterlogged soils (Cooper 1982). Also there is an increase in shoot and root yield of Salicornia europaea agg. growing on saline soils over those found in waterlogged soils.

The physiological ecology of halophytes has been extensively reviewed by Bernstein and Hayward (1958), Waisel (1972), and Maas and Nieman (1978). Kuramoto and Brest (1979) studied the photosynthesis of different halophytic species under various salinity levels and specific ion concentrations. They reported that succulent halophytes possess the C_3 pathway for carbon fixation, while the halophytic grasses utilize the C_4 pathway. They also concluded that photosynthetic rate of grasses was lower than succulents growing under high salinities. Another study (Tiku 1976) showed that additions of NaCl induces the uptake of CO_2 by succulents and inhibits it in grasses.

Since halophytes are naturally selected to live in saline environments, they have a number of unique morphological and structural characteristics (Waisel 1972). These

adaptations include smaller leaves, fewer stomata, increased succulence, thickening of leaf surfaces, and reduced vascular systems, which vary from one plant to another (Poljakoff-Mayber 1975; Maas and Nieman 1978).

Salt stress may cause an increase in specific ion levels within the plant tissues. Halophytic plants are distinguished into two categories: halophytic species which are able to regulate the amount of internal salts (by salt glands, salt leaching, guttation, shedding of leaves, or by increase in succulence) and those plants which accumulate salts continuously throughout their life cycles (Waisel 1972; Albert 1975).

Greenway (1962) stated that ion accumulation by halophytes is a response to the saline environment. Ion uptake by halophytic plants has been intensively discussed by Waisel (1972) and T.J. Flowers (1975), who stated that halophytes have the ability to accumulate massive amounts of ions when exposed to high salinities. It has been shown that the most commonly encountered ions in these plant tissues are Na^+ and Cl^-.

Austenfeld (1976) reported that cation absorption by halophytes is often balanced by the uptake of anions, particularly Cl^- ion. He observed that there were high concentrations of both Na^+ and Cl^- ions within the shoots of Salicornia europaea growing under high salinity levels.

Other ions, such as K^+, were low. These findings were also supported by T.J. Flowers (1975), Riehl and Ungar (1982) and Cooper (1982).

Little information has been reported on the effects of various cations and anions on the uptake of Na^+ and other ions by halophytic plants. Black (1960) studied the internal salt levels of Atriplex leaves. He suggested that there is an antagonistic effect involved in the Na^+ and K^+ ions uptake by this halophyte. Such a mechanism is also described by Waisel (1972).

Recently much attention has been given to the ion uptake processes and salt levels in halophytic plant tissues and their roles in the osmotic adjustment of plant cells to salt-stress conditions (Stewart et al. 1972; Stewart and Lee 1974; T.J. Flowers 1975; T.J. Flowers and Hall 1978; Storey and Wyn Jones 1979; Jefferies et al. 1979a, 1979b; Cooper 1982; Riehl and Ungar 1982; Briens and Larher 1982; Bennert and Schmidt 1984).

In order to survive in saline habitats, halophytic plant cells must maintain an internal osmotic potential lower than the external medium (Epstein 1969). These plants therefore possess an osmoregulatory system to control salt uptake and regulate their levels within the tissues. Jefferies (1981) and others (e.g., Stewart and Lee 1974; Stewart and Boggess 1978; Triechel 1975, 1979; Cavalieri

and Huang 1979; Sing and Rai 1981; Boucard and Billard 1981; Buhl and Stewart 1983) have suggested that a high accumulation of salts is accompanied by the formation of highly soluble organic compounds such as polyols and amino acids inside the cells. These serve as compatible osmotica to achieve salt regulation in these plants.

Salt Marsh Fungi

The pioneering work on the soil fungi in salt marshes was carried out by Bayliss-Elliot (1930). Nevertheless, relatively little information is available on these fungi compared with the mycoflora of other ecosystems, although fungi have been isolated from rhizospheres in salt marshes (Pugh 1960, 1962, 1963, 1974; Pugh and Beeftink 1980). Pugh (1960) categorized salt marsh soil fungi into two main groups: salt marsh inhabitants and salt marsh transients. He also reported that rhizosphere fungi of salt marsh plants are usually affected by waterlogging of the soils.

The vast majority of information available on salt marsh fungi is limited to examination of rhizospheres of dead and living plants. Apinis and Chesters (1964) studied the Ascomycetes on senescent and dead parts of several grasses, including Agropyron, Puccinellia and Spartina. Dickinson (1965) reported that the mycoflora of Halimione

portulacoides can be categorized into three groups: species present on the leaf surfaces as deposited propagules, those species which are actively growing and sporulating on the leaf surface, and fungi which grow vegetatively on living leaves and produce fruiting bodies after the leaf becomes moribund. Dickinson and Pugh (1965) examined the fungi associated with Halimione portulacoides (L.) Aellen during various plant growth stages. They observed that the two fungal species Dendryphiella salina (Sutherland) Pugh et Nicot and Ascochytula obions (Jaap) Diedicke were dominant on root surfaces. The seedling roots rendered mainly sporulating forms, while the mature plants were colonized by sterile hyaline forms. They also discussed the seasonal fluctuation of the fungi on this plant. A study of Pugh and Williams (1968) on fungi of living and dead Salsola kali L. showed that the aerial parts of the plants were colonized by dark-pigmented fungi, while light-colored forms were usually observed on the roots. Furthermore, the mature and decaying plants rendered a greater number of fungal isolations than the seedlings. The mycoflora of rhizosphere of healthy and dead Spartina townsendii H. et J. Groves were studied by Sivanesan and Manners (1970), and the possible role of fungi in die-back of this plant was suggested by Goodman (1959). Recently, the rhizosphere fungi of various plant roots, including those of Halimione, Puccinellia, Salicornia, Spartina and Suaeda, were studied by Henderarto

and Dickinson (1984).

Few ecological studies have been made on fungi of salt marsh plants. Gessner (1977) studied the seasonal occurrence and distribution of fungi on the aerial parts of Spartina alterniflora Loisel in Rhode Island, U.S.A. He observed that marine species occurred on the submerged parts while exposed parts were inhabited by terrestrial forms. Furthermore, Deuteromycetes such as Alternaria alternata (Fr.) Keissler were most frequently isolated from late growth stages and particularly during seed set. He also suggested that fungal succession on S. alterniflora is a seasonal phenomenon rather than a replacement of one fungal species by another.

Since the majority of studies of fungi on salt marsh plants have been carried out in England and the United States, limited information on the geographical distribution of these organisms is available (Kohlmeyer and Kohlmeyer 1979).

The role which fungi play in a salt marsh ecosystem is poorly understood. Possible degradation of salt marsh plants by fungi has been suggested (Meyers et al. 1970; May 1974; Kohlmeyer and Kohlmeyer 1979; Pugh 1979). Gessner (1980) examined the degradative enzymatic activity of various fungal species isolated from Spartina alterniflora. He observed that various enzymes (such as Cχ-cellulase and β-

glucosidase) were produced by salt marsh fungi.

The growth of fungi in saline environments in relation to salinity has been investigated by, for example, T.W. Johnson and Sparrow (1961) and Jones and Byrne (1976). Jones (1976) reported that the biological activities of the fungi inhabiting saline environments are often influenced by salinity, and that the growth of fungi under saline conditions may vary from one species to another. Jones and Jennings (1964) examined the growth of several marine and non-marine species. They found that species of marine origin have a higher growth rate than non-marine forms when salinity levels are high. Specific ion effects on growth of some fungi, particularly Dendryphiella salina, have been also conducted (Jones and Jennings 1965; Allaway and Jennings 1970, 1971). These studies suggested that Na^+ concentration is the most important determinant of growth in this fungus. Effects of salinity on growth of some fungi isolated from salt marsh plants have also been undertaken (Gessner 1976; Crabtree and Gessner 1982).

CHAPTER 1

FUNGI ASSOCIATED WITH HALOPHYTES FROM DELTA MARSH, MANITOBA

INTRODUCTION

Inland salt marshes, like their maritime counterparts, are among the most productive habitats in nature (Odum 1971; Chapman 1974). Various transitional vegetation types can be recognized (e.g., Zosteretum, Salicornietum, Spartinetum, Puccinellitum, Asteretium, Halimonionetum, Festucetum, Plantoginetum, Juncetum, Scizpetum, Phragmitetum) along salinity or alkalinity and moisture gradients. The principal genera in these associations include leafy annuals (i.e., Artemisia, Atriplex, Chenopodium, Halimione, Monolepis, Myrosurus, Plantago, Rumex, Spergularia), lanceolate-leaved annuals (i.e., Kochia, Salicornia, Salsola, Suaeda) and several perennials (i.e., Agropyron, Carex, Distichlis, Eleocharis, Glyceria, Hordeum, Juncus, Phragmitis, Puccinellia, Ruppia, Schedomordus, Scolochloa, Spartina, Triglochin, Zannichellia).

Broadly generalized, the associations are considered to represent the "low marsh" (Salicornietum, early Asteretum), replaced by the "high marsh" supplanted by the highest marsh (Juncetum) and giving way to the salt pasture during succession from wet lands to dry lands (Hepburn 1966).

The concepts of "low marsh", "high marsh" and plant succession have been utilized in previous mycological studies, and some workers have shown that halophytes support diverse groups of fungi (Hudson and Webster 1958; Pugh 1960, 1961, 1962, 1963, 1974, 1979; Apinis and Chesters 1964; Dickinson 1965; Dickinson and Pugh 1965a, 1965b; Pugh and Dickinson 1965; Dickinson and Morgan-Jones 1966; Pugh and Williams 1968; Sivanesan and Manners 1970; Gessner et al. 1972; Holownia 1972; Gessner and Goos 1973a, 1973b; Dickinson and Preece 1976; Gessner and Kohlmeyer 1976; Kohlmeyer and Gessner 1976; Lindsey and Pugh 1976; Gessner 1977, 1978; Gessner and Lamore 1978; van der Aa and van Kestern 1979; Miller 1979; Pugh and Beeftink 1980; Henderarto and Dickinson 1984) such as rhizosphere, cauloplane and phyloplane entities. The vast majority of information is on fungi in the rhizosphere of a few plants (i.e., Agropyron, Halimione, Puccinellia, Salicornia, Salsola, Spartina and Suaeda), and data on fungi of the rhizoplane and phyloplane are limited.

This study considers fungi on six inland salt marsh halophytes (i.e., Atriplex patula L., Glaux maritima L., Hordeum jubatum L., Puccinellia nuttalliana (Schutt.) Hitch., Salicornia europaea agg., Suaeda depressa (Pursh) Wats.). Our principal aim is to taxonomically document the fungi as a precussor to a series of ecological studies.

METHODS AND MATERIALS

Collections of the plants, from two sites at the University of Manitoba Field Station (Delta, Manitoba), occurred at two-week intervals during the summers of 1982 and 1983. Upon collection the samples were immediately processed for cauloplane and rhizoplane fungi by a washing technique (Harley and Waid 1955). Root and shoot pieces, cut into 2- to 4-mm lengths and mixed thoroughly, were washed in 20 changes of sterile distilled water. Washing took place in Sartorius plastic filter apparatus as contamination was effectively reduced by asceptic addition and draining of water. The washed pieces were plated on OAES medium (Tuite 1969) in lots of five per plate to a total of 15 root fragments and 15 shoot fragments for each collection. Following plating and incubation at 20±1 C^{o}, the pieces were surveyed for developing fungi. Also at each collection date larger root and shoot pieces, 1.5 to 2.0 cm long, were washed in 20 changes of sterile distilled water, dried for 24 hours at room temperature, and plated on sterile moistened filter paper. During the incubation period at 20±1 C^{o}, the pieces were repeatedly surveyed for developing fungi. Permanent slides and dried cultures are deposited in the laboratory of Dr. T. Booth at the Department of Botany, University of Manitoba.

RESULTS AND DISCUSSION

1. Acremonium furcatum F. et V. Moreau ex Gams. Nova Hedwigia, 18:30. 1970.

CONIDIA: hyaline; oval; 3.5-(4.7±0.6)-5.5 x 2.5-(3.2± 0.5)-3.5 um; smooth (Fig. 1-1); produced in slimy heads (Fig. 1-6) on phialides. PHIALIDES (Figs. 1-1,5): hyaline; cylindrical; 21-32 um long; smooth; straight or slightly curved. HYPHAE: hyaline; smooth; usually in bundles (Fig. 1-6). COLONIES: colorless at the beginning and turning pale to yellow.

ISOLATES EXAMINED: on OAES plated Salicornia europaea seedling pieces. SLIDE: SMHF 103.

In the past this taxon was possibly referred to as Cephalosporium (Pugh 1960). This genus is now considered synonymous with Acremonium (Domsch et al. 1980). Our isolate is morphologically similar to A. breve (Skup. et Thirum.) Gams, which was previously reported on Salicornia (Booth et al. unpublished data), and A. murorum (Corda) Gams. Acremonium furcatum, unlike A. breve, has hyphal bundles and the conidia are hyaline and chromophilic. Furthermore, the conidia of our material are smooth-walled and those of A. murorum are verrucose. Acremonium furcatum has been previously isolated from alkaline soils (Gams 1971; Domsch et al. 1980), and this is the first report of this fungus on

Salicornia europaea (Pref. seedlings).

2. Alternaria alternata (Fr.) Keissler. Beih, Bot. Zbl. 29:434. 1912.

CONIDA: golden brown to dark brown; variable in shape (ovate, obovate or subclavate) (Figs. 1-2,8,9); 12-(30.6± 8.4)-42 x 7-(11.3±2.3)-17.5 um; mostly verrucose (Fig. 1-9) (infrequently smooth); one to six (two to four) transverse septa, zero to three longitudinal septa; beaks short, 3.7 x 2.5-3.5 um. CONIDIOPHORES: pale brown; 10-87 (21-38) x 3.5-5.0 um; smooth, straight or flexous; arising singly or in groups (Figs. 1-2,7). COLONIES: dark olivacious to dark brown.

ISOLATES EXAMINED: on OAES and filter paper plated of live and moribund roots and shoots of Atriplex patula, Glaux maritima, Hordeum jubatum, Puccinellia nuttalliana, Salicornia europaea and Suaeda depressa. SLIDES: SMHF 105, 106, 107, 108. CULTURES: CSMHF 201.

This taxon is similar to Alternaria tenuissima (Kunze ex Perse.) Wilttshire which, contrary to A. alternata, produces relatively long beaked, smooth conidia in short chains (Ellis 1971b). Our material is also conspecific with A. salicornia Reidle and Ershad which was described on dead Salicornia (Reidle and Ershad 1977). The conidia of this fungus are 25-35 x 5-6.5 um and are well within the reported

ranges of A. alternata. Also, as in another study (Giha 1973), we observed pronounced conidial size and shape variation in isolates of A. alternata from different plants. This along with other similarities suggests that perhaps A. salicorniae is synonymous with A. alternata.

Previous reports of A. alternata on salt marsh halophytes include various plants, i.e., Agropyron repens (L.) Beauv. (Hudson and Webster 1958), Halimione portulacoides (L.) Aellen (Dickinson and Pugh 1965a), Salsola kali L. (Pugh and Williams 1968), Spartina alterniflora Loisel (Gessner and Goos 1973a, 1973b; Gessner 1977, 1978) and S. townsendii H. et J. Groves (Sivanesan and Manners 1970).

Although A. alternata is previously reported from Salicornia (Reidle and Ershad 1977, as A. salicorniae), these are the first reports of this fungus on Atriplex patula, Glaux maritima, Hordeum jubatum, Puccinellia nuttalliana and Suaeda depressa.

3. Alternaria chlamydospora Mouchacca. Mycopath. Mycol. appl. 50:217-222. 1973.

CONIDIA: brown to dark brown; subspherical, oboval or irregular (Figs. 1-3,10 to 13); 17-(38±13.2)-55 x (20.4± 7.1)-35 um; smooth; immature conidia having a few cells (Fig. 1-13) and becoming multicellular later (Figs. 1-10 to 12); constructed at septa (Fig. 1-3); several transverse, longi-

tudinal and oblique septa (Fig. 1-3); beak absent (Fig. 1-11) or short (Figs. 1-12,13). CONIDIOPHORES: hyaline; 7-32 x 3.5-5 um. COLONIES: brown to dark brown, effuse.

ISOLATES EXAMINED: on OAES and filter paper plated pieces of mature live to standing dead Salicornia europaea. SLIDES: SMHF 110, 116, 118.

The production of large and irregularly shaped, constricted conidia characterize this fungus (Mouchacca 1973). However, immature conidia may be confused with spores of Chuppia sarcinifera Deighton but the conidiogenous cells of this taxon differ from those of Alternaria chlamydospora. Generally, our isolates conformed with those previously reported (Mouchacca 1973; Ellis 1976).

Alternaria chlamydospora, most frequently isolated from moribund or dead Salicornia, is reported for the first time on this plant.

4. Alternaria citri Ellis and Pierce apud Pierce. Bot. Gaz. 33:234. 1902.

CONIDIA: pale brown to brown or dark brown; oval, subglobose or obclavate (Figs. 1-4,17,18A,18B); 27-43.8±10.4)-45 x 14-(17.9±3.9)-21 um; smooth, or verrucose (about 25%); in short chains; two to five transverse septa, one to three longitudinal septa; pale brown beak present (Fig. 1-18B), 3.5-9 x 3.5 um, or absent (Fig. 1-18A). CONIDIOPHORES: pale

brown; 21-175 (40-75) x 3-5 um; simple; smooth; straight or slightly flexous; usually with one terminal scar. COLONIES: dark brown above, black below; effuse.

Although Alternaria citri is morphologically very similar to A. radicina Meier, Drechsler et Eddy, our material most closely fits the description (Ellis 1971b) of the former on the basis of the verrucose and beaked characteristics of the conidia. This is the first report of this fungus on Salicornia and Suaeda.

5. Alternaria dennisii M.B. Ellis. Mycological pap. 125:27-29. 1971.

CONIDIA: pale brown to golden brown; cylindrical to clavate (Figs. 1-14,19,21); 17-(28.9±6.7)-50 x 5-(8.8±1.3)-14 um; minutely verrucose (Fig. 1-19) or smooth (Fig. 1-21); frequently with two to ten transverse septa and occasionally one to two longitudinal septa (Fig. 1-14); sometimes in chains of two to three conidia; abundant in culture. CONIDIOPHORES: pale brown; lateral or terminal; 9-70 (17-35) x 3-5 um; simple; straight; with one terminal scar (Figs. 1-14, 20). COLONIES: pale brown; effuse.

ISOLATES EXAMINED: one OAES and filter paper plated pieces of Suaeda depressa. SLIDES: SMHF 126, 128.

Unlike the type material of Alternaria dennisii (Ellis 1971a) and subsequent description (Ellis 1976), our isolates

produce minutely verrucose conidia. This somewhat relates our material to the Alternaria state Pleospora infectoria Fuckel which produces heavily verrucose conidia (Ellis 1971b).

Conidia of this taxon appear, unlike those of the Alternaria state of Pleospora infectoria and our fungus, as long-branched chains. When devoid of longitudinal septa, conidia of our isolates are similar in appearance with those of Dendryphiella salina (Sutherland) Pugh et Nicot. Also the reported (Pugh and Nicot 1964) size range, i.e., (20-45 x 6-9) um) of D. salina is within that of our fungus. Despite these problems, we consider the Delta Marsh material to be A. dennisii when all morphological features are considered.

This is the first report of Alternaria dennisii from Suaeda depressa.

6. Alternaria petrosilini (Neergaard ex Simmons) M.B. Ellis. More Dematiaceous Hyphomycetes. Common. Mycol. Instit. Kew, England. p. 417-418. 1976.

CONIDIA: brown to dark brown or black; clavate or cylindrical (Figs. 1-15,22 to 24); 49-(65.1±11.2)-115 x 10-(17.7±3.8)-24 um; smooth (Figs. 1-22,23) or verrucose (Fig. 1-24); slightly constricted at the septa; in short chains; 5-14 (7-11) transverse and one to three longitudinal septa;

beak short, 3-10 x 3-5 um, or absent. CONIDIOPHORES: pale brown; 21-87 x 4-6 um; smooth; with a terminal scar (Fig. 1-15). COLONIES: dark brown to black; effuse.

ISOLATES EXAMINED: on OAES plated live to dead pieces of Hordeum jubatum, Puccinellia nuttalliana and Salicornia europaea. SLIDES: SMHF 135, 140, 142.

Alternaria petrosilini most closely resembles A. triticicola Vassant Pao and A. pluriseptata (Karst. et Har.) Jorstad. A dark brown coloration and shorter beak of the conidia of our collections more closely relates them to A. petrosilini than to A. triticicola which has conidia with a considerably longer beak and light brown color. Secondly, conidia of the Delta Marsh material more closely approximate the dimensions of A. petrosilini spores than the smaller ones of A. pluriseptata.

This is the first report of A. petrosilini from halophytes.

7. Alternaria phragmospora van Emden. Acta bot. neerl. 19:393. 1970.

CONIDIA: pale brown; obclavate, obovate or cylindrical (Fig. 1-16); 17-(31±6.4)-49 x 7-(9.9±1.2)-14 um; smooth; solitary; occasionally with oil droplets; constricted at septa, two to seven (three to five) transverse septa, zero to one longitudinal septa; short beak present (Fig. 1-25A),

3.5-12 x 3.5-5 um, or absent (Fig. 1-25B). CONIDIOPHORES: hyaline; short; 9-32 (12-17) x 2.5-4 um; simple; solitary (Fig. 1-16). CHLAMYDOSPORES: pale brown; intercalary (Fig. 1-16). COLONIES: grey to pale brown above, dark brown below; effuse.

ISOLATES EXAMINED: on OAES plated live segments of Salicornia europaea. SLIDES: SMHF 145, 146, 154.

Alternaria helianthi (Hansf.) Tubaki and Nichihara and A. chrysanthemi Simmons and Crosier are morphologically similar to A. phragmospora. Conidia of our isolates are within the size range of those of A. phragmosphora, i.e., 20-50 x 6-13 um (Mouchacca 1973; Ellis 1976) and smaller than spores of A. helianthi at 45-145 x 10-30 um (Tubaki and Nishihora 1969) and A. chrysanthemi at 66-119 x 19-33 um (Simmons and Crosier 1965).

Although Alternaria phragmospora has been recently reported from the roots and leaves of various higher plants (Abdel-Hafez 1981, 1982), ours is the first report from Salicornia europaea.

8. Alternaria raphani Groves and Skolko. Can. J. Res. Sect. C. 22:227. 1944.

CONIDIA: golden brown; obclavate or subglobose (Figs. 1-26,33); 17-(33.6±7.6)-66 x 10-(14.5±3.1)-26 um; smooth; constricted at the septa; with oil droplets; three to six

transverse septa, one to three longitudinal or oblique septa; beak when present, 5-10 x 3.5 um. CONIDIOPHORES: hyaline; micro or macronematous; 9-42 (17-35) x 3.5-5 um; solitary. COLONIES: pale brown to brown; effuse.

ISOLATES EXAMINED: on OAES plated live pieces of Atriplex patula and live and moribund Salicornia europaea. SLIDES: SMHF 141.

Even though Alternaria raphani tends to demonstrate features which overlap with other described species (Ellis 1971b, 1976), we designated our material as this taxon. Alternaria chlamydospora and A. triticina Parasada and Prabhu can be confused with A. raphani. Except for the slightly longer beaks and diminished construction at the septa of the conidia of A. triticina, material of A. raphani can be incorrectly allotted to this taxon. Also young conidia of A. raphani are entirely similar with those of A. chlamydospora which necessitates seeing the mature spores of material of the previous fungus before attempting classification.

Alternaria raphani is reported from higher plants including the rhizoplane of Triticum sp. (Abdel-Hafez 1981, 1982). Ours is the first report of this fungus on marsh halophytes.

9. Alternaria tenuissima (Kunze ex Pers.) Wiltshire. Tarns. Br. Mycol. Soc. 18:157. 1933.

CONIDIA: brown; clavate to subclavate (Figs. 1-27,34); 17-(30±7.5)-57 x 7-(11.3±2.5)-19 um; smooth; in short chains; two to seven transverse septa and zero to two longitudinal septa; beak, pale brown, 5-35 (10-23) x 3.5-5 um. CONIDIOPHORES: pale brown; 10.5-98 (17.45) x 3.5 um; smooth; simple; straight, with one or more scars (Figs. 1-27,35). COLONIES: centrally dark brown to black, peripherally grey; effuse.

ISOLATES EXAMINED: on OAES plated live to dead fragments of Atriplex patula and Suaeda depressa.

Due to beak length and the smooth wall of the conidia, our isolates are more firmly related to Alternaria tenuissima than to the similar taxa A. alternata and A. longipes (Ellis and Everh.) Mason. Conidial beaks of our material are longer than those of A. alternata conidia.

Alternaria longipes spores are consistently verrucose while those of Delta Marsh are smooth-walled. Generally, our isolates are conspecific with most previous descriptions (Ellis 1971b; Domsch et al. 1980).

This taxon is a known secondary invader of different plant species (Ellis 1971b), and it has been reported from salt marsh soils (Moustafa 1975; Moustafa and Musallam 1975). Ours is the first report of Alternaria tenuissima on the surfaces of salt marsh halophytes.

10. Arthrinum phaeospermum (Corda) M.B. Ellis. Mycol.

pap. 103:8-10. 1965.

CONIDIA: pale brown to brown with a conspicuous colorless band; lenticular or flattened ellopsoidal (Figs. 1-28, 36,37); 8.5-(10.2±1.3)-11 x 5-(5.9±0.8)-7 um; smooth; usually produced in groups directly on conidiophores or on short denticles on conidiophores; single-celled. CONIDIOPHORES: hyaline; 5-17.5 x 1.5-2.5 um; smooth; simple. COLONIES: colorless becoming grey with age; effuse.

ISOLATES EXAMINED: on OAES plated live pieces of Glaux maritima, Hordeum jubatum, Puccinellia nuttalliana and Suaeda depressa. SLIDES: SMHF 120, 143.

Arthrinum saccharicola Stevenson and A. aureum Calvo and Guarro are similar to our isolates and A. phaeospermum, but the former organism has wider conidiophores than our fungus and the latter, as recently described (Calvo and Guarro 1980), has larger conidia (i.e., 10-30 x 10-15 um). The fungus described here most closely approximates material of A. phaeospermum as circumscribed by Ellis (1965).

Considered to be cosmopolitan (Ellis 1971b), Arthrinum phaeospermum is commonly assigned its synonym Papularia phaeosperma (Pers. ex Gray) Hohnel, and it has previously been reported on the salt marsh plants Spartina alterniflora (Gessner and Goos 1973b) and S. townsendii (Sivanesan and Manners 1970). We are reporting A. phaeospermum on Glaux

maritima, Hordeum jubatum, Puccinellia nuttalliana and Suaeda depressa for the first time.

11. Ascochyta chenopodii Roster. Bot. Tidsskr. 26:311. 1905.

CONIDIA: hyaline; cylindrical to ellipsoidal with rounded ends (Figs. 1-30,39); 8-(10.9±1.2)-12 x 3.5-(4.1± 0.5)-5 um; smooth; constricted at the septum; equally two-celled. PYCNIDIUM: dark brown to black; subglobose to pyriform (Fig. 1-29); 200-390 x 180-300 um; ostiolate; immersed; perdium (Figs. 1-31,38) outwardly dark and inwardly pale brown. PHIALIDES: hyaline; short; lining inner perdium wall (Figs. 1-31,38). COLONIES: white to buff to grey; rapidly growing floccose.

ISOLATES EXAMINED: on OAES and filter paper plated live to dead pieces of Atriplex patula, Salicornia europaea and Suaeda depressa. SLIDES: SMHF 117, 129, 147. CULTURES: IMI 279591, CSMHF 222.

Ascochyta salicornia P. Maganus, reported from several different species of Salicornia (Kohlmeyer and Kohlmeyer 1979), is, with exception of larger conidia (i.e., 10-19 (20) x 4-7 um), morphologically similar to our material. However, it has been judged (Sutton personal communication) that our deposited material (International Mycological Institute material No. 279591 and personal herbarium

specimen (slides SMHF 117, 129, 147; culture CSMHF 222) are most suitably assigned to A. chenopodii.

This organism was observed on various species of Chenopodium and Atriplex (van der Aa and van Kestern 1979) as the synonym Ascochyta caulina (P. Karst.) Aa and Kest. Another closely related fungus, Ascochytula obions (Jaap) Diedicke, which is possibly synonymous with Pseudodiplodia (Sutton 1977), has been reported from the salt marsh plant Halimione portulacoides (Dickinson and Morgan-Jones 1966).

We are reporting Ascochyta chenopodii from Atriplex patula, Salicornia europaea and Suaeda depressa for the first time.

12. Aureobasidium pullulans (De Bary) Arnand. Ann. Ec. Agr. Mont pellier. N.S. 16:39. 1918.

CONIDIA: hyaline; ellipsoidal to oval (Figs. 1-32,41); 3.4-7 x 2.5-3.5 um; smooth; one-celled; produced singly or in slimy masses (Fig. 1-40) either directly from the hyphae or by short projections (Fig. 1-41). CHLAMYDOSPORES: usually present in old cultures. COLONIES: slimy; colorless at the first, becoming straw-colored, brown and black in old cultures.

ISOLATES EXAMINED: on OAES plated seedling pieces of Glaux maritima and Salicornia europaea. SLIDES: SMHF 104. CULTURE: CSMHF 99.

Our isolates demonstrating the previously studied yeast-like phase (Davenport 1976), are closely associated with Aureobasidium pullulans as described by Ellis (1971b) and Domsch et al. (1980). This fungus has been recorded from various halophytes (Hudson and Webster 1958; Dickinson 1965; Last and Deighton 1965; Hudson 1968; Pugh and Williams 1968; Pugh and Buckley 1971; Lindsey 1976) and red mangrove (Rhizophora) seedlings (Newell 1976).

Commonly found on seedlings of Salicornia europaea and Suaeda depressa in our study, Aureobasidium pullulans is herein reported on these substrates for the first time.

13. Cladosporium herbarum (Pers.) Link ex S.F. Gray. Nat. Nat. Arr. Br. Pl. 1:556. 1821.

CONIDIA: pale brown or olivacious brown; ellipsoidal or oval (Figs. 1-42,43,48); 6-(11.9±3.9)-20 x 4-(6.4±0.9)-8 um; verrucose; zero to one septate; in chains; one or two scars present on ramoconidia (Fig. 1-48). CONIDIOPHORES: hyaline; 40-110 x 4-6 um; smooth; straight or flexuous; occasionally geniculated and nodose; one to three scars present on the apices (Figs. 1-42,48). COLONIES: olivacious green to dark green.

ISOLATES EXAMINED: on OAES plated pieces of Glaux maritima, Hordeum jubatum, Puccinellia nuttalliana, Salicornia europaea and Suaeda depressa. SLIDES: SMHF 107, 133. CUL-

TURE: CSMHF 217.

Our isolates show affinity with Cladosporium variable (Cooke) de Vries and C. cucumerinum Ellis and Arth. as well as C. herbarum. Verrucose, nonseptate, small conidia in long chains serve to distinguish Delta Marsh isolates as C. herbarum rather than C. cucumerinum or C. variable. Cladosporium herbarum is commonly encountered as an early colonizer of dead organic matter and plant surfaces (Ellis 1971b; Domsch et al. 1980).

Several workers have reported this fungus from salt marsh rhizosphere soils (Pugh 1960, 1962; Dickinson and Pugh 1965a; Moustafa 1975; Abdel-Fattah et al. 1977; Abdel-Hafez 1981, 1982). Cladosporium herbarum was also observed on the root surfaces of Halimione portulacoides (Dickinson and Pugh 1965a, 1965b). In our study this fungus was isolated on all of the considered halophytes excluding Atriplex patula.

14. Cladosporium oxysporum Berk. et Curt. J. Linn. Soc. 10:362. 1868.

CONIDIA: green; ellipsoidal, cylindrical or oboval (Figs. 1-45,49); 4-(18.7±5.2)-32 x 3.5-(4.3±0.8)-5.5 um; smooth; zero to one septate. CONIDIOPHORES: hyaline to pale brown; 35-300 x 3.5-5.5 um; smooth; geniculated, with swelling at intervals (Figs. 1-44,49). COLONIES: brownish; cottony to effuse.

ISOLATES EXAMINED: on OAES plated living pieces of Atriplex patula. SLIDES: SMHF 109, 132.

Cladosporium algarum Cooke and Masse, C. cucumerinum, C. oxysporum, C. spongiosum Berk. and Curt., and C. tenuissimum Cooke are all possibly conspecific with our specimen. Unlike our material with narrower, single-celled ramo-conidia, C. algarum has wider, septate ramo-conidia. Delta Marsh isolates have swellings along the conidiophore, while the same structure in C. cucumerinum has no such swellings and its ramo-conidia are larger than in our isolates. Hyphal septations of C. spongiosum are much darker than in our fungus. Conidia of C. tenuissmum, produced on long conidiophores, are lightly verrucose, and conidia of our material are smooth and produced on short, stout conidiophores. In final analysis, our organism most closely agrees with C. oxysporum as delimited by Ellis (1971b).

This is the first report of this fungus on inland salt marsh halophytes.

15. Dendryphiella arenaria Nicot. Rev. Mycol. 23:93. 1958.

CONIDIA: pale brown; ellipsoidal, cylindrical or subcylindrical (Figs. 1-47,50); 11-(17.5±2.7)-26 x 4-(5.9±0.8)-7.5 um; smooth; one to four septate; arising singly or in groups (Fig. 1-46). CONIDIOPHORES: hyaline to pale brown;

10-30 x 3.5-5 um; smooth; simple; straight or slightly flexuous (Figs. 1-46,50). COLONIES: pale brown to brown above, dark brown below; effuse.

ISOLATES EXAMINED: on OAES plated live pieces of Atriplex patula, Glaux maritima, Salicornia europaea and Suaeda depressa, and live and dead of Hordeum jubatum and Puccinellia nuttalliana. SLIDES: SMHF 108, 112, 131, 160. CULTURES: CSMHF 206, 211.

Assignment of our isolates to Dendryphiella arenaria is somewhat problematical. In the first place the genus is considered to be synonymous with Dendryphion (S.J. Hughes 1958; Barron 1968; Carmichael et al. 1980). Secondly, the species D. arenaria and its closely related counterpart, D. salina (Sutherland) Pugh et Nicot, are placed in Scolecobasidium (Ellis 1976) as S. arenarium (Sutherland) M.B. Ellis. Finally, Delta Marsh isolates overlap both "arenaria" and "salina" regarding conidium size and septation.

Various workers have chosen not to accept the synonymy of Dendryphiella with Dendryphion (Pugh and Nicot 1964; Reisinger 1968; Reisinger and Gaedenet 1968; G.C. Hughes 1975; Kohlmeyer and Kohlmeyer 1979), and we therefore follow this precedent.

As the conidiophores of our specimen do not produce on visible denticles, we are maintaining them in Dendryphiella.

(The reader may wish to consult Kohlmeyer and Kohlmeyer (1979) for a complete discussion of the situation.) Despite the overlap of the conidia of our material with D. arenaria and D. salina, the mean conidia dimensions (5.9±0.8 x 17.5± 2.7 um) and the normal number of spore septations (i.e., three) of the Delta Marsh fungus concur most closely with D. arenaria. This fungus, frequently reported from saline environments (T.W. Johnson and Sparrow 1961; Pugh and Nicot 1964; Kohlmeyer and Kohlmeyer 1979), is known from various salt marsh halophytes (Gessner and Goos 1973b; Kohlmeyer and Kohlmeyer 1979). Our specimens represent the first report of Dendryphiella arenaria on the cauloplane and rhizoplane of halophytes of this study.

16. Drechslera halodes (Drechsler) Subram. and Jain. Curr. Sci. 35:354. 1966.

CONIDIA: pale brown to golden brown; broadly fusiform, ellipsoidal or cylindrical (Figs. 1-51,59,60); 35-(65±12.0)-87 x 14-(17.2±1.9)-19 um; smooth; hilum black and conspicuous; 4-10 pseudosepta; apical cell lighter than the other cells in color, and separated by dark septa; straight or somewhat curved (Fig. 1-51). CONIDIOPHORES: pale brown to brown; up to 200 um long, 4-7 um thick (Figs. 1-51,58).

ISOLATES EXAMINED: on OAES and filter paper plated pieces of standing dead Glaux maritima, Hordeum jubatum,

Puccinellia nuttalliana and Suaeda depressa. SLIDES: SMHF 215, 221.

Isolates in our study are related to Drechslera halodes, D. miyake (Nisikado) Subram. and Jain and the Drechslera state of Cochliobolus bicolor Pual and Parbery. Conidia of Delta Marsh isolates, like those of D. halodes, are wider (14-19 um) than spores of D. miyake. Also the conidia are dark, while they are lighter in D. miyake. Conidia of the Drechsler state of C. bicolor have an elliptical shape and flattened attachment scars rather than more generally broad fusiform spores with distinctly protuberant attachement scars of D. halodes and our specimens. Our material is most closely related to that described by Shoemaker (1962), Ellis (1971b) and Kohlmeyer and Kohlmeyer (1979). Despite the suggestion of D. halodes as a synonym of Exserohilum rostratum (Drechsler) Leonard and Suggs. (Leonard 1976), we are maintaining the taxa.

This fungus has been reported on the aerial parts of Spartina alterniflora (Gessner 1977), but ours are the first reports from Glaux maritima, Hordeum jubatum, Puccinellia nuttalliana and Suaeda depressa.

17. Epicoccum purpurascens Ehrenb. ex Schlecht. Synop. Pl. Crypt. 136. 1824.

CONIDIA: dark brown; globose to subglobose (Figs. 1-52,

61); 10.5-(16.4±2.3)-28 um in diameter; rough, reticulated walls, with short conspicuous protoburances at the bases (at the point of the attachment with conidiophores). CONIDIOPHORES: pale brown or hyaline; short; 3.5-10.5 x 2.5-3.5 um; smooth; simple. COLONIES: grey or yellow-orange above, dark orange below; sporodochia present in culture.

ISOLATES EXAMINED: on OAES plated pieces of Salicornia europaea. SLIDES: SMHF 119, 127, 136. CULTURES: CSMHF 232, 237.

Morphological characteristics of our specimens are similar to Epicoccum purpurascens as previously reported (Ellis 1971b; Matsushima 1975).

Epicoccum purpurascens, considered a secondary invader of plant tissues (Domsch et al. 1980), is reported from salt marsh soils (Schol-Schwarz 1959; Abdel-Fattah et al. 1977) and various halophytes (Pugh and Williams 1968) including: (1) Salicornia sp. (Kohlmeyer and Kohlmeyer 1979) and (2) Spartina alterniflora (Gessner and Kohlmeyer 1976; Gessner 1978).

18. Fusarium moniliforme Sheldon. Rep. Neb. Agric. Exp. Stn. 17:23-32. 1904.

CONIDIA: microconidia hyaline; suboval to subellipsoidal (Figs. 1-53,63); 5-10 x 1.5-2.5 um; smooth with slightly flattened bases; occasionally with one septum; produced in

chains on phialides; very abundant; macroconidia absent. PHIALIDES: hyaline; cylindrical; 20-30 x 3-3.5 um; smooth; single or in groups (Figs. 1-53,62). COLONIES: white or peach above, violet below, rapid growth with a powdery appearance.

ISOLATES EXAMINED: on OAES plated root and shoot pieces of Atriplex patula and Suaeda depressa. SLIDES: SMHF 151, 157. CULTURES: IMI 287792, CSMHF 241.

Morphological features of our isolates comply with Fusarium moniliforme (C. Booth personal communication). This is particularly so as microconidia are produced in chains as previously described (C. Booth 1971).

This taxon was reported from salt marsh soils and the rhizosphere of various plant species (Moubasher et al. 1984). During my study, it appeared most abundantly on sodium nitrate-treated Atriplex patula (unpublished data). These are the first reports of Fusarium moniliforme on A. patula, Salicornia europaea and Suaeda depressa.

19. Fusarium tricinctum (Corda) Sacc. Sylloge Fung. 4: 700. 1886.

CONIDIA: macroconidia hyaline; fusiform (Figs. 1-54,65); 28-40 (35) x 3-5 um; smooth; curved; abundant; produced from phialidic cells (Figs. 1-54,64); three to four septate (Fig. 1-65); microconidia hyaline; abovoid; 9-12 x 3-5 um; smooth;

one-celled; sparsely produced. CONIDIOPHORES: single or in groups; simple; short; terminated with one to three phialidic cells. PHIALIDES: cylindrical; short; smooth (Fig. 1-54). CHLAMYDOSPORES: present in old cultures. COLONIES: pink to red above, dark red below; growing rapidly on OAES medium.

ISOLATES EXAMINED: on OAES plated live to dead segments of Atriplex patula, Glaux maritima, Hordeum jubatum, Puccinellia nuttalliana, Salicornia europaea and Suaeda depressa. SLIDES: SMHF 156, 160. CULTURES: IMI 287793, CSMHF 240.

Initially we considered our specimens to be Fusarium culmorum (W.G. Smith) Sacc., but they were subsequently identified to be F. tricinctum at the Commonwealth Mycological Institute (C. Booth personal communication). Subsequently, we observed sparse production of microconidia.

Although this taxon may be among the Fusarium spp. commonly reported from salt marsh plants (Dickinson 1965; Pugh and Williams 1968; Gessner and Goos 1973a, 1973b; Lindsey and Pugh 1976), this is the first definite report of F. tricinctum on halophytes.

20. Gliocladium roseum Bain. Bull. Soc. Mycol. Fr. 23: 111-112. 1907.

CONIDIA: hyaline or pinkish; ellipsoidal or subovate (Fig. 1-55); 5-8 x 3-4 um; smooth; produced in slimy masses from the phialidic cells. PHIALIDES: hyaline; 15-25 x 2.5-

3.5 um; in whorles of 3-5; verticellate (Fig. 1-66) or penicillate (Fig. 1-67); smooth. COLONIES: whitish pink to salmon; sclerotium-like structures produced in old cultures.

ISOLATES EXAMINED: on OAES plated seedling pieces of Glaux maritima and Salicornia europaea. SLIDES: SMHF 139. CULTURE: CSMHF 218.

The hyaline or pinkish conidia produced on verticellate or penicillate conidiophores relate our specimens to Gliocladium roseum rather than Verticillium intertextum Isaac and Davies with verticellate phialidic arrangement only, and G. catenulatum Gilm and Abbott with greenish conidia. Our material most closely conforms to that reported by Isaac (1954), Barron (1968) and von Arx (1970). The conidia are symmetrical rather than asymmetrical as previously reported (Domsch et al. 1980).

Common in the rhizosphere of Salicornia, Spartina, Suaeda and Halimione (Pugh 1962, 1963; Dickinson 1965; Henderarto and Dickinson 1984), this is the first report of Gliocladium roseum in the rhizosplane and cauloplane of halophytes.

21. Monodictys pelagica (Johnson) E.B.G. Jones. Trans. Br. Mycol. Soc. 46:138. 1963.

CONIDIA: pale brown to brown; spherical to subspherical or pyriform (Figs. 1-56,68,69); 14-25 (18-21) x 11-22 um;

smooth; constricted at the septa; irregularly septate; aleuriospores on short conidiophores (Fig. 1-69) or sessile (Fig. 1-69). CONIDIOPHORES: hyaline to pale brown; micronematous; simple. COLONIES: grey to pale brown.

ISOLATES EXAMINED: on OAES plated pieces of live Salicornia europaea. SLIDES: SMHF 102, 111.

Careful examination of the conidiogenous cells of our isolates relates them to Monodictys pelagica rather than Chuppia sarcinifera Deighton with intercalary, sessile conidiophores (Deighton 1965). Conidia of the Delta Marsh material are smooth-walled and distinctly different from the verrucose conidia (sensu S.J. Hughes 1958) of M. castaneae (Wallr.) Hughes, a fungus morphologically similar to M. pelagica. Among our isolates conididal size agrees closely with material reported by Ellis (1971b) but is smaller than described by Kohlmeyer and Kohlmeyer (1979).

Monodictys pelagica is known from salt marsh halophytes (Gessner and Goos 1973a, 1973b; Davidson 1974), and it is widely distributed in marine environments (Kohlmeyer and Kohlmeyer 1979). Our isolations on Salicornia europaea were particularly high from plants treated with sea salt (see Chapter 3 of this dissertation).

22. Mucor hiemalis Wehmer. Ann. Mycol. 1:39. 1903.

SPORANGIOSPORES: hyaline; ellipsoidal (Figs. 1-57,71);

5-7 x 2.5-4.5 um; smooth. SPORANGIA: golden brown to brown; globose; 45-75 um in diameter; with a colorless or yellowish subglobose columella (Fig. 1-70); 20-28 um in diameter. SPORANGIOPHORES: yellowish; up to 15 um in diameter; sympodially or irregularly branched; smooth. COLONIES: greyish to yellowish brown or buff.

ISOLATES EXAMINED: on OAES plated pieces of Atriplex patula, Glaux maritima, Hordeum jubatum, Puccinellia nuttalliana, Salicornia europaea and Suaeda depressa. SLIDES: SMHF 155. CULTURE: CSHMF 227.

Our material is similar to previously reported Mucor hiemalis (Zycha et al. 1969; Mehrotra et al. 1972; Schipper 1978). This fungus is known from the rhizosphere of salt marsh plants (Pugh 1962; Pugh and Beeftink 1980); the rhizoplane of Salicornia stricta agg. (Pugh 1960); living Spartina townsendii (Sivanesan and Manners 1970) and decomposing S. alterniflora (Gessner and Goos 1973a, 1973b). In our collections Mucor hiemalis, which grows well in sea water of up to 20% to full strength (Jones and Byrne 1976), occurred most frequently on Atriplex patula and Glaux maritima.

23. Nais inornata Kohlm. Nova Hedwigia. 4:409. 1962.

PERITHECIA: dark brown to black; subglobose with a short neck, ostiolate; 210-260 x 190-230 um; immersed beneath the plant epidermal tissue; solitary; peridium dark

brown, up to 13 um thick, easily cracking (Fig. 1-72). ASCI: unitunicate (Figs. 1-72,73,83); thin-walled, apically thickened (Figs. 1-73,84); broadly ovoid; eight-spored (Figs. 1-72,73). ASCOSPORES: hyaline; ellipsoidal; 20-25 x 7-11 um; smooth; one septate; constricted at the septum, with a single oil globule in each cell; without appendages (Fig. 1-85).

ISOLATES EXAMINED: on filter paper plated pieces of standing dead Salicornia europaea. SLIDE: SMHF 230.

With exception of the wider spore and the thick-walled acsus tip, our material generally agrees with the type (Kohlmeyer 1962) and subsequent description (Shearer and Crane 1978; Kohlmeyer and Kohlmeyer 1979) of Nais inornata. As previously stated (T. Booth 1981), it is possible to confuse N. inornata with Aniptodera chesapeakensis Shearer and Miller and Lignicola leavis Hohnk. Unlike A. chesapeakensis (Shearer and Miller 1977), our collections have darkly colored perithecia, asci without subapical constrictions and ascospores with marked constriction at the septum.

Nais inornata is found on Spartina alterniflora (Gessner et al. 1972; Gessner and Goos 1973a, 1973b), Juncus spp. (Davidson 1974; Shearer and Crane 1978) and Phragmitis australis (Cav.) Trin. ex Stendel (Schmidt 1974). Ours is the first report on Salicornia europaea.

24. Papulaspora halima Anastasiou. Nova Hedwigia. 6: 266. 1963.

PAPULOSPORES: golden to yellowish brown; globose to subglobose (Figs. 1-74,86); 80-410 um in diameter; directly arising from the hyphae or on lateral short branches; central cells yellowish brown; subglobose. CONIDIA AND CONIDIOPHORES: absent. COLONIES: yellowish brown to brown.

ISOLATES EXAMINED: on OAES plated seedling pieces of Salicornia europaea. SLIDES: SMHF 113, 137.

Our isolates seem to fall within the parameters of Kohlmeyer and Kohlmeyer (1979) for Papulaspora halima. The papulaspores, bulbils as previously described (Hoston 1917; Wersub and LeClair 1971), fall within the size limits of P. halima but are lighter-colored than originally described (Anastasiou 1963).

Despite the doubtful taxonomic disposition of this fungus (Wersub and LeClair 1971; Kohlmeyer and Kohlmeyer 1979), we consider our isolate to be adequately circumscribed until perfect stages are encountered.

Although this form has not been reported from salt marsh halophytes, it is known from seedlings of Rhizophora mangle L. (Newell 1976).

25. Phoma glomerata (Corda) Wollen. and Hochapf. Z.

Parasitenk. 8:561. 1936.

PYCNIDIA: brown to dark brown; subglobose to obpyriform (Figs. 1-75,88); 130-210 x 100-180 um. CONIDIA: hyaline, becoming light green later; ellipsoidal (Figs. 1-75,87); 6-10 x 2.5-3.8 um; smooth, one-celled, sliming from the pycnidium. COLONIES: brown to dark brown; rapidly growing.

ISOLATES EXAMINED: on OAES plated segments of Atriplex patula, Glaux maritima, Hordeum jubatum, Puccinellia nuttalliana, Salicornia europaea and Suaeda depressa. SLIDES: SMHF 100, 101. CULTURES: IMI 287794, CSMHF 205.

Our isolates were considered to have strong affinity with Phoma suaeda Jaap as the pycnidial and spore dimensions, as well as other features, closely approximated previous descriptions (Pirozynksi and Morgan-Jones 1968; Kohlmeyer and Kohlmeyer 1979). However, an isolate (IMI 287794) of the Delta Marsh material was designated as P. glomerata (Punithalingam personal communication), and we comply with the identification.

Species of Phoma are frequently reported from salt marsh soils (Pugh 1960, 1962) and halophytes, i.e., Chenopodium sp. (van der Aa and van Kestern 1979); Halimione portulacoides (Dickinson and Pugh 1965b); Salicornia sp. (Gessner and Lamore 1978; Kohlmeyer and Kohlmeyer 1979) and Spartina alterniflora (Gessner and Goos 1973a, 1973b; Gessner and

Kohlmeyer 1976). This wide range of substrates along with our observations of this fungus on Atriplex patula, Glaux maritima, Hordeum jubatum, Puccinellia nuttalliana and Suaeda depressa suggests that its substrate specificity is low.

26. Pleospora herbarum (Pers. ex Fr.) Rabenh. Syn. vid. E.E. Muller. 277. 1951.

PSEUDOPERITHECIA: dark brown to black; depressed-globose to subglobose; 230-300 um in diameter; solitary; ostiolate. ASCI: bitunicate (Figs. 1-76,89); cylindrical to subclavate (Fig. 1-76); 140-190 x 20-30 um; thick-walled; no apical apparatus; eight-spored; rounded tips (Fig. 1-89). ASCOSPORES: yellow-brown; ellipsoidal to subellipsoidal (Figs. 1-76,89,90); 20-35 x 15-22 um; smooth; biserrate; five to seven transverse and one to two longitudinal septa; usually constricted at the middle septum, no appendages or surrounding sheath. PSEUDOPARAPHYSIS: cylindrical.

ISOLATES EXAMINED: on filter paper plated of dead Salicornia europaea. SLIDES: SMHF 241, 340, 341.

Despite various treatments of the genus Pleospora (Wiltshire 1938; Muller 1951; Munk 1957; Wehmeyer 1961; Dennis 1968; Simmons 1969; von Arx and Muller 1975), taxonomic deposition of our collections is somewhat tentative. Except for the lack of a gelatinous sheath and appendages, our material would be circumscribed by P. gaudefroyi

Patouillard as described from Salicornia ambigua Michx. (Kohlmeyer and Kohlmeyer 1979). Lack of a sheath around spores of our specimens also separates them from P. pelvetiae Sutherland. Generally the Delta Marsh collections can be identified as P. herbarum. Matsushima (1975), however, clouds the issue by recognizing the presence of a gelatinous sheath around spores of P. herbarum. Perhaps the presence of Stemphylium botryosum Wallr., the anamorph of P. herbarum, in our collections supports our taxonomic decision for the material.

This fungus may have been reported as various synonyms of Pleospora gaudefroyi on Salicornia spp. (Kohlmeyer and Kohlmeyer 1979). Perhaps ours is the first definite report of P. herbarum on Salicornia europaea.

27. Pleospora spartinae (Webster and Lucas) Apinis and Chesters. Trans. Br. Mycol. Soc. 47:432. 1964.

ASCOCARPS: dark brown to black; globose to subglobose; 240-310 um in diameter; ostiolate; immersed beneath the epidermal tissue of the plant stem. ASCI: bitunicate, cylindrical (Figs. 1-77,91,92); 90-170 x 13-32 um; no apical apparatus observed; rounded tips; eight-spored. ASCOSPORES: ellipsoidal or boat-shaped (Figs. 1-77,91); 20-33 x 11-14 um; smooth; three to four transverse septa; one longitudinal septum; slightly constricted at the septum; rounded ends.

ISOLATES EXAMINED: on filter paper plated pieces of standing dead Salicornia europaea. SLIDE: SMHF 250.

Delta Marsh collections are very similar to P. spartinae (Apinis and Chesters 1964) and P. vagans described by Webster and Lucas (1961) but accepted as synonymous with the former taxon (Kohlmeyer and Kohlmeyer 1979).

Pleospora spartinae is known from Spartina townsendii, and this is the first report of it on Salicornia europaea.

28. Pleospora sp.

ASCOCARPS: dark brown to black; subglobose to globose; 285-320 x 270-350 um; ostiolate; immersed; peridium dark brown; to 20 um thick. ASCI: bitunicate; clavate or subclavate (Figs. 1-78,93); 120-185 x 24-32 um; with a gelatinous cap-like structure on the top of the ascus (Fig. 1-94); short stalks; eight-spored. ASCOSPORES: golden brown; ellipsoidal (Figs. 1-78,95); 30-40 x 15-20 um; biserrate with obtuse ends; muriform; seven to nine transverse septa; one to three longitudinal or oblique septa; surrounded by a thick gelatinous sheath (up to 7 um) (Fig. 1-95); no appendages. PSEUDOPARAPHYSIS: filamentous; simple.

ISOLATES EXAMINED: on filter paper plated pieces of standing dead Salicornia europaea. SLIDE: SMHF 245.

Our collections are morphologically similar to Pleospora

pelagica Johnson. However, Delta Marsh collections are represented by shorter and wider sheathed ascospores, and the ascus tip is uniquely capped as previously described (T.W. Johnson 1956). Pleospora pelvetiae, with a deliquiescing spores sheath (Kohlmeyer 1973), differs with shorter asci and thinner ascospores (sensu T.W. Johnson and Sparrow 1961). An as yet unnamed Pleospora sp. (Kohlmeyer and Kohlmeyer 1979) described from Salicornia virgina L. seems to most closely comply with our material. This is the first report of the taxon from Salicornia europaea.

29. Scytalidium lignicola Pesante. Annali. Sper. Agr. N.S. 11:264-265. 1957.

ARTHROCONIDIA: hyaline, pale brown to dark brown; cylindrical or subcylindrical (Figs. 1-79,96,97); 5-12 x 3-7 um (when hyaline) or 7-15 x 4-9 um (when dark); smooth; normally aseptate or infrequently once septate.

ISOLATES EXAMINED: on OAES plated root pieces of Puccinellia nuttalliana and Salicornia europaea. SLIDES: SMHF 121, 148.

Despite the somewhat close relationship of the Scytalidium state of Hendersonula toruloidea Nattrass with our isolates, the presence of hyaline conidia confirm them to be S. lignicola.

Although the taxon is previously recorded on seedlings

of Rhizophora mangle (Newell 1976), this is its first report on a salt marsh halophyte.

30. Stemphylium botryosum Wallr. Flora Cryptogamica germaniae, Pars. Post. 300. 1833.

Telomorph: Pleospora herbarum.

CONIDIA: golden brown to brown; broadly ellipsoidal or oblong (Figs. 1-80,99); 25-(27.5±4.3)-38 x 15-(20.5±2.2)-30 um; minutely verrucose; three to four transverse septa, one to two longitudinal or oblique septa; constricted at the middle septum. CONIDIOPHORES: pale brown to dark brown near the tips; macronematous; 40-90 x 5-8 um; with swollen apices (Figs. 1-80,98); minutely verrucose or smooth; straight to somewhat flexuous; single or branched (Fig. 1-80). COLONIES: grey or pale brown; effuse.

ISOLATES EXAMINED: on OAES plated pieces of live Atriplex patula, Glaux maritima, Hordeum jubatum, Puccinellia nuttalliana, Salicornia europaea and Suaeda depressa. SLIDES: SMHF 124, 149, 153.

Our isolates are related to Stemphylium botryosum, S. globuliferum (Vestergr.) Simmons and S. sarciniform (Cav.) Wiltsh. Stemphylium globuliferum has smaller conidia than in our material, and S. sarciniform conidia are smooth-walled. With the exception of a larger-spored circumscription (Matsushima 1975), the Delta Marsh fungus agrees

with previous descriptions of S. botryosum (Simmons 1969; Ellis 1971b; Domsch et al. 1980).

This fungus, known to be an anamorph of Pleospora herbarum (Wiltshire 1938; Simmons 1969) as previously stated, occurs in salt marsh soil (Abdel-Fattah et al. 1977). Halophytic plants are reported as a substrate for the first time.

31. Trichocladium achrasporum (Meyers and Moore) Dixon. Mycologia. 63:244. 1971.

CONIDIA: pale brown to brown; clavate to subclavte (Figs. 1-81,100); 20-38 x 9-17.5 um; smooth; solitary; occasionally two conidia are produced from a common conidiogenous cell (Figs. 1-81,100); constricted at the septa; thick-walled; the terminal cell is usually darker than the others (Fig. 1-81); straight; two to three transverse septa. CONIDIOPHORES: inconspicuous or micronematous. COLONIES: pale brown, becoming dark brown in aged cultures.

ISOLATES EXAMINED: on OAES plated root pieces of Salicornia europaea. SLIDES: SMHF 125, 134, 138.

Of the species of the genus Trichocladium as treated by S. J. Hughes (1951), Kendrick and Bhatt (1966), Dixon (1968) and Ellis (1971b), T. achrasporum and T. opacum (Corda) Hughes are morphologically similar to our fungus. The larger apical cell and constricted nature of the conidia in our

collections relate them most closely to T. achrasporum as described earlier (Meyers and Moore 1960; Shearer and Crane 1971; Kohlmeyer and Kohlmeyer 1979).

Known from Spartina alterniflora seeds (Gessner 1977), ours is the first report on Salicornia europaea.

32. Trichoderma koningii Oudem. Archs. neerl. Sci. 7:291. 1902.

CONIDIA: light green or green in masses; ellipsoidal to subcylindrical (Figs. 1-82,102); 3.5-4.4 x 1.8-2.5 um; smooth; rounded ends; produced in dry heads on the tips of the phialides. PHIALIDES: hyaline; pin or spindle-shaped (Figs. 1-82,101); 8-13 x 2.2-3.5 um; the terminal phialides longer; smooth; mostly in pairs; occasionally branched. COLONIES: bright green to dark green, rapidly growing in cultures.

ISOLATES EXAMINED: on OAES plated pieces of live to dead Atriplex patula, Salicornia europaea and Suaeda depressa. SLIDES: SMHF 159, 163. CULTURE: CSMHF 213.

Verrucose conidia produced on paired terminal conidiophores serve to distinguish our isolates from Trichoderma viride Pers. ex Gray and T. pseudokoningii Rifai respectively. Trichoderma koningii, to which our material is related, is reported from salt marsh soils (Baylis-Elliot 1930) and Spartina townsendii (Sivanesan and Manners 1970). Ours is

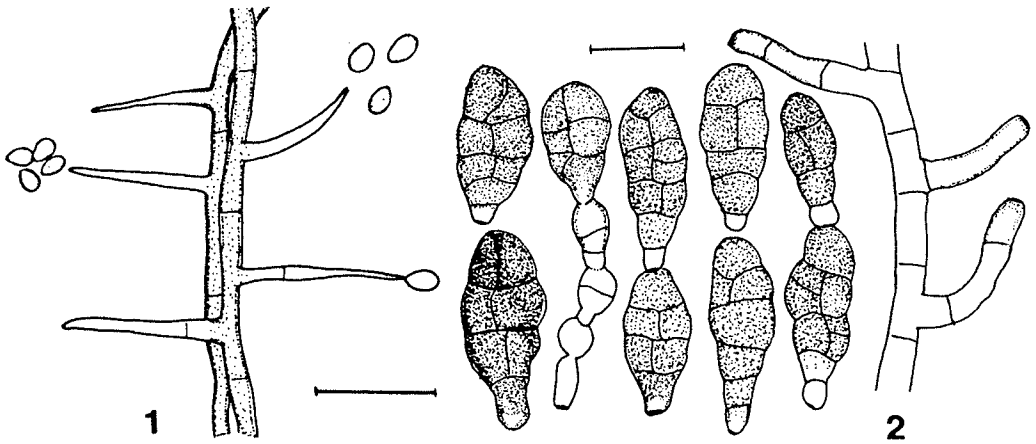
the first report on *Atriplex patula*, *Salicornia europaea* and *Suaeda depressa*.

Fig. 1-1. *Acremonium furcatum*, conidia and conidiophores (20 um).

Fig. 1-2. *Alternaria alternata*, conidia and conidiophores (20 um).

Fig. 1-3. *A. chlamydospora*, conidia and conidiophores (20 um).

Fig. 1-4. *A. citri*, various shapes of conidia (20 um).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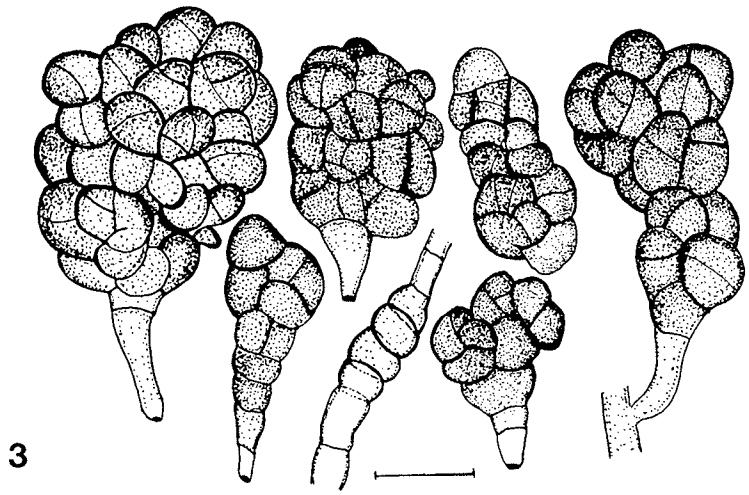
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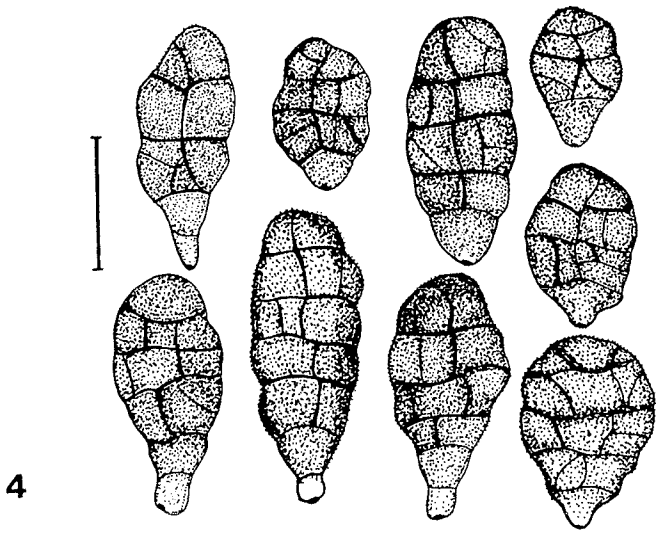
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Figs. 1-5 to 6. *Acremonium furcatum*, 5. A phialide arising on hypha (x 1040), 6. Hyphal bundles with numerous phialides and conidial heads (x 260).

Figs. 1-7 to 9. *Alternaria alternata*, 7. Conidiophores (x 1040), 8. Various shapes of conidia (x 1040), 9. Verrucose conidium (x 1040).

Figs. 1-10 to 13. *A. chlamydospora*, 10. Matured conidium with several septation (x 1040), 11. Conidium with no beak (x 1040), 12. Irregular conidial shape with a conspicuous beak (x 1040), young conidium (x 1040).

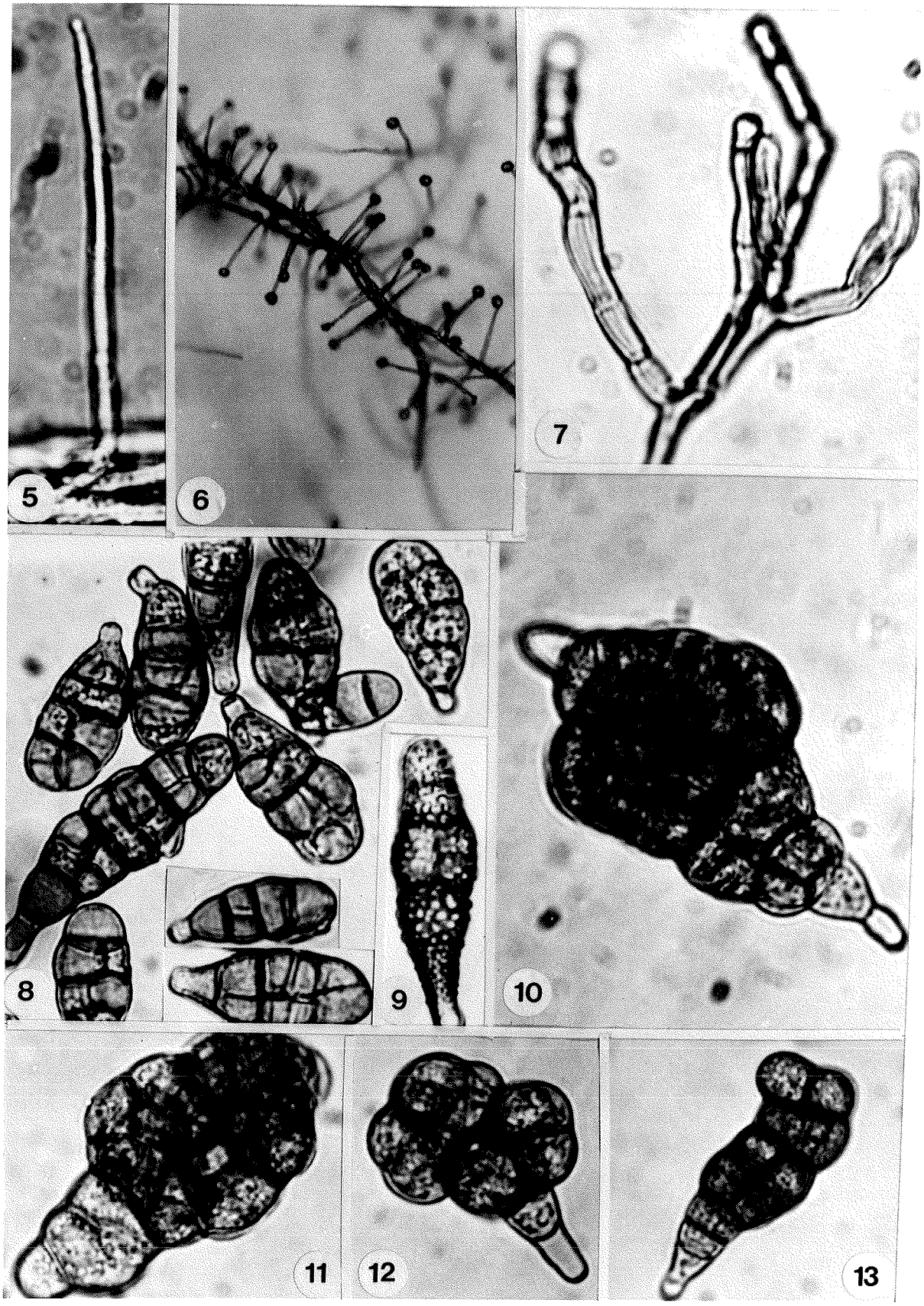
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Fig. 1-14. A. dennisii, conidia (20 um scale).

Fig. 1-15. A. petrosilini, conidia and conidiophores (20 um).

Fig. 1-16. A. phragmospora, conidia and conidiophores (20 um).

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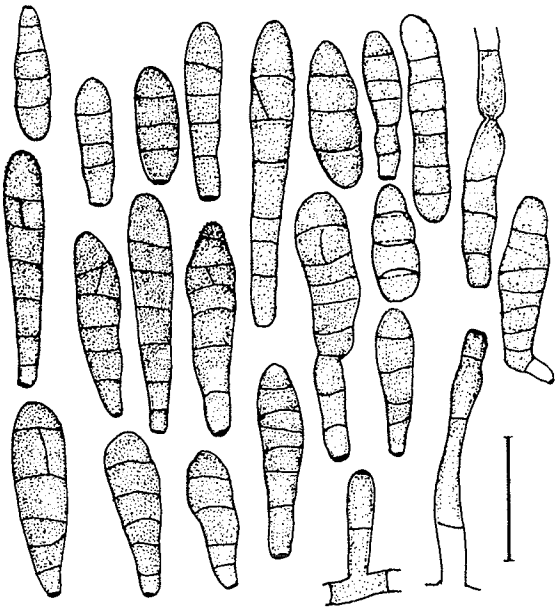

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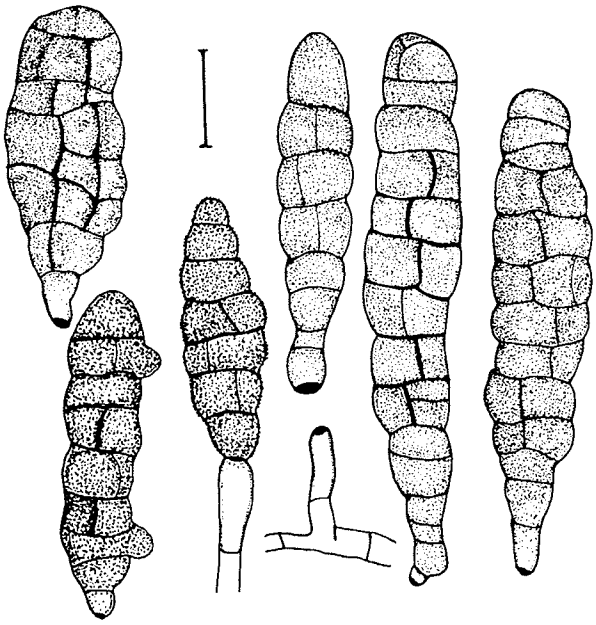

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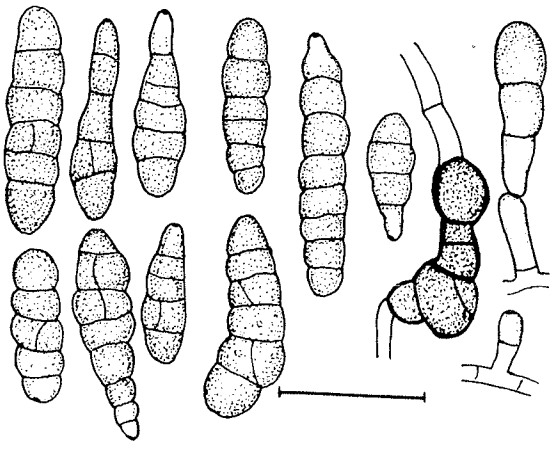

Figs. 1-17 to 18A-B. A. citri, 17. Various shapes of conidia (x 1040), 18A. Conidium without beak (x 1040), 18B. Conidium with a beak (x 1040).

Figs. 1-19 to 21. A. dennisii, 19. Minutely verruculose conidia with one transverse septum and long beak (x 1040), 20. Conidiophores (x 1040), 21. Smooth conidia without transverse septa (x 1040).

Figs. 1-22 to 24. A. petrosilini, 22. Clavate smooth conidium swollen beak (x 650), 23. Minutely verruculose conidium (x 650), 24. Young verrucose conidium arising on the conidiophore apex (x 650).

Figs. 1-25 A-B. A. phragmospora, 25A. Phragmospored conidium with a conspicuous beak (x 1040), 25B. Conidia constricted at the septa and without beak (x 1040).

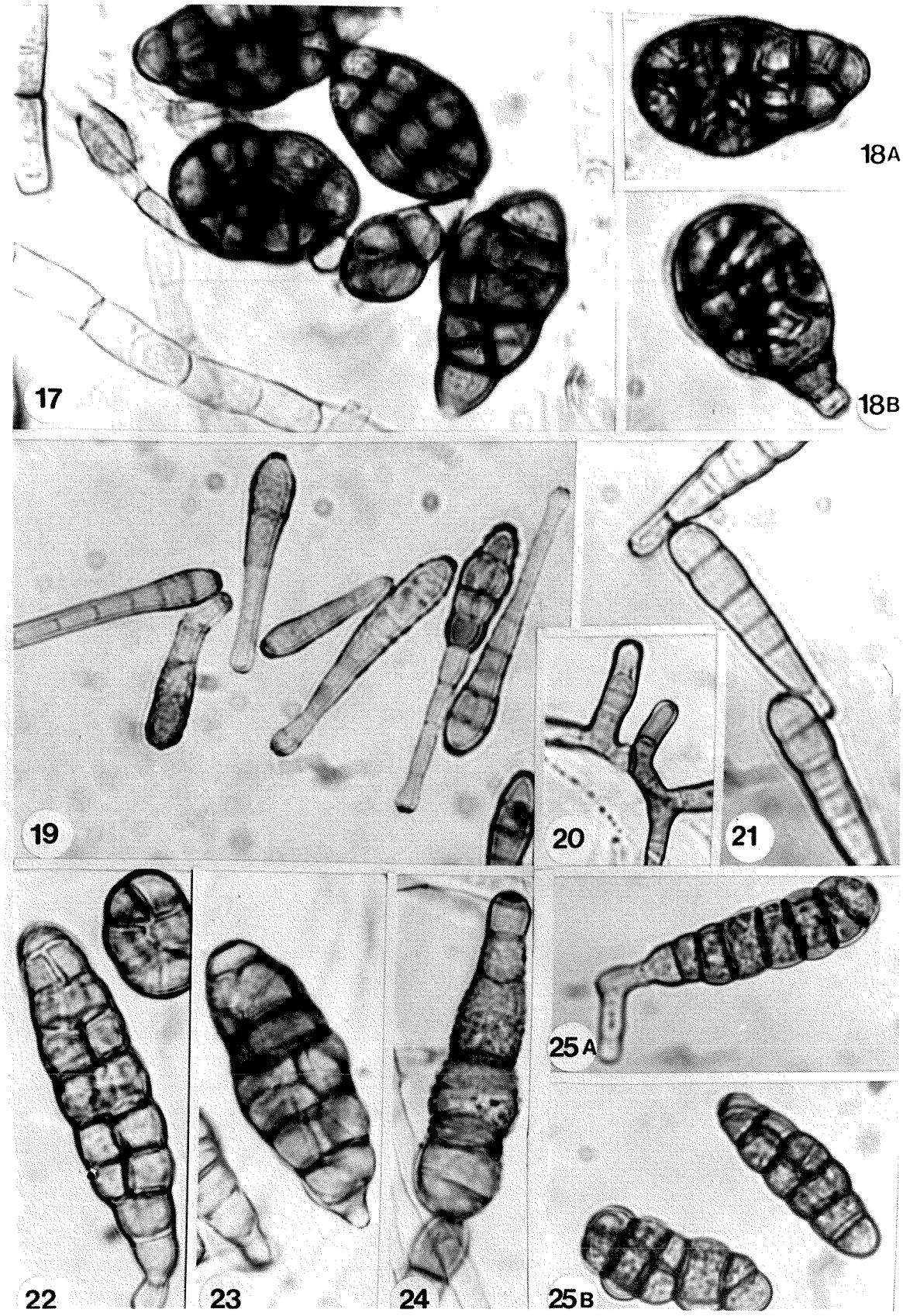
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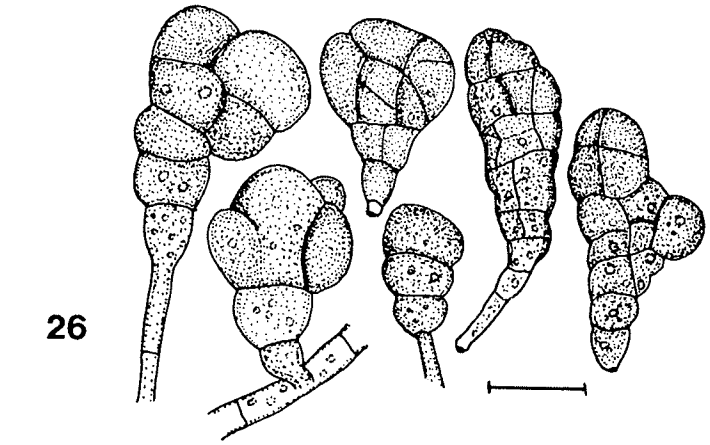
Fig. 1-26. A. raphani, conidia and conidiosphores (20 um).

Fig. 1-27. A. tenuissima, conidia and conidiophores (20 um).

Fig. 1-28. Arthrinum phaeospermum, conidia arising on denticles, notice the colorless band on the conidia (20 um).

Figs. 1-29 to 31. Ascochyta chenopodii, 29. Ascocarp (20 um), 30. Conidia (20 um), 31. Section through the ascocarp showing conidia and conidiophores (20 um).

Fig. 1-32. Aureobasidium pullulans, conidia aggregated on hyphae (20 um).



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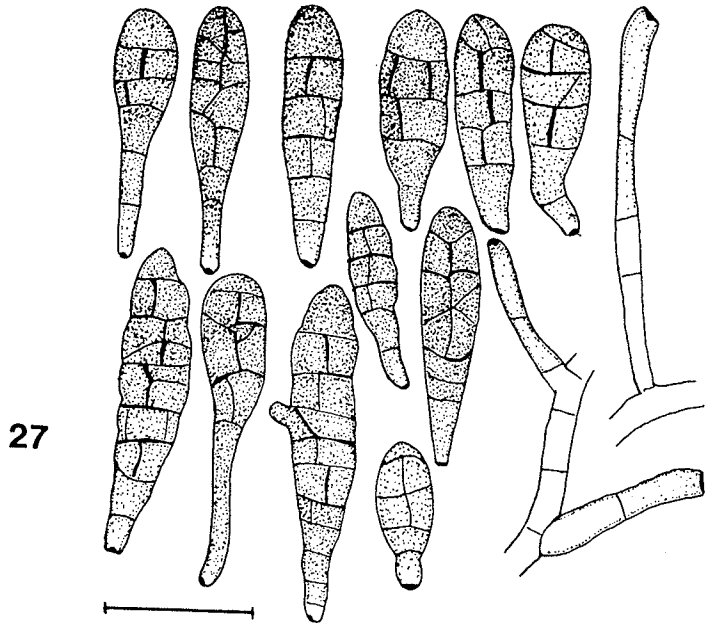

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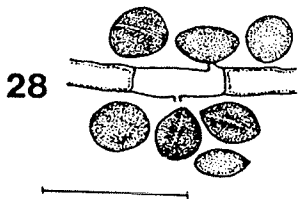

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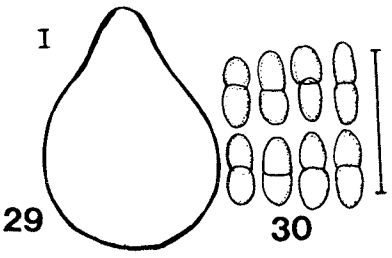

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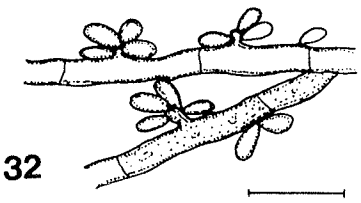

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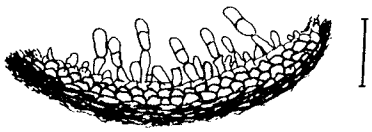

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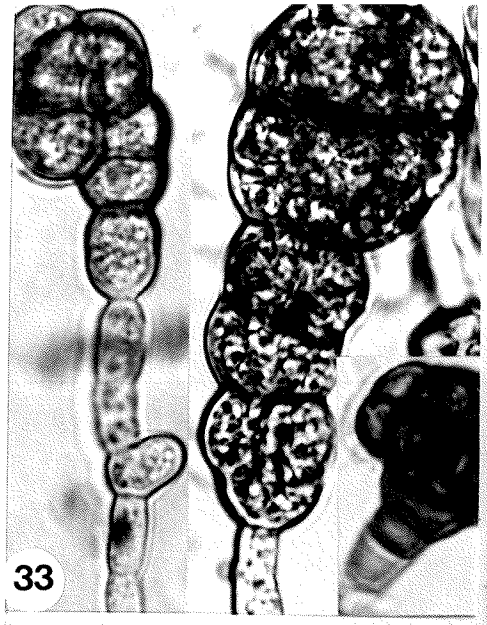
Fig. 1-33. *Alternaria raphani*, conidia on conidiophores (x 1040).

Figs. 1-34 to 35. *Alternaria tenuissima*, 34. Various shapes of conidia (x 1040), 35. Young conidia arising on the tip of conidiophore (x 1040).

Figs. 1-36 to 37. *Arthrinum phaeospermum*, 36. Lenticle-shaped conidia (x 1040), 37. A cluster of conidia arising from the hyphae (x 1040).

Figs. 1-38 to 39. *Ascochyta chenopodii*, 38. Section through the ascocarp (x 260), 39. Two-celled conidia (x 1040).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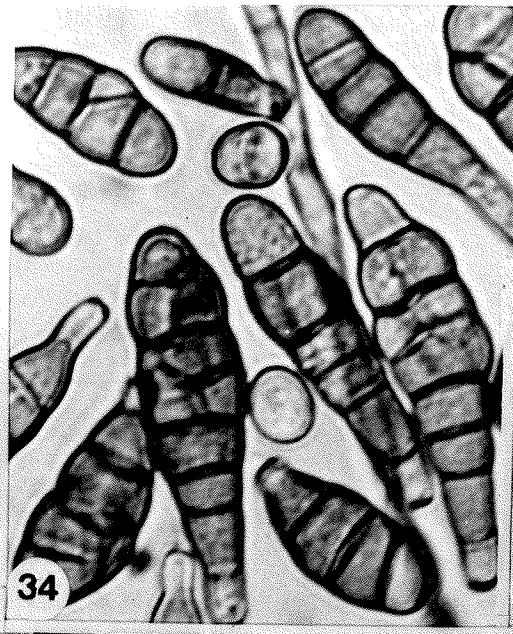
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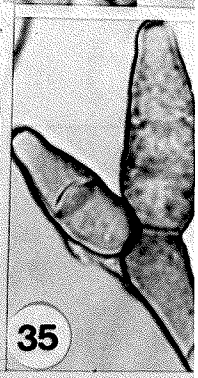
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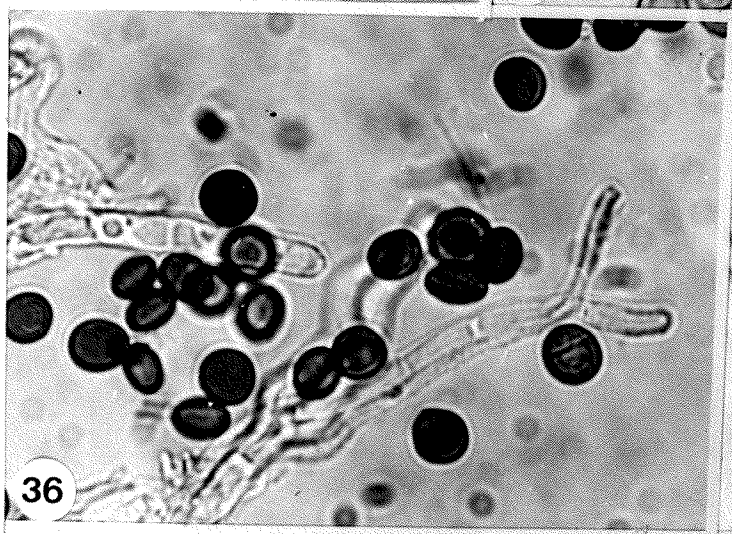
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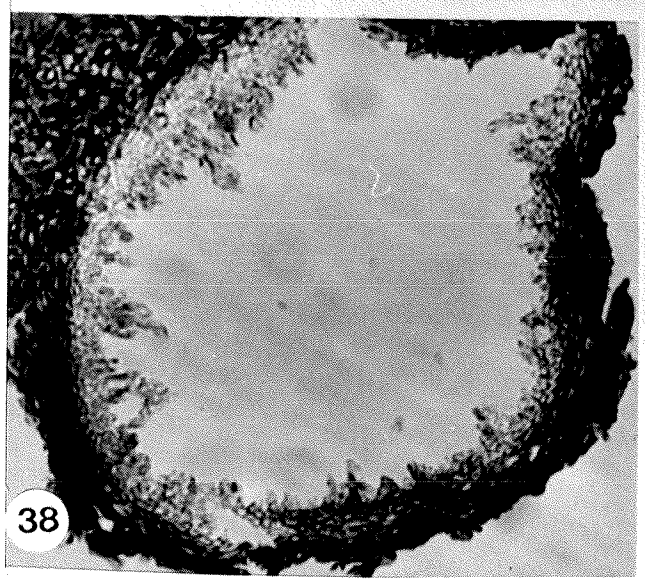
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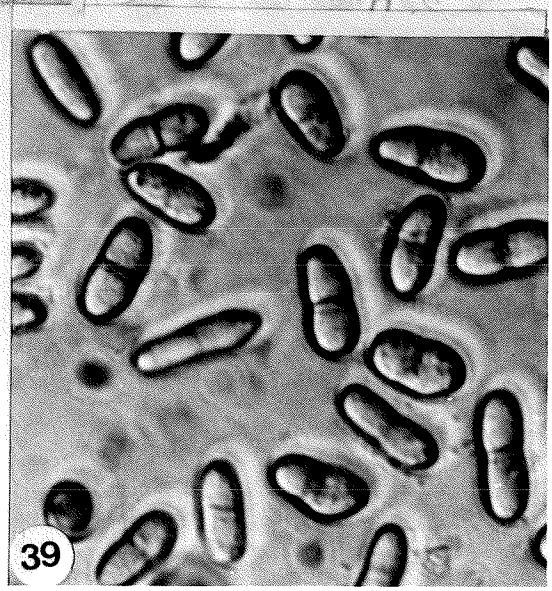
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Figs. 1-40 to 41. Aureobasidium pullulans, 40. Conidia aggregated on a hyphae (x 1040), 41. Conidia arising on short protuburances (x 1040).

Figs. 1-42 to 43. Cladosporium herbarum, 42. Conidiophore producing conidia (x 1040), 43. Verrucose conidia (x 1040).

Figs. 1-44 to 45. Cladosporium oxysporum, 44. Geniculated conidiophore with conspicuous scars on the apical part (x 1040), 45. Smooth conidia (x 1040).

Figs. 1-46 to 47. Dendryphiella arenaria, 46. Conidia arising on conidiophores (x 260), 47. Conidia (x 1040).

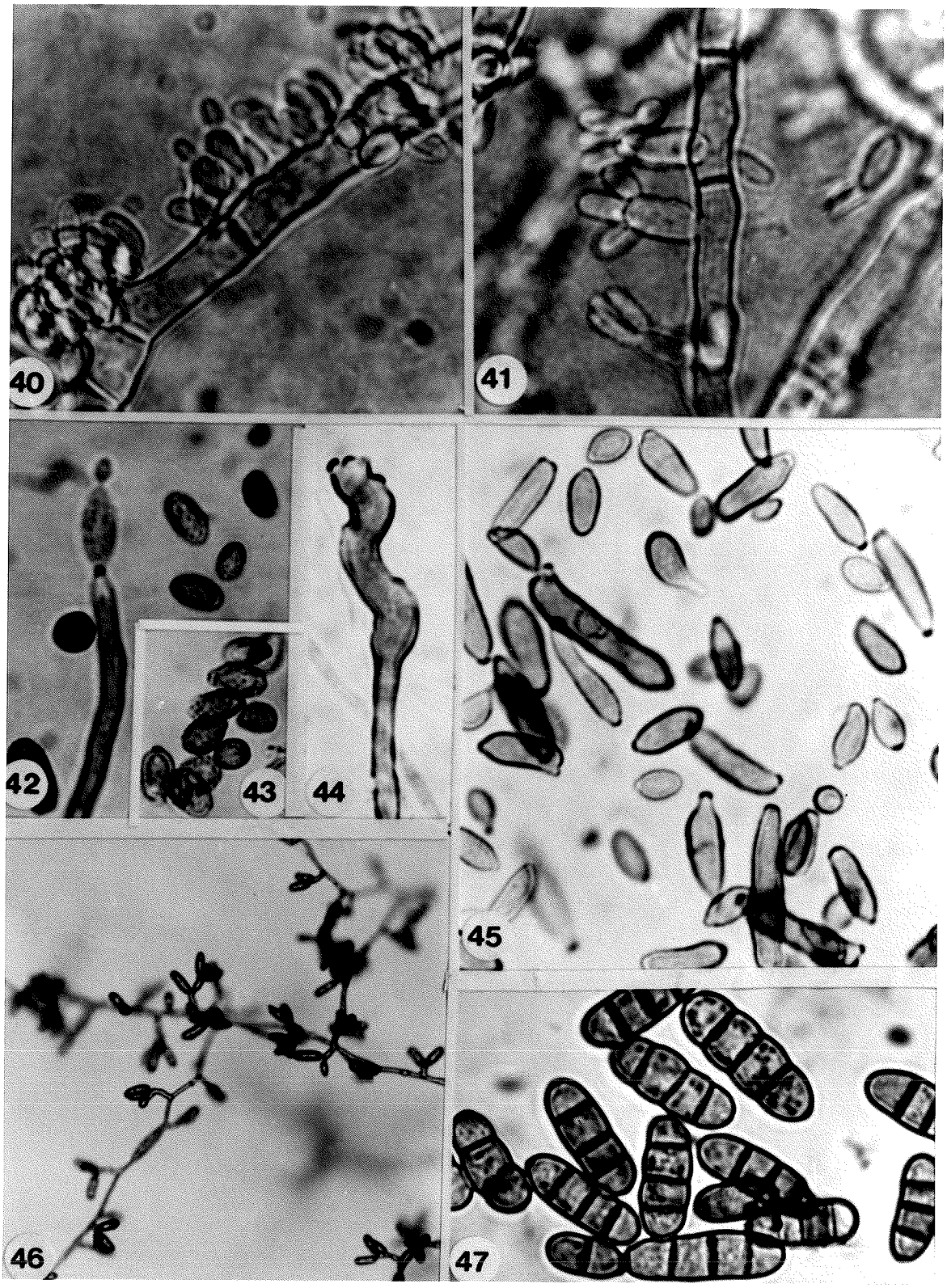
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Fig. 1-48. Cladosporium herbarum, conidia and conidiophore (20 um).

Fig. 1-49. C. oxysporum, conidia and conidiophore (20 um).

Fig. 1-50. Dendryphiella arenaria, conidia and conidiophore (20 um).

Fig. 1-51. Drechslera halodes, conidia and conidiophores (20 um).

Fig. 1-52. Epicoccum purpurascens, conidia (20 um).

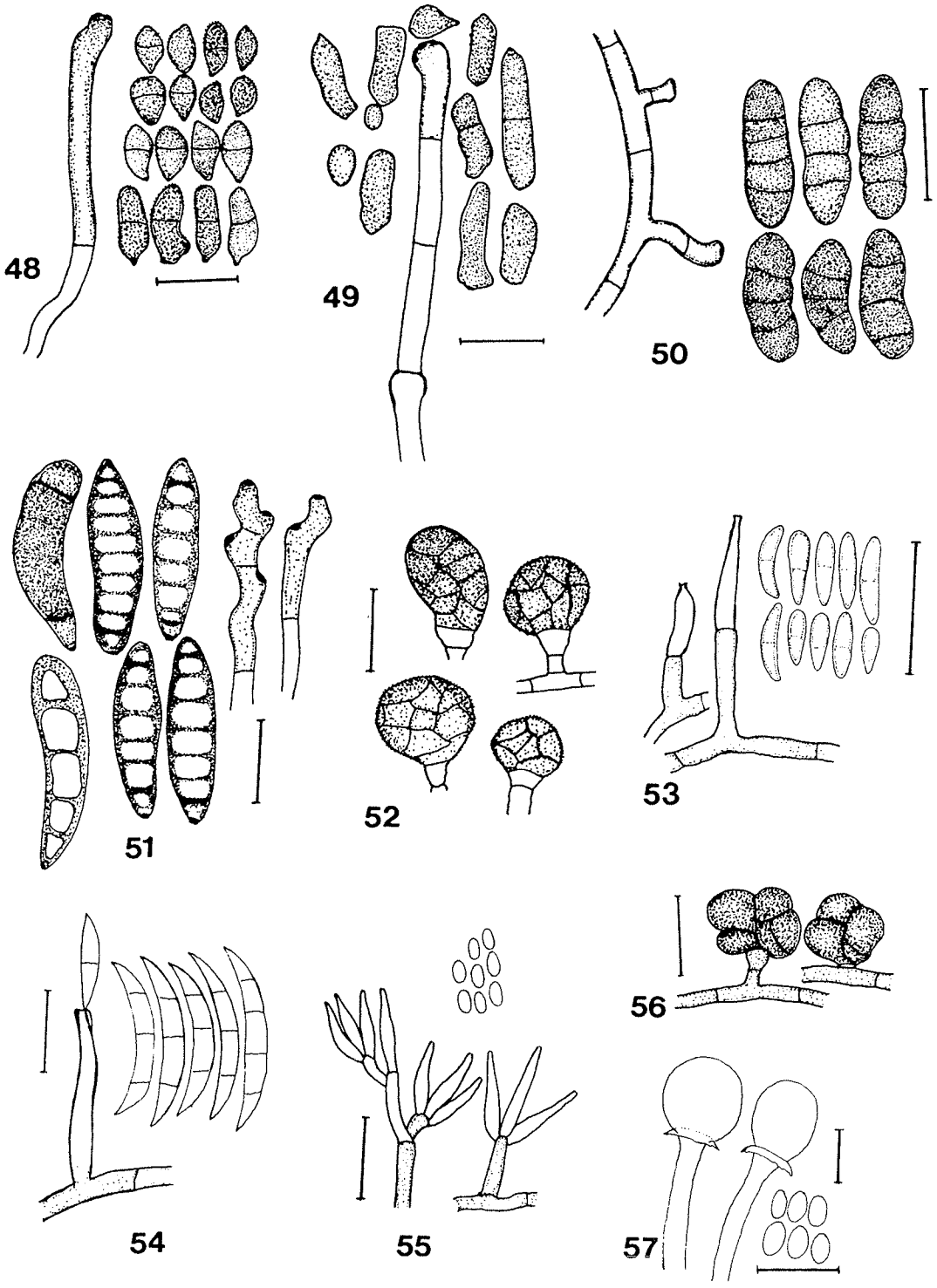
Fig. 1-53. Fusarium moniliforme, microconidia and phialides (20 um).

Fig. 1-54. F. tricinctum, conidia and phialidic cell (20 um).

Fig. 1-55. Gliocladium roseum, conidia and penicillate or verticellate phialides (20 um).

Fig. 1-56. Monodictys pelagica, conidia (20 um).

Fig. 1-57. Mucor hiemalis, spores and sporangiophores (20 um).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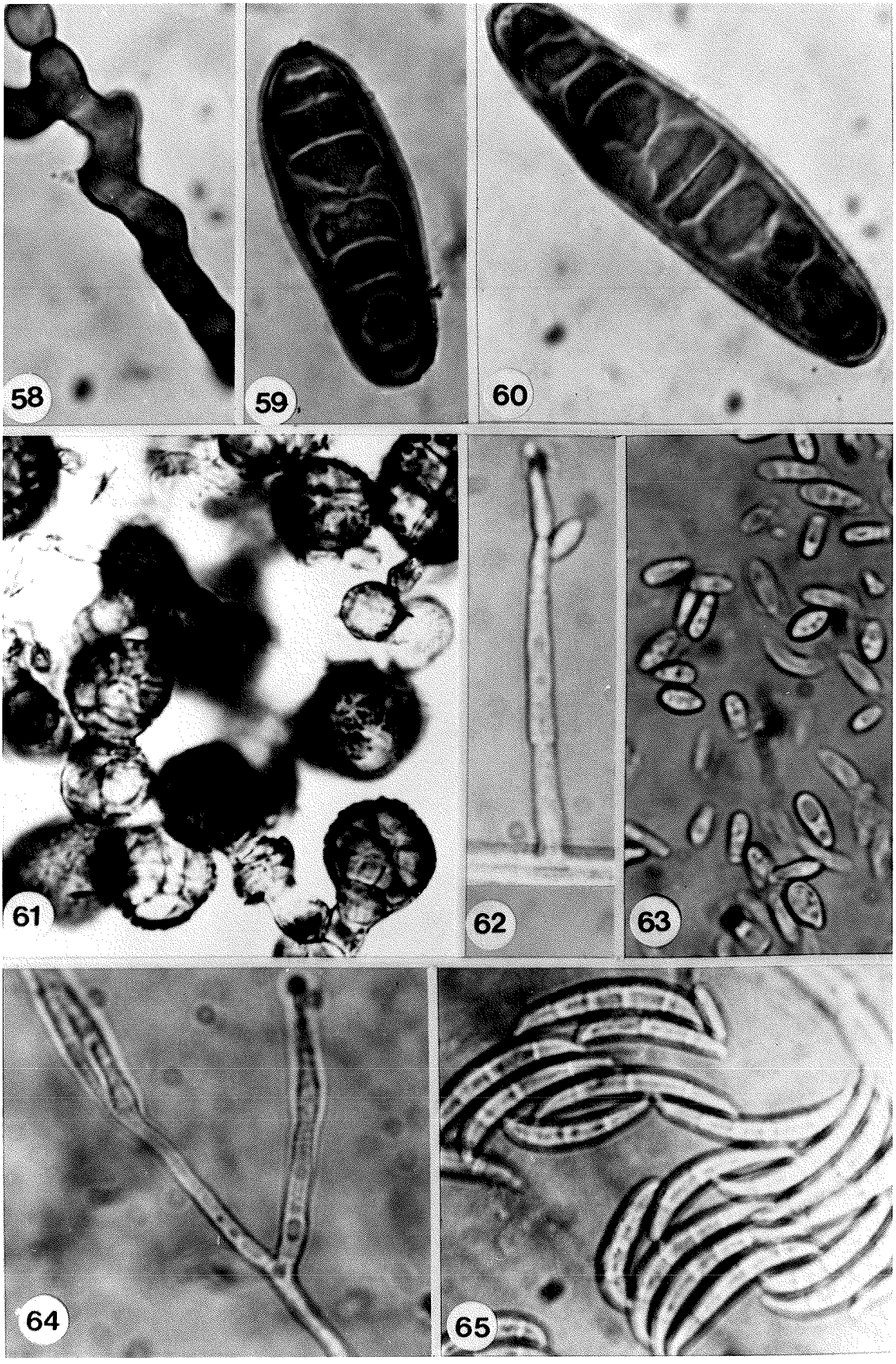
Figs. 1-58 to 60. Drechslera halodes, 58. Conidiophore (x 1040), 59. Pseudoseptate conidium shows a conspicuous scar on the distal end (x 1040), 60. Cylindrical multi-pseudoseptate conidium (x 1040).

Fig. 1-61. Epicoccum purpurascens, reticulated verrucose conidia (x 1040).

Figs. 1-62 to 63. Fusarium moniliforme, 62. Conidiophore with a phialidic cell producing conidia (x 1040), 63. Microconidia (x 1040).

Figs. 1-64 to 65. F. tricinctum, 64. Simple conidiophore (x 1040), 65. Three-septated conidia (x 1040).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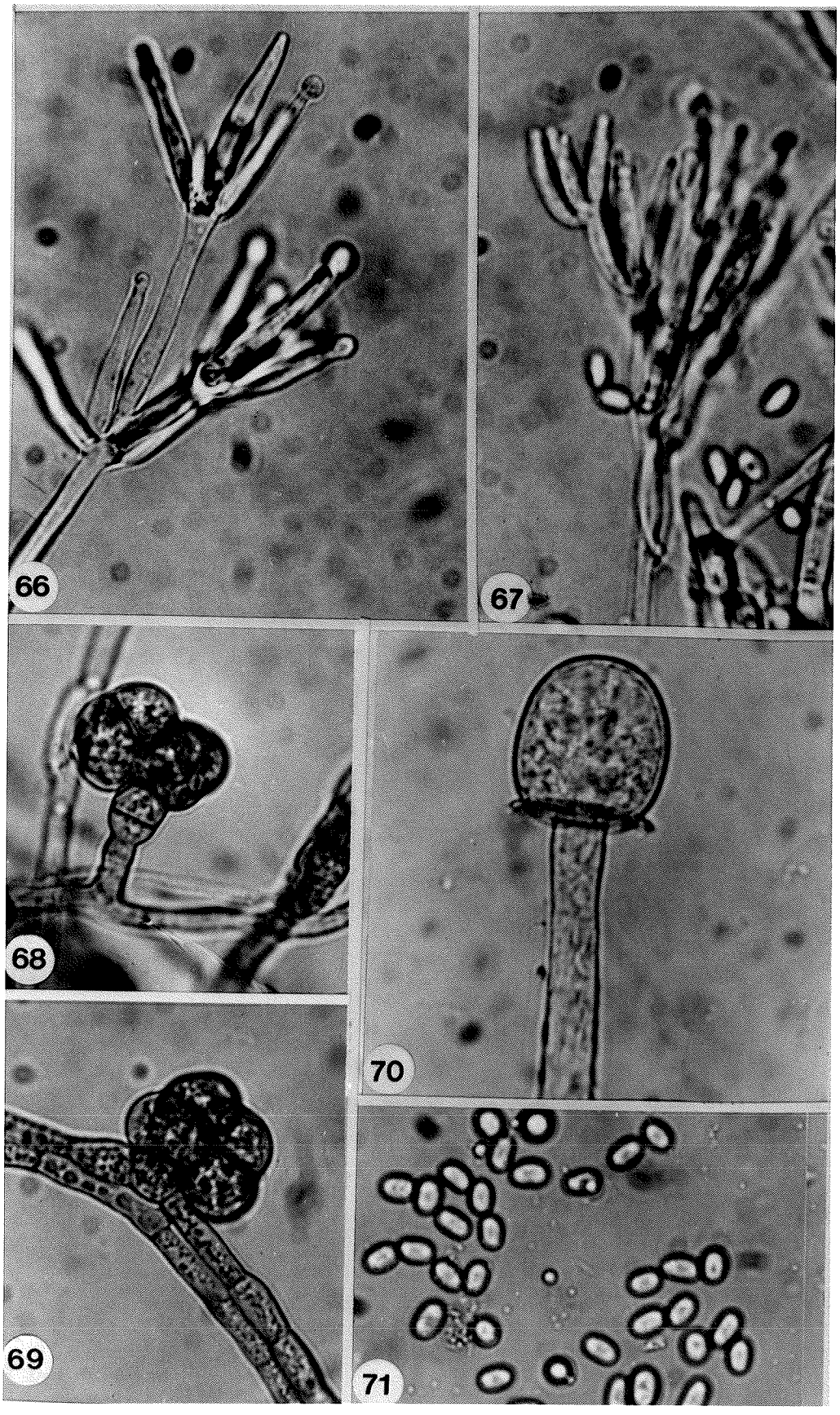
Figs. 1-66 to 67. Gliocladium roseum, 66. Verticellated phialides on conidiophores (x 1040), 67. Penicellated phialides on conidiophores (x 1040).

Figs. 1-68 to 69. Monodictys pelagica, 68. Conidium arisen on a short conidiophore (x 1040), 69. Sessile conidium (x 1040).

Figs. 1-70 to 71. Mucor hiemalis, 70. Sporangiophore with a columellum (x 1040), 71. Spores (x 1040).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Figs. 1-72 to 73. Nais inornata, 72. Ascocarp with asci (20 um), 73. Ascus containing eight ascospores (20 um).

Fig. 1-74. Papulaspora halima, bulbulous structures (20 um).

Fig. 1-75. Phoma glomerata, pyriform pycnidium and conidia (20 um).

Fig. 1-76. Pleospora herbarum, asci with eight ascospores, notice the ruptured bitunicate ascus (20 um).

Fig. 1-77. P. spartinae, three-septated ascospore with cylindrical eight-ascospored ascus (20 um).

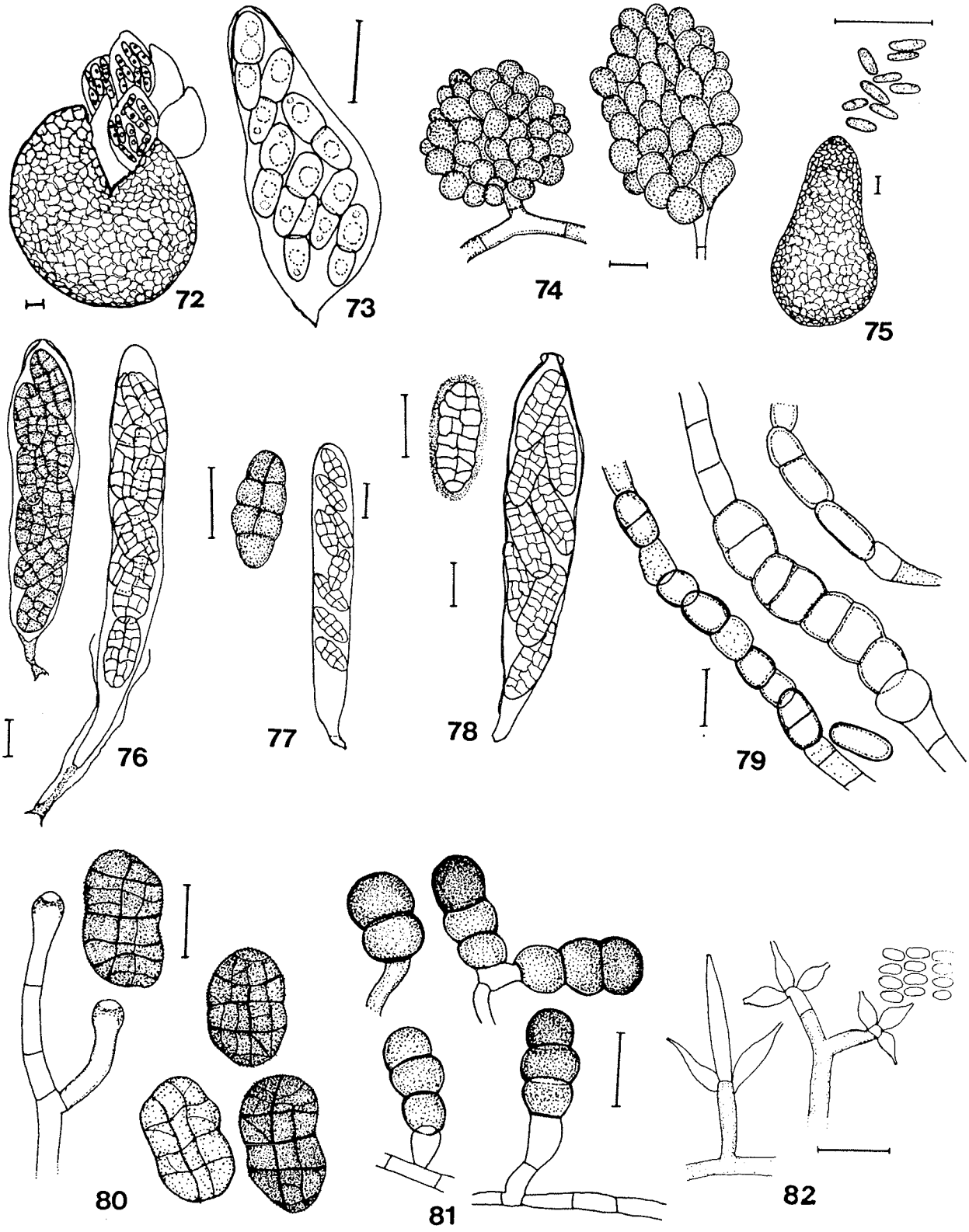
Fig. 1-78. Pleospora sp., bitunicate ascus with eight ascospores, ascospore surrounded by a gelatinous sheath (20 um).

Fig. 1-79. Scytalidium lignicola, arthrospored conidia and hyphal segments (20 um).

Fig. 1-80. Stemphylium botryosum, conidia and conidiophores (20 um).

Fig. 1-81. Trichocladium achrasporum, conidia (20 um).

Fig. 1-82. Trichoderma koningii, conidia and phialides (20 um).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Figs. 1-83 to 85. *Nais inornata*, 83. Asci (x 650), 84. Ascus apical part (x 1040), 85. Two-celled ascospores constricted at the septum and containing one large and one small oil globules in each cell (x 2600).

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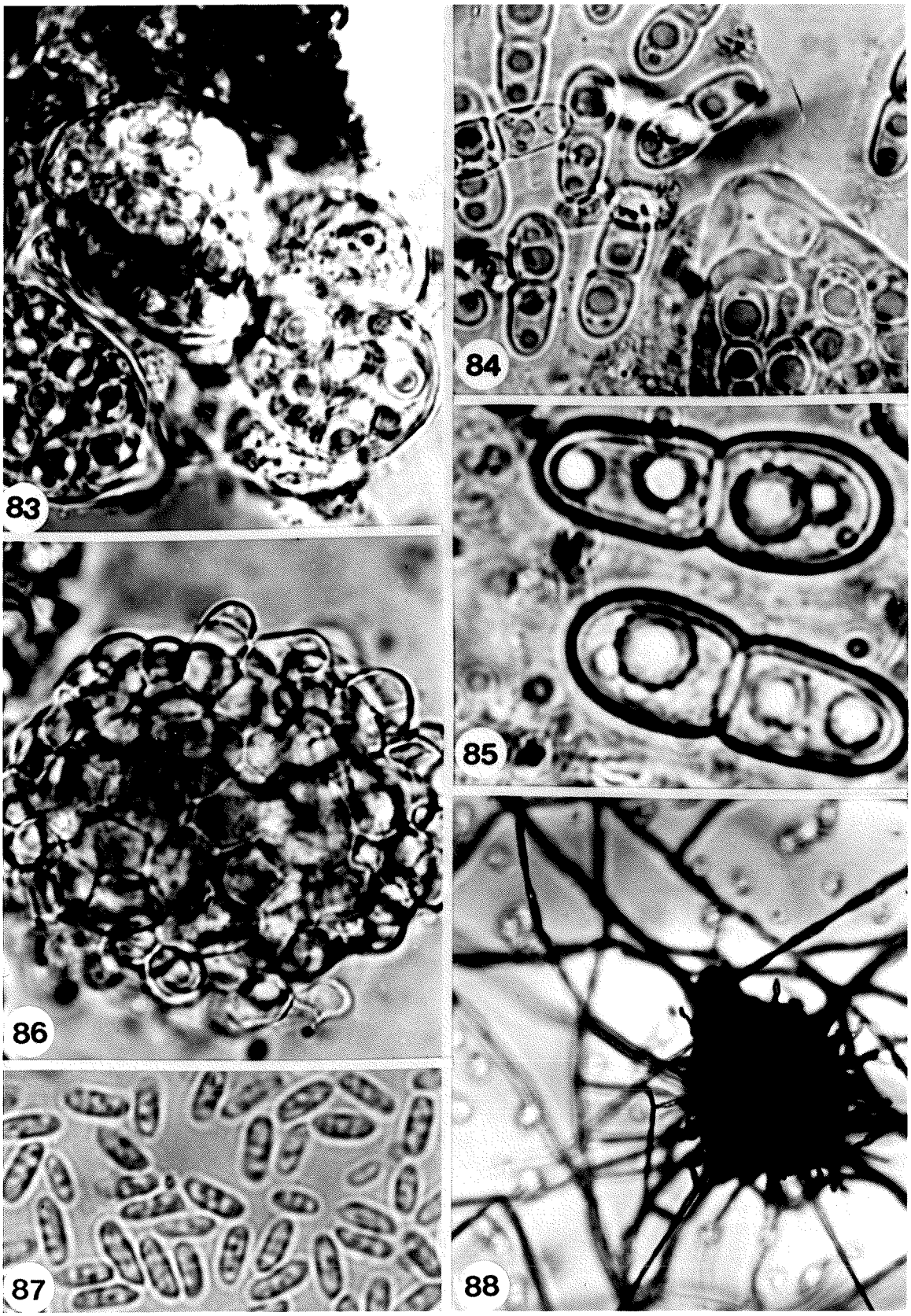
Figs. 1-87 to 88. *Phoma glomerata*, 87. Elliptical one-celled conidia (x 1040), 88. Pyriform-shaped pycnidium (x 260).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Figs. 1-89 to 90. Pleospora herbarum, 89. Distal part of the bitunicate ascus (x 1040), 90. Ascospore (x 1040).

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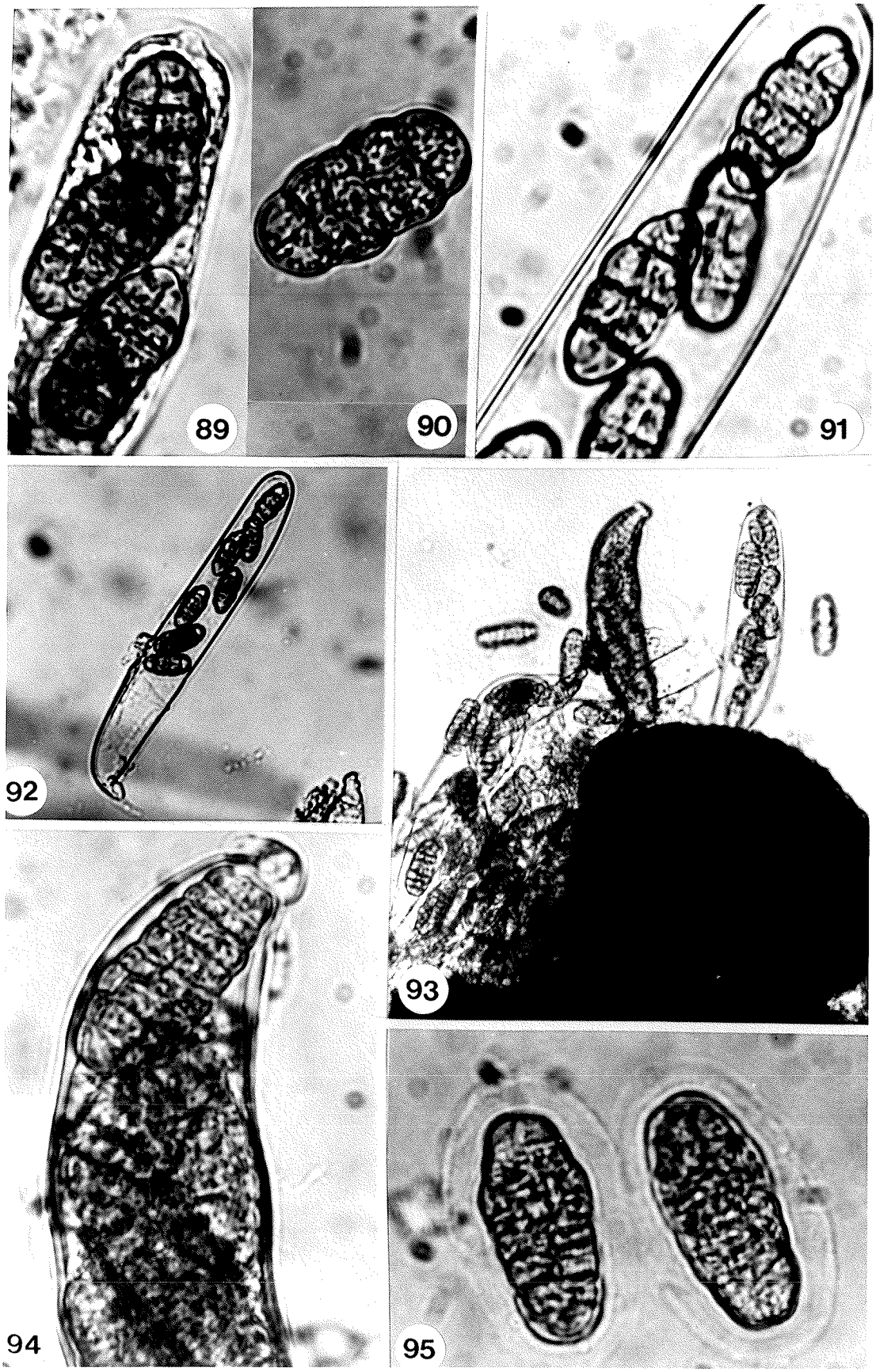
Figs. 1-93 to 95. Pleospora sp., 93. Ascocarp and asci (x 260), 94. Bitunicate ascus shows a pad-like structure on the apex (x 1040), 95. Ascospores surrounded by gelatinous sheath (x 1040).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Figs. 1-96 to 97. *Scytalidium lignicola*, 96. Dark and hyaline segmented hyphae (x 260), 97. Arthoconidia (x 1040).

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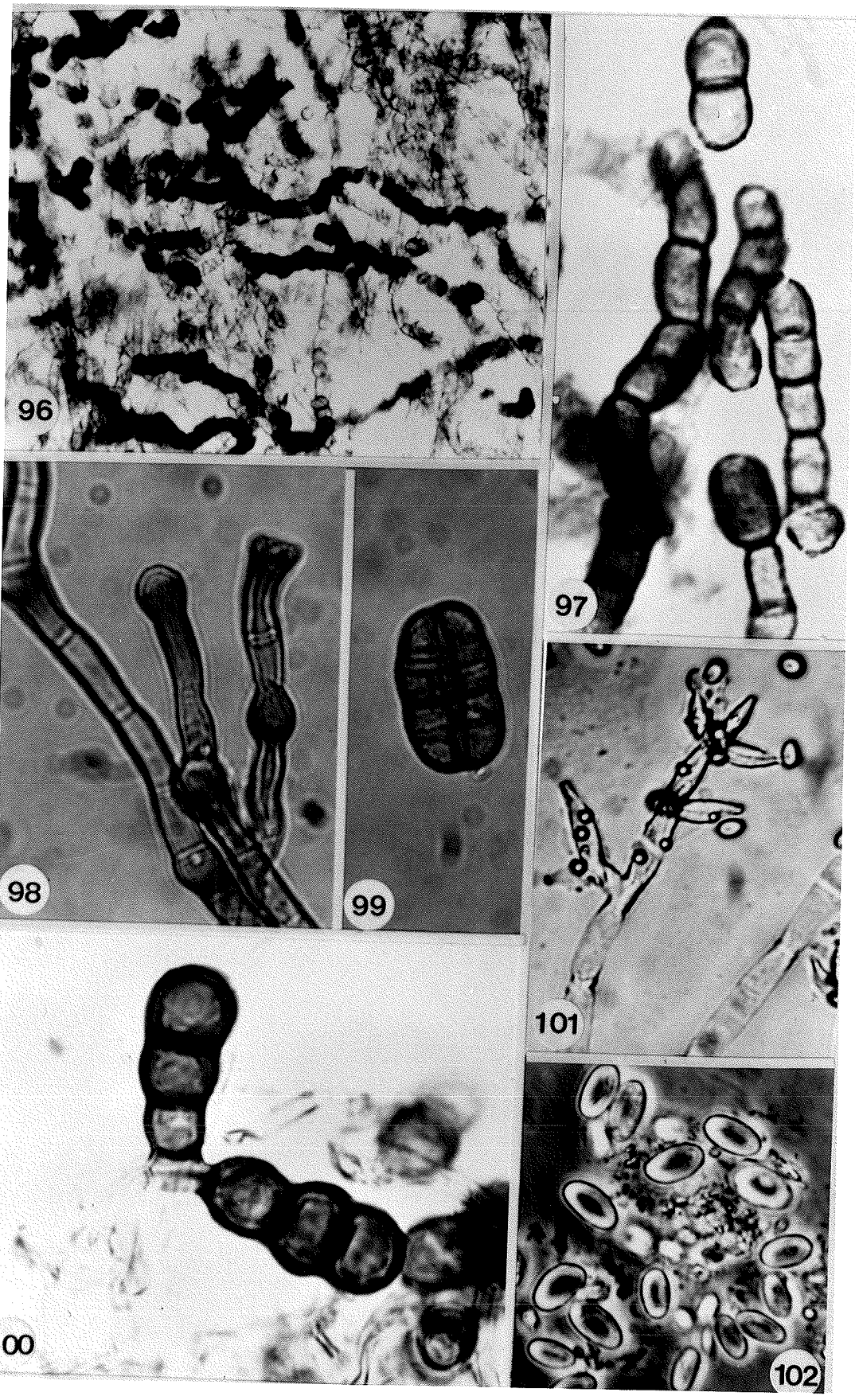
Fig. 1-100. *Trichocladium achrasporum*, three-celled conidia arising from a common cell (x 1040).

Figs. 1-101 to 102. *Trichoderma koningii*, 101. Conidiophores and phialides (x 1040), 102. Conidia (x 2600).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CHAPTER 2

COMMUNITY STRUCTURE OF FUNGI ON SALT MARSH HALOPHYTES FROM DELTA MARSH, MANITOBA

INTRODUCTION

Inland salt marshes are characterized by salt-requiring or salt-tolerant grasses, succulent and non-succulent annuals, hard-stemmed perennials and shrubs (S. Flowers 1934; Waisel 1972; Ungar 1974). The soils of these habitats are generally water-saturated early in the growing season and, with drying, become increasingly saline. Vegetation of these sites, therefore, is exposed to various salinity regimes. For example, plants in the low marsh, where the salinity is high (up to 90 mmhos/cm, T. Booth unpublished data), are mostly obligate halophytes such as Salicornia europaea agg. (Ungar 1974). Plants in the high marsh, with lower salinity (2.2 to 14 mmhos/cm, Ungar et al. 1979), include facultative halophytes such as Hordeum jubatum L.

In fact, soil salinity is considered a major controlling factor in the distribution and growth of halophytes (Chapman 1960; Waisel 1972; Ungar 1974, 1978; T.J. Flowers 1975; Maas and Nieman 1978; Jefferies et al. 1979b).

Literature dealing with fungi on salt marsh halophytes from maritime regions is extensively reviewed by Pugh (1974, 1979) and Kohlmeyer and Kohlmeyer (1979). These authors

establish the presence of fungi on halophyte detritus and living plants. As previously stated (Lindsey 1976) most of the studies on fungi infesting halophytes deal with senescent or dead plants. An interesting point established for fungi infesting healthy tissues is that these organisms are affected by plant salt leachates (Pugh and Lindsey 1975).

This study is intended to consider the composition of the fungal assemblage on all phenological stages of six different halophytes, i.e., Atriplex patula L., Glaux maritima L., Hordeum jubatum L., Puccinellia nuttalliana (Schutt.) Hitch., Salicornia europaea agg. and Suaeda depressa (Pursh.) Wats., beginning with seedlings and terminating with standing dead plants. Fungal assemblage composition is described using general community parameters (Krebs 1978; Muller-Dombois 1981). As the plants demonstrate different osmotic strategies (Waisel 1972), successional patterns of the fungi may relate to these strategies. Also, distinct stages in the succession, as discussed by Park (1968), Swift (1976) and Frankland (1981), may appear in the time variable assemblages.

METHODS AND MATERIALS

Study Area

Delta Marsh occupies an area of approximately 14,000 ha

at the south end of Lake Manitoba (50°11'N, 98°19'W). This area is characterized by an organo- to peaty-saline and poorly drained soils (Walker 1965). The marsh receives water from adjacent uplands and from Lake Manitoba through a series of interconnected channels. The vegetation of Delta Marsh can be distinguished into several communities (Walker 1965). The collection site is located on the eastern side of the Portage Diversion, i.e., 1.5 km from Lake Manitoba. The site is featured by plant zonations; the central zone is occupied by succulent vegetation such as Salicornia europaea and Suaeda depressa, while the peripheral zones are covered by grass and shrub communities.

Collection Methods

Collections of Atriplex patula L., Salicornia europaea agg. and Suaeda depressa (Pursh.) Wats. were made from June 6 to September 6 of 1982 and June 6 to October 9 of 1983. Material of Glaux maritima L., Hordeum jubatum L. and Puccinellia nuttaliana (Schutt.) Hitch. was gathered only in 1982 (June 6 to September 9). Samples were processed for cauloplane and rhizoplane fungi as previously described (Muhsin and Booth 1985). A total of 19 collections were made for S. europaea and 18 for each of A. patula and S. depressa over 1982 and 1983. G. maritima, H. jubatum and P. nuttalliana are represented by seven collections. A

total of 2,280 root and shoot pieces from the six plants were plated during this study.

Data Treatments

GENERAL STRUCTURE: The total number of different fungal taxa from all six plants was determined. Also the total number of isolates over the plants was used to ascertain the percentage isolations from each plant (number of isolates per plant divided by total number of isolates from all six plants). Percentage recovery of isolates was calculated (total isolates per plant divided by total number of plated pieces per plant).

SIMILARITY: Percentage total similarity (IS_T) is expressed by the number of species in common (a) between each of the 15 pairings of the six plants divided by the total number (N) of different taxa over the six plants multiplied by 100. A mean ($\bar{X}$) IS_T and its standard deviation (s) for all 15 IS_T values is used to indicate the degree of similarity of the assemblages on the plants.

Jaccard's index (IS_j) (Jaccard 1928) is calculated as the number of fungal species in common between two plants (a) divided by a + species unique to the first plant (b) + species unique to the second plant (c) multiplied by 100. A $\bar{X}$ IS_j and its s was determined utilizing all combinations

of plants. Krebs' (1978) coefficient of variation (V) was produced for all cases:

$$V = \frac{ad-bc}{\sqrt{(a+b)\ (c+d)\ (a+c)\ (b+c)}}$$

where d = number of taxa not encountered on the first or second plants. A $\bar{X}$ V with its s was calculated.

DIVERSITY: This parameter was partly characterized by dividing the number of species on each plant (S) by the total number of different species on all six plants (N). Simpson's index (Simpson 1949) was calculated as:

$$D_V = 1 - \Sigma\ (P_1)^2 + (P_2)^2 + \ldots\ (P_i)^2$$

where D_V is the diversity index and P is the proportion of the number of finds per start (as calculated from Appendices 1-6). A $\bar{X}$ D_V and its s were calculated for the fungi on each plant. Maximum diversity (MD) = 1 - 1/S and percentage realized diversity (RD) = (D_V/MD) x 100 were determined.

TEMPORAL GROUPS: Each collecting date was designated by a letter (T) and number combination. As there was a slight difference in collecting dates in 1982 and 1983, some designates include two separate dates. Principal component analysis (PCA) described by Orloci (1978) and Gauch (1982) was utilized to establish temporal groups, i.e., temporal I to temporal IV:

T_1 = June 6 (1982, 1983)

T_2 = June 18 (1982), June 13 (1983)

T_3 = June 23 (1983)

T_4 = July 3 (1982, 1983)

T_5 = July 15 (1983)

T_6 = July 21 (1982), July 23 (1983)

T_7 = August 4 (1982), August 6 (1983)

T_8 = August 17 (1983)

T_9 = August 23 (1982), August 26 (1983)

T_{10} = September 6 (1982, 1983)

T_{11} = September 17 (1983)

T_{12} = October 9 (1983)

These temporal groups were based upon the number of isolates of various fungal species for each of the collecting dates (the reader may wish to consult Appendices 1-6). They were subjectively defined according to the placement of T designates on the two perpendicular axes, i.e., A_1 and A_2 (Appendices 9-14), of the PCA analysis.

SPATIAL GROUPS: Occurrence (O), defined as the percentage presence of a fungal taxon over the collecting dates of a temporal group, was multiplied by the square root of the percentage frequency (f) (the summed number of isolates of a taxon divided by the summed number of starts multiplied by 100 for all the collecting dates within the temporal group) to obtain a modified distribution intensity index (DII)

(T. Booth 1971) for each species. These DII values were spatially represented by placing occurrence on the horizontal axis and frequency on the vertical axis for each species of the temporal groups on each plant. Fungal presence as represented by a DII diamond in the first temporal group was considered "early" while those in the last temporal group were considered "late". Presence in the middle group(s) dictated a "middle" assignment.

DOMINANCE: Isolates of each species were summed for the temporals. Those species with less than five isolates were considered to be very rare (VR). Deleting the VR forms, a mean ($\bar{X}$) value and its standard deviation (s) were determined for all species in each temporal group. Taxa with $>\bar{X}_1 + s_1$ were called dominant (D). A second $\bar{X}$ and its s were calculated ignoring the D taxa. Fungi $>\bar{X}_2 + s_2$ were designated subdominant (SD). A third $\bar{X}$ and its s were determined ignoring the SD taxa in turn. Organisms $>\bar{X}_3 + s_3$ were common (C). Rare forms (R) occurred between $\bar{X}_3 + s_3$ and $\bar{X}_3 - s_3$. Fungi $<\bar{X}_3 - s_3$ were considered very rare (VR). Based on these calculations and designations, each fungus was assigned a dominance function over all plants (Appendices 15-20). Community dominance (Krebs 1978) for each temporal group of the plants was calculated by dividing the total abundance of all the taxa into the sum of the two most-abundant taxa. This was then converted to percentage.

LIFE SPECTRA: Based upon previous proposals (Pugh 1980; Muller-Dombois 1981), morphological features, growth habits, temporal and quantitative aspects of sporulation and time of isolation, arbitrary life strategies were assigned to each fungus. These assignments were: competitors, escapers, survivors, ruderals, and stress-tolerant. Life spectra over the temporal groups for the fungi on each plant were drawn using the cumulative DII for all the taxa of the strategy groups.

RESULTS

General Assemblage Structure

A total of 30 taxa are included among the 2,211 isolates from 2,280 root and shoot pieces of the six plants, i.e., Atriplex patula, Glaux maritima, Hordeum jubatum, Puccinellia nuttalliana, Salicornia europaea and Suaeda depressa (Appendices 1-6). The percentage isolation on each of the plants of the total number of isolates is: (1) S. europaea at 28.7%, (2) S. depressa at 22.6%, (3) A. patula at 21.6%, (4) P. nuttalliana at 9.7%, (5) H. jubatum at 9.4%, and (6) G. maritima at 8%. Recovery of isolates (total isolates per plant divided by total number of pieces plated per plant) is 111.2% for S. europaea, 103.8% for P. nuttalliana, 98.6% for H. jubatum, 92.4% for S. depressa, 88.3% for A. patula and

83.8% for G. maritima. Mean recovery is 96.4±10.2%, indicating that for S. europaea it is more than one standard deviation above the mean and for G. maritima it is more than one standard deviation below the mean. Of the total of 30 different species, nine represent slightly more than 75% of all of the isolates for the six plants. These include Alternaria alternata (Fr.) Keissler at 39.8%, Fusarium tricinctum (Corda) Sacc. at 8.6%, Dendryphiella arenaria Nicot at 6.2%, Stemphylium botryosum Wallr. at 4.6%, Mucor hiemalis Wehmer at 4.3%, Phoma glomerata (Corda) Wollen. et Hochapfel at 4.1%, Alternaria chlamydospora Mouchacca at 3.3%, Ascochyta chenopodii Roster at 2.9%, and Alternaria dennisii M.B. Ellis at 2.7%. Acremonium furcatum F. et V. Moreau ex Gams, Cladosporium oxysporium Berk. et Curt., Monodictys pelagica (Johnson) E.B. Jones, Papulaspora halima Anastasiou, Scytalidium lignicola Pesante and Trichoderma koningii Oudem are all considered to be vary rare as they are represented by less than 10 isolates. Those fungi restricted to a single plant species include Acremonium furcatum, Alternaria chlamydospora, A. phragmospora van Emden, A. raphani Groves et Skolko, Monodictys pelagica, Papulaspora halima and Trichocladium achrasporum (Meyers et Moore) Dixon on Salicornia europaea, and Fusarium moniliforme Sheldon on Atriplex patula.

Similarity

Comparison of the fungal assemblage between the various plants (Appendices 7-8) using total similarity (IS_T) (Fig. 2-1) indicates similarity greater than one standard deviation from the mean (30±6.9) for the combinations of *Salicornia europaea* with *Suaeda depressa* and *Hordeum jubatum* with *Puccinellia nuttalliana*. The IS_T values for the combinations of *Atriplex patula* with *Glaux maritima*, *H. jubatum* with *P. nuttalliana* are more than one standard deviation below the mean. The mean Jaccard's index value (IS_j) is 49.7±17.4, and the three combinations between *G. maritima*, *H. jubatum* and *P. nuttalliana* are more than one standard deviation above the mean. The combination of *A. patula* and *P. nuttalliana* is more than one standard deviation below the mean. Values of the coefficient of association (V) are all negative or more than one standard deviation below the mean (0.25±0.35) for most of the combinations of *S. europaea* with the other plants. Values for the three combinations between *G. maritima*, *H. jubatum* and *P. nuttalliana* are more than a standard deviation above the mean.

Diversity

Simpson's index ranges from .35 to .92 ($\bar{X}$ = .7±.16) over the collecting dates for the fungi on *Salicornia*

Fig. 2-1. Similarity indices (i.e., total species in common, a; total similarity, IS_T; Jaccard's index, IS_j; and the coefficient of association, V) of the fungal assemblage on the six plants. The reader may wish to see Appendices 7 and 8.

	S. depressa	A. patula	G. maritima	P. nuttalliana	H. jubatum
S. europaea	13 43 45 −0·21	10 33 36 −007	10 33 36 −0·15	11 37 39 −0·12	10 33 37 0·0
S. depressa		10 33 50 −0·36	11 37 58 0·49	11 37 55 0·41	10 33 53 0·44
A. patula			7 23 37 0·19	6 20 29 −0·01	6 20 32 0·11
G. maritima				11 37 69 0·67	11 37 79 0·80
P. nuttalliana					12 40 86 0·87
H. jubatum					

a	IS_T
IS_j	V

LEGEND

europaea (Table 2-1). In these collections, diversity is low ($<\bar{X} - s$) during the period T_5 through T_7, and it is high ($>\bar{X} + s$) during T_1, T_3 and T_4. Other ranges in D are: .46-.9 ($\bar{X}$ = .69±.13) on Suaeda depressa (Table 2-2); .4-.86 ($\bar{X}$ = .66±.12) on Atriplex patula (Table 2-3); .59-.79 ($\bar{X}$ = .73±.08) on Glaux maritima (Table 2-4); .57-.78 ($\bar{X}$ = .69±.07) on Puccinella nuttalliana (Table 2-6); and .25-.78 ($\bar{X}$ = .65±.18) on Hordeum jubatum (Table 2-5). Times of diversity highs and lows for the fungi on these plants are: T_2 and T_3 high, T_6, T_{10} through T_{12} low on S. depressa; T_2 high, T_4, T_8 and T_9 low on A. patula; no high, T_9 and T_{10} low on G. maritima; no high, T_{10} on H. jubatum; and T_1 high, T_9 low on P. nuttalliana. Maximum diversity (MD) does not generally change over the collections and realized diversity (RD) changes in consort with changes in D_V (Tables 2-1 to 6).

Temporal Groups

Principal component analysis (Appendices 9-14) of the fungi for each plant over the collecting dates indicates a general separation of the fungal assemblages over time. Fungi on Salicornia europaea demonstrate generally four temporal groups, i.e., I(T_1-T_6); II(T_6-T_7); III(T_7-T_{10}); IV(T_{10}-T_{12}) (Fig. 2-2, Appendix 13). The temporal groups for the fungi of Suaeda depressa are: I(T_1-T_5,T_{12}); II(T_6-T_8); III(T_7,T_9-T_{11}) (Fig. 2-3, Appendix 14). Atriplex patula has

TABLE 2-1

Total number of species, Simpson's index, maximum diversity, and realized diversity on *Salicornia europaea* over the 1982 and 1983 collecting dates

Year	Temporal group	Collecting date	Number of taxa	Simpson's index	Maximum diversity (MD)	Realized diversity (RD)
1982	T_1	6/6	9	0.87	0.89	97.8%
	T_2	18/6	14	0.92	0.93	98.9%
	T_4	3/7	10	0.87	0.90	96.7%
	T_6	21/7	5	0.74	0.80	98.8%
	T_7	4/8	8	0.84	0.88	95.5%
	T_9	23/8	9	0.74	0.89	83.1%
	T_{10}	6/9	8	0.81	0.88	92.0%
1983	T_1	6/6	6	0.78	0.83	93.9%
	T_2	13/6	9	0.83	0.89	93.3%
	T_3	23/6	6	0.76	0.80	95.0%
	T_4	3/7	6	0.80	0.83	96.4%
	T_5	15/7	5	0.47	0.80	58.7%
	T_6	23/7	5	0.35	0.80	43.8%
	T_7	6/8	5	0.45	0.80	56.3%
	T_8	17/8	6	0.59	0.83	71.7%
	T_9	26/8	7	0.62	0.86	72.1%
	T_{10}	6/9	6	0.54	0.83	65.1%
	T_{11}	17/9	4	0.66	0.75	88.0%
	T_{12}	9/10	6	0.67	0.83	80.7%
				$\bar{X}$ = 0.70± 0.16	no change	$\bar{X}$ = 83± 16.9

TABLE 2-2

Total number of species, Simpson's index, maximum diversity, and realized diversity on Suaeda depressa over the 1982 and 1983 collecting dates

Year	Temporal group	Collecting date	Number of taxa	Simpson's index	Maximum diversity (MD)	Realized diversity (RD)
1982	T_1	6/6	9	0.87	0.89	97.7%
	T_2	18/6	11	0.90	0.91	99.0%
	T_4	3/7	7	0.81	0.86	94.2%
	T_6	21/7	6	0.77	0.83	92.8%
	T_7	4/8	5	0.64	0.80	80.0%
	T_9	23/8	6	0.72	0.83	86.8%
	T_{10}	6/9	8	0.69	0.85	81.3%
1983	T_1	6/6				
	T_2	13/6	5	0.69	0.80	86.3%
	T_3	23/6	7	0.81	0.86	94.2%
	T_4	3/7	7	0.76	0.86	88.4%
	T_5	15/7	7	0.72	0.86	83.7%
	T_6	23/7	5	0.46	0.80	57.5%
	T_7	6/8	9	0.81	0.89	91.0%
	T_8	17/8	4	0.65	0.75	86.7%
	T_9	26/8	5	0.65	0.80	86.7%
	T_{10}	6/9	3	0.53	0.67	79.1%
	T_{11}	17/9	6	0.46	0.83	55.4%
	T_{12}	9/10	6	0.56	0.83	67.5%
				$\bar{X}$ = 0.69± 0.13	no change	$\bar{X}$ = 83.8± 12.5

TABLE 2-3

Total number of species, Simpson's index, maximum diversity, and realized diversity on *Atriplex patula* over the 1982 and 1983 collecting dates

Year	Temporal group	Collecting date	Number of taxa	Simpson's index	Maximum diversity (MD)	Realized diversity (RD)
1982	T_1	6/6				
	T_2	18/6	6	0.80	0.83	96.4%
	T_4	3/7	8	0.78	0.88	88.6%
	T_6	21/7	7	0.70	0.86	81.4%
	T_7	4/8	4	0.68	0.75	90.6%
	T_9	23/8	4	0.70	0.75	93.3%
	T_{10}	6/9	7	0.78	0.86	85.6%
1983	T_1	6/6	3	0.66	0.67	98.5%
	T_2	13/6	8	0.86	0.88	97.7%
	T_3	23/6	6	0.74	0.83	89.2%
	T_4	3/7	3	0.51	0.67	67.0%
	T_5	15/7	8	0.63	0.88	71.6%
	T_6	23/7	4	0.63	0.75	84.0%
	T_7	6/8	5	0.68	0.80	78.8%
	T_8	17/8	3	0.49	0.67	73.1%
	T_9	26/8	4	0.42	0.75	56.0%
	T_{10}	6/9	4	0.56	0.75	74.7%
	T_{11}	17/9	5	0.62	0.80	77.5%
	T_{12}	9/10	8	0.58	0.88	65.9%
				$\bar{X}$ = 0.66± 0.12	no change	$\bar{X}$ = 81.7± 12.1

TABLE 2-4

Total number of species, Simpson's index, maximum diversity, and realized diversity on Glaux maritima over the 1982 collecting dates

Year	Temporal group	Collecting date	Number of taxa	Simpson's index	Maximum diversity (MD)	Realized diversity (RD)
1982	T_1	6/6	6	0.79	0.83	95.2%
	T_2	18/6	6	0.79	0.83	95.2%
	T_4	3/7	6	0.76	0.83	95.0%
	T_6	21/7	5	0.78	0.80	97.5%
	T_7	4/8	5	0.73	0.80	91.3%
	T_9	23/8	5	0.59	0.80	73.7%
	T_{10}	6/9	6	0.65	0.83	81.3%
				$\bar{X}$ = 0.73± 0.08	no change	$\bar{X}$ = 89.9± 8.9

TABLE 2-5

Total number of species, Simpson's index, maximum diversity, and realized diversity on Hordeum jubatum over the 1982 collecting dates

Year	Temporal group	Collecting date	Number of taxa	Simpson's index	Maximum diversity (MD)	Realized diversity (RD)
1982	T_1	6/6	6	0.72	0.83	86.7%
	T_2	18/6	6	0.68	0.83	81.9%
	T_4	3/7	5	0.69	0.80	86.3%
	T_6	21/7	8	0.76	0.87	87.4%
	T_7	4/8	6	0.78	0.83	93.9%
	T_9	23/8	5	0.66	0.80	82.5%
	T_{10}	6/9	6	0.25	0.83	30.1%
				$\bar{X}$ = 0.65± 0.18	no change	$\bar{X}$ = 78.4± 21.7

TABLE 2-6

Total number of species, Simpson's index, maximum diversity, and realized diversity on *Puccinellia nuttalliana* over the 1982 collecting dates

Year	Temporal group	Collecting date	Number of taxa	Simpson's index	Maximum diversity (MD)	Realized diversity (RD)
1982	T_1	6/6	5	0.78	0.80	97.5%
	T_2	18/6	5	0.72	0.80	90.0%
	T_4	3/7	7	0.74	0.86	86.1%
	T_6	21/7	5	0.67	0.80	83.7%
	T_7	4/8	5	0.68	0.80	85.0%
	T_9	23/8	5	0.57	0.80	71.3%
	T_{10}	6/9	5	0.68	0.80	85.0%
				$\bar{X}$ = 0.69± 0.07	no change	$\bar{X}$ = 85.5± 7.9

four temporal groups: I(T_1-T_4,T_9); II(T_5-T_7,T_9-T_{10}); III(T_7-T_8); IV(T_{10}-T_{12}) (Fig. 2-4, Appendix 9). The general temporal separations for the fungal assemblage of Glaux maritima are: I(T_1-T_4); II(T_5); III(T_6-T_7) (Fig. 2-5, Appendix 10). Both Hordeum jubatum and Puccinellia nuttalliana have fungal temporal groups in three periods. These are: I(T_1-T_4); II(T_5-T_6); III(T_7) (Fig. 2-6, Appendix 11) for H. jubatum, and I(T_1-T_2); II(T_3-T_4); III(T_5-T_7) (Fig. 2-7, Appendix 12) for P. nuttalliana.

Spatial Groups

On Salicornia europaea, those species appearing only during the early period (i.e., the first temporal group) include: Alternaria citri M.B. Ellis et Pierce, A. phragmospora, Aureobasidium pullulans (De Bary) Arnand, Cladosporium herbarum (Pers.) Link ex S.F. Gray, Monodictys pelagica, Mucor hiemalis, Scytalidium lignicola and Trichocladium achrasporum (Fig. 2-8). Fungal species of the early to middle temporal groups are: Epicoccum purpurasens Ehrenb. ex Schlecht, Stemphylium botryosum and Trichoderma koningii. Acremonium furcatum and sterile white mycelia are in all four temporal groups but are most-prevalent in the early groups. Phoma glomerata is about equally frequent across temporal groups. Species restricted to the two middle temporal groups are: Alternaria petrosilini (Neergaard ex

Figs. 2-2 to 7. Principal component analysis of the total number of isolations from various fungal taxa over 1982 (▲) and 1983 (●) collecting dates on

Salicornia europaea (Fig. 2-2)

Suaeda depressa (Fig. 2-3)

Atriplex patula (Fig. 2-4)

and over 1982 (▲) collecting dates on

Glaux maritima (Fig. 2-5)

Hordeum jubatum (Fig. 2-6)

Puccinellia nuttalliana (Fig. 2-7).

Time designates and actual dates are given in Appendices 1-6 for each plant.

Fig.2-Salicornia europaea

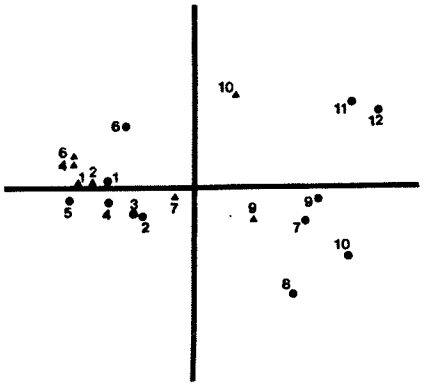


Fig3-Suaeda depressa

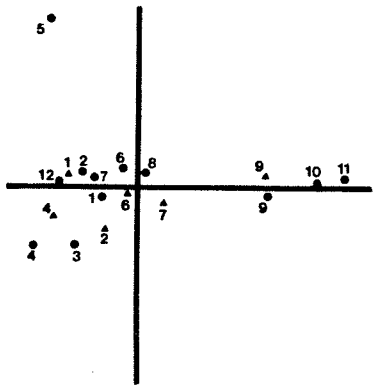


Fig4-Atriplex patula

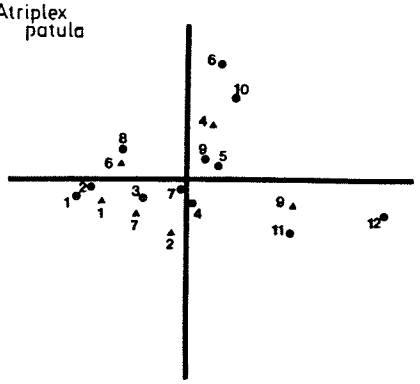


Fig5-Glaux maritima

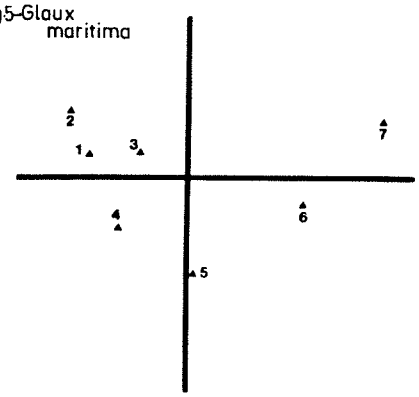


Fig6-Hordeum jubatum

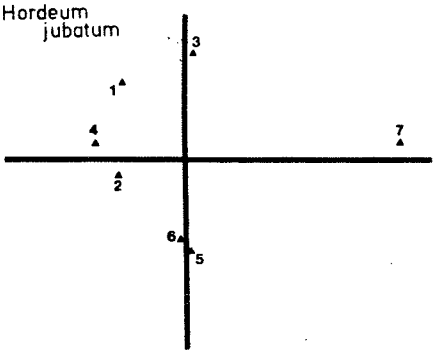


Fig7-Puccinellia nuttalliana

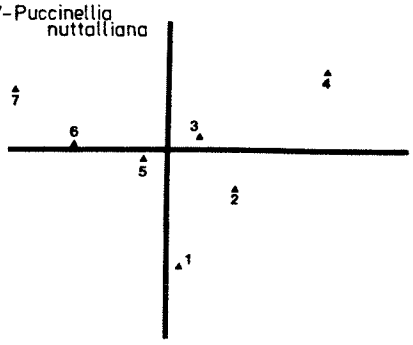
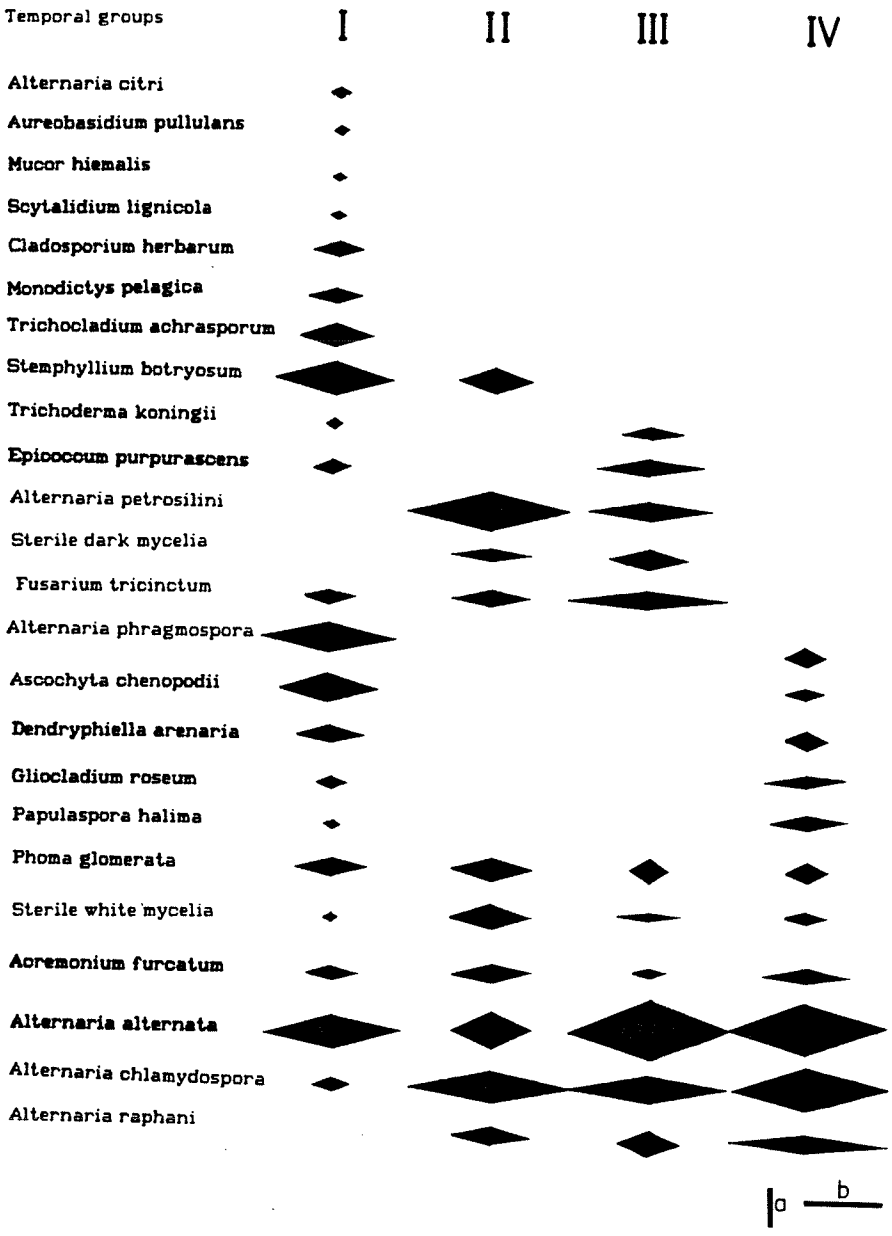


Fig. 2-8. Spatial groups over time of various fungal taxa on Salicornia europaea. Vertical bar a = 5% frequency, and horizontal bar b = 50% occurrence as calculated from Appendix 19.


Temporal groups
I
II
III
IV
Alternaria citri
Aureobasidium pullulans
Mucor hiemalis
Scytalidium lignicola
Cladosporium herbarum
Monodictys pelagica
Trichocladium achrasporum
Stemphyllium botryosum
Trichoderma koningii
Epicoccum purpurascens
Alternaria petrosilini
Sterile dark mycelia
Fusarium tricinctum
Alternaria phragmospora
Ascochyta chenopodii
Dendryphiella arenaria
Gliocladium roseum
Papulaspora halima
Phoma glomerata
Sterile white mycelia
Acremonium furcatum
Alternaria alternata
Alternaria chlamydospora
Alternaria raphani
a
b

Simmons) M.B. Ellis and sterile dark mycelia. Ascochyta chennopodii, Dendryphiella arenaria, Gliocladium roseum Bain. and Papulaspora halima occur in the first and last temporal groups. Species across the temporal groups but most-prevalent late in the collections are: Alternaria alternata, A. chlamydospora and Fusarium tricinctum. Alternaria raphani is in the middle to late temporal groups.

On Suaeda depressa, Cladosporium herbarum and Stemphylium botryosum are restricted to the early temporal group (Fig. 2-9). Alternaria citri and Mucor hiemalis are found in the early to middle temporal groups. Alternaria dennisii and Dendryphiella arenaria occur in all three temporal groups but are most-common early in the collecting season. Alternaria tenuissima (Kunze ex Pers.) Wiltshire, Arthrinum phaeospermum (Corda) M.B. Ellis, Ascochyta chenopodii and Phoma glomerata are equally frequent across all three temporal groups. Those species restricted to the early and late periods are: Epicoccum purpurascens, sterile dark mycelia and Trichoderma koningii. Occurring across all the groups, Alternaria alternata, Fusarium tricinctum and sterile white mycelia are most-frequent in the late temporal groups. Drechslera halodes (Drechsler) Subram. et Jain is restricted to the late temporal group.

Of the fungi from Atriplex patula, Trichoderma koningii is found only in the early collections (Fig. 2-10). Alter-

Fig. 2-9. Spatial groups over time of various fungal taxa on Suaeda depressa. Vertical bar a = 5% frequency, and horizontal bar b = 50% occurrence as calculated from Appendix 20.

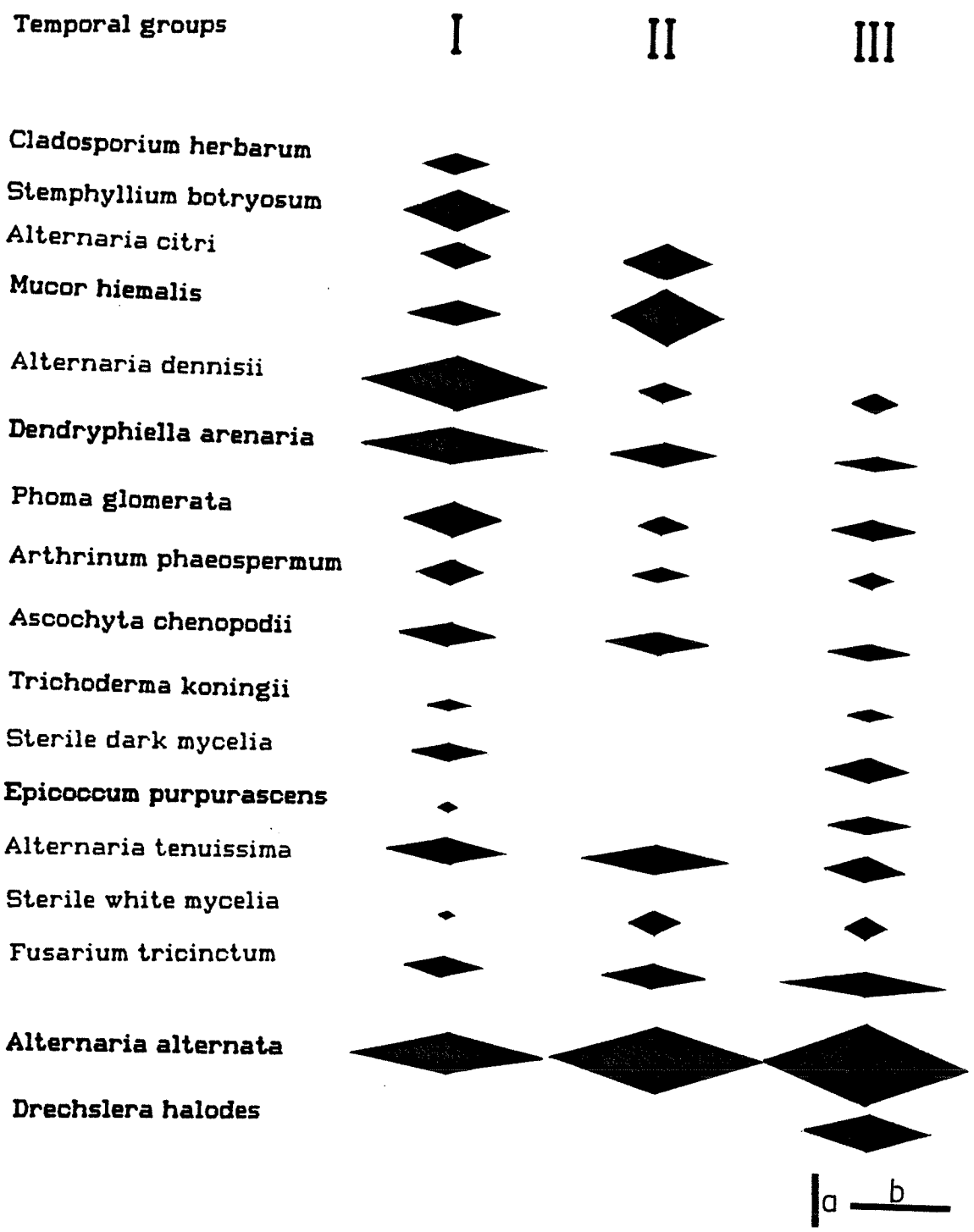
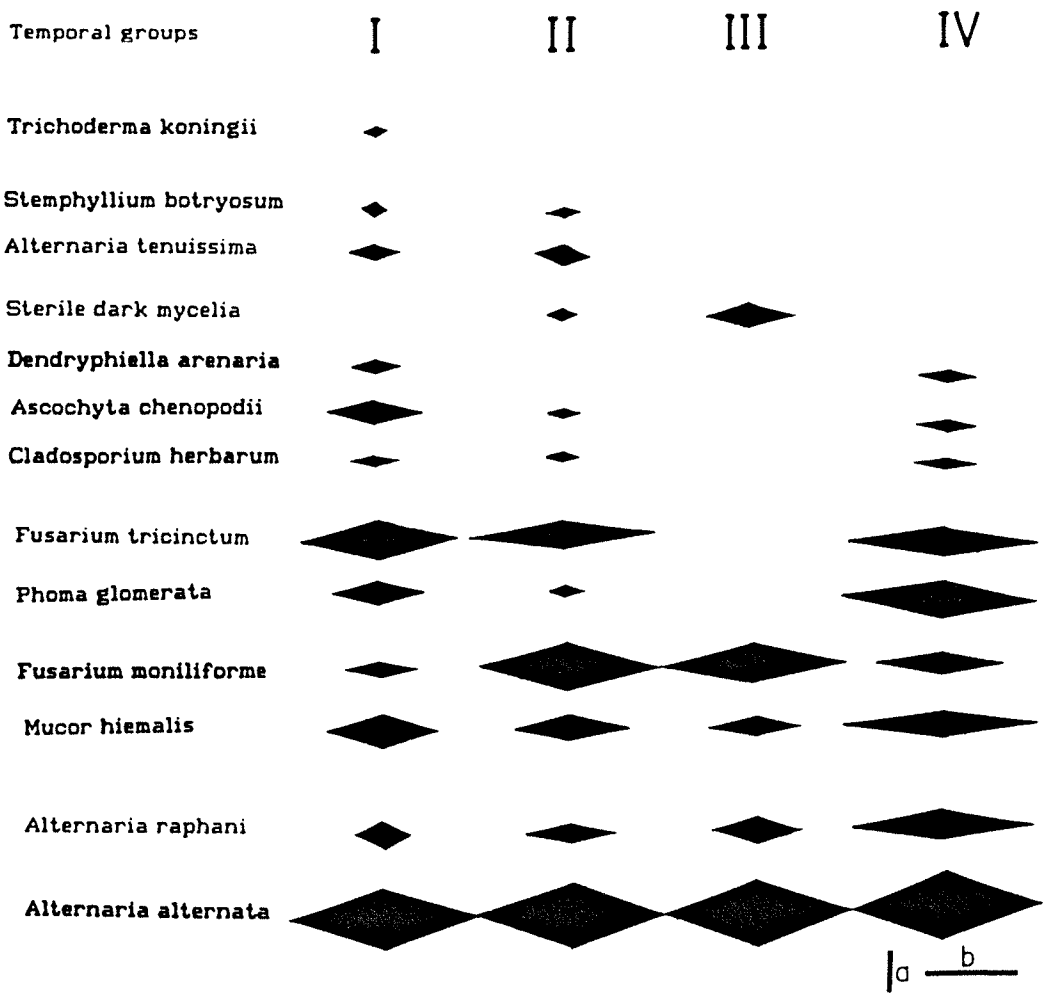

Temporal groups
I
II
III
Cladosporium herbarum
Stemphyllium botryosum
Alternaria citri
Mucor hiemalis
Alternaria dennisii
Dendryphiella arenaria
Phoma glomerata
Arthrinum phaeospermum
Ascochyta chenopodii
Trichoderma koningii
Sterile dark mycelia
Epicoccum purpurascens
Alternaria tenuissima
Sterile white mycelia
Fusarium tricinctum
Alternaria alternata
Drechslera halodes
a
b

Fig. 2-10. Spatial groups over time of various fungal taxa on Atriplex patula. Vertical bar a = 5% frequency, and horizontal bar b = 50% occurrence as calculated from Appendix 15.

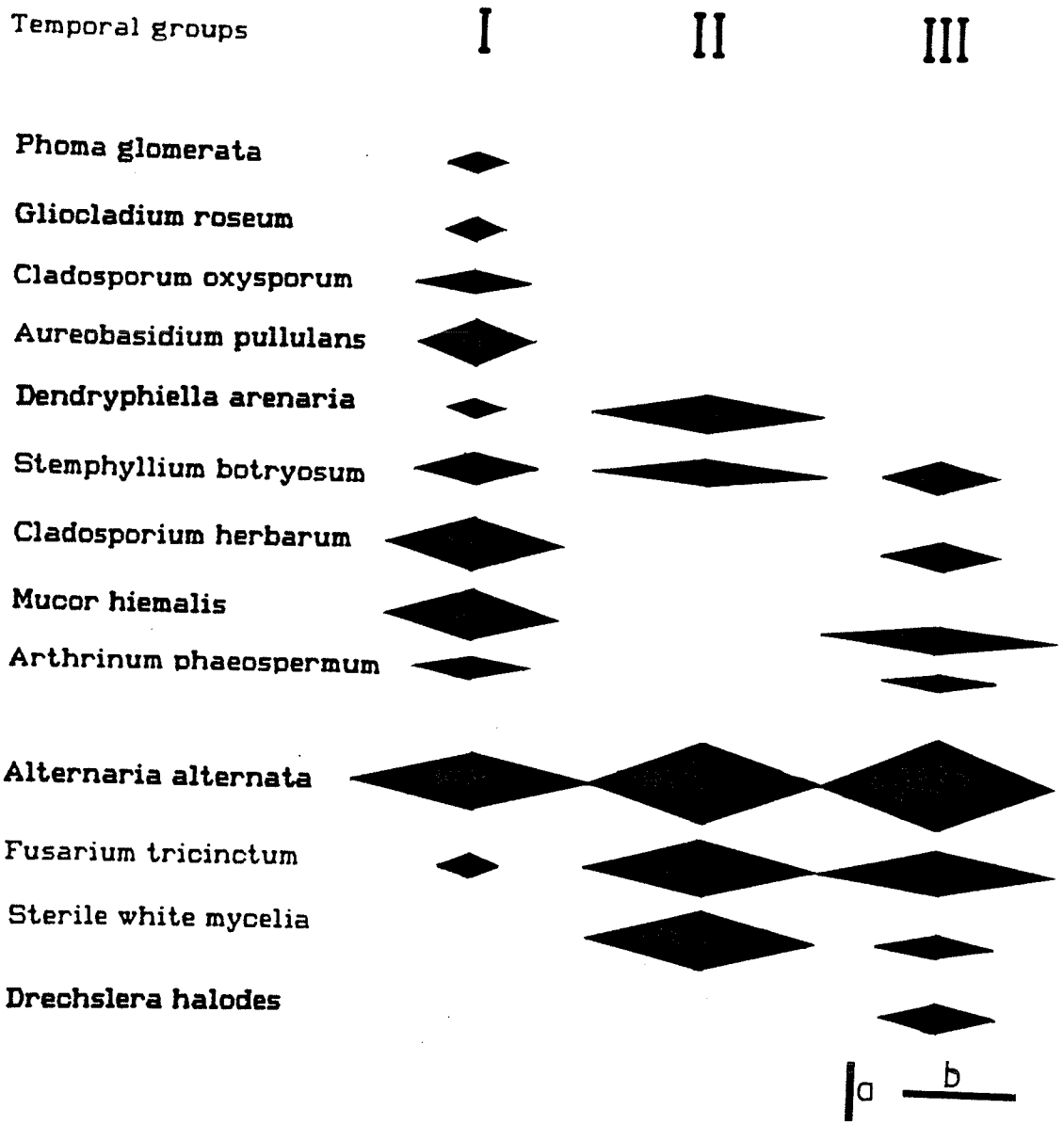

Temporal groups
I
II
III
IV
Trichoderma koningii
Stemphyllium botryosum
Alternaria tenuissima
Sterile dark mycelia
Dendryphiella arenaria
Ascochyta chenopodii
Cladosporium herbarum
Fusarium tricinctum
Phoma glomerata
Fusarium moniliforme
Mucor hiemalis
Alternaria raphani
Alternaria alternata
a
b

naria tenuissima and Stemphylium botryosum are of the early to middle temporal groups. Across all four groups, Ascochyta chenopodii is most-frequent in the earliest dates; Alternaria alternata, Cladosporium herbarum, Fusarium tricinctum and Mucor hiemalis are equally frequent across all the groups, while sterile dark mycelia are restricted to the middle groups, and Dendryphiella arenaria is found only in the beginning and ending temporal groups. Alternaria raphani, Fusarium moniliforme and Phoma glomerata are most-frequent late in the collections, though they occur in all groups.

Aureobasidium pullulans, Cladosporium oxysporum, Gliocladium roseum and Phoma glomerata are restricted to the early temporal group of the fungi on Glaux maritima (Fig. 2-11). Dendryphiella arenaria is found in the early and middle groups. Alternaria alternata and Stemphylium botryosum are almost equally frequent over all three temporal groups. Arthrinum phaeospermum, Cladosporium herbarum and Mucor hiemalis are found in the early and late groups. Fusarium tricinctum is in all three temporal groups but is most-frequent in the late one. Sterile while mycelia are found in the middle and late collections, and Drechslera halodes is restricted to the late group.

In the three temporal groups of Puccinellia nuttalliana, Alternaria dennisii and Gliocladium roseum are restricted to

Fig. 2-11. Spatial groups over time of various fungal taxa of Glaux maritima. Vertical bar a = 5% frequency, and horizontal bar b = 50% occurrence as calculated from Appendix 16.


Temporal groups
I
II
III
Phoma glomerata
Gliocladium roseum
Cladosporum oxysporum
Aureobasidium pullulans
Dendryphiella arenaria
Stemphyllium botryosum
Cladosporium herbarum
Mucor hiemalis
Arthrinum phaeospermum
Alternaria alternata
Fusarium tricinctum
Sterile white mycelia
Drechslera halodes
a
b

the early collections (Fig. 2-12). Arthrinum phaeospermum and Cladosporium herbarum are found in the early and middle temporal groups. Across all the groups, Dendryphiella arenaria is most-prevalent early in the collections. Mucor hiemalis is restricted to the middle temporal group, while Alternaria alternata and Fusarium tricinctum occur in all groups but are most-frequent in the late one. Stemphylium botryosum appears in the middle to late temporal groups. Alternaria petrosilini, Drechslera halodes, Phoma glomerata, Scytalidium lignicola and sterile while mycelia are restricted to the late group.

On Hordeum jubatum, the fungal assemblage also appears in three temporal groups (Fig. 2-13). Cladosporium herbarum, Gliocladium roseum and Mucor hiemalis are restricted to the early group. Arthrinum phaeospermum, Phoma glomerata and Stemphylium botryosum are found in the early and middle temporal groups. Occurring in all three groups, Dendryphiella arenaria is most-frequent in the early group, while Alternaria alternata is about equally frequent in all the groups, and Fusarium tricinctum is most-frequent in the late group. Sterile while mycelia is observed in the middle to late temporal groups, and Alternaria petrosilini and Drechslera halodes are restricted to the late group.

Fig. 2-12. Spatial groups over time of various fungal taxa on Puccinellia nuttalliana. Vertical bar a = 5% frequency, and horizontal bar b = 50% occurrence as calculated from Appendix 17.

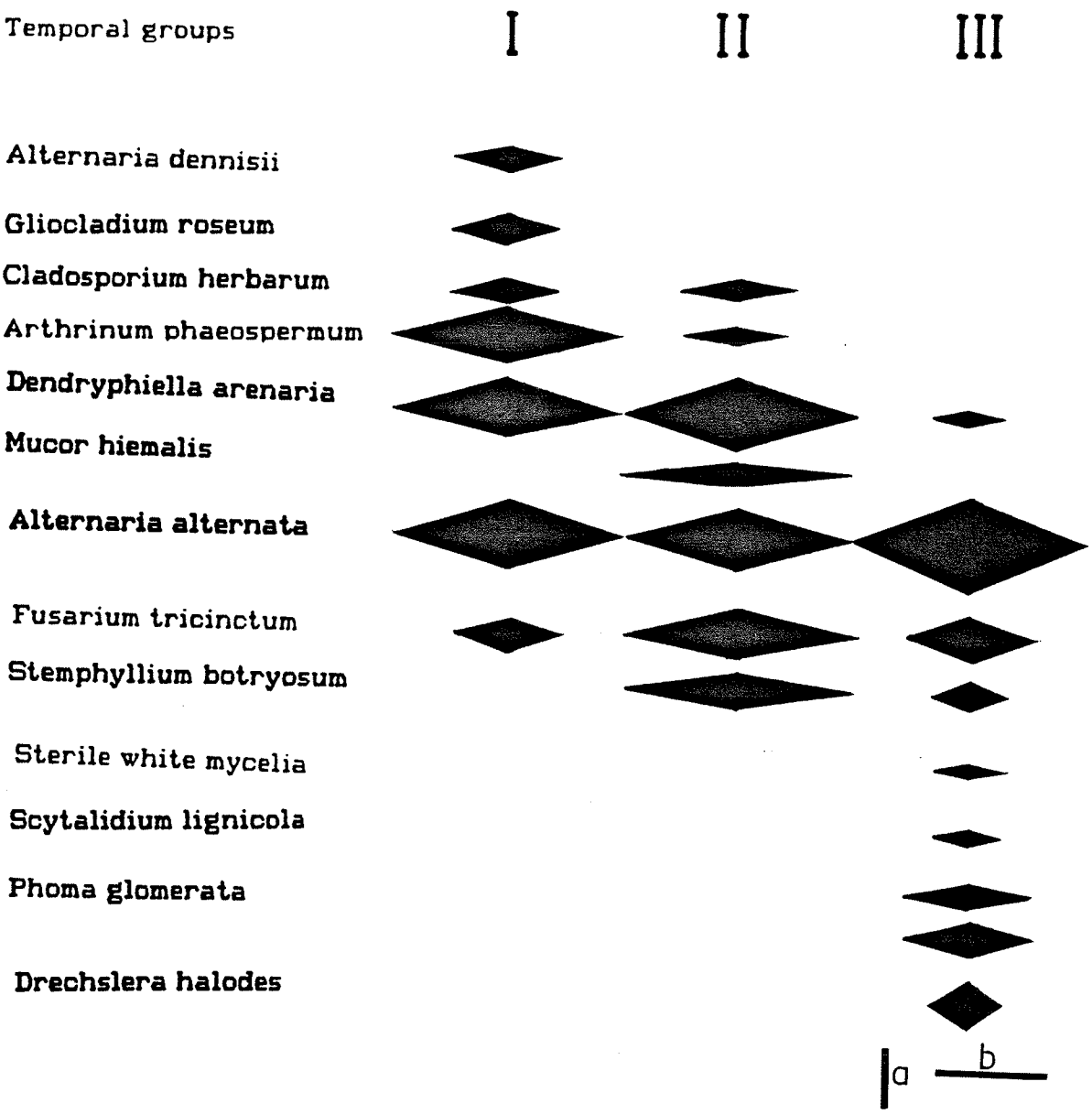
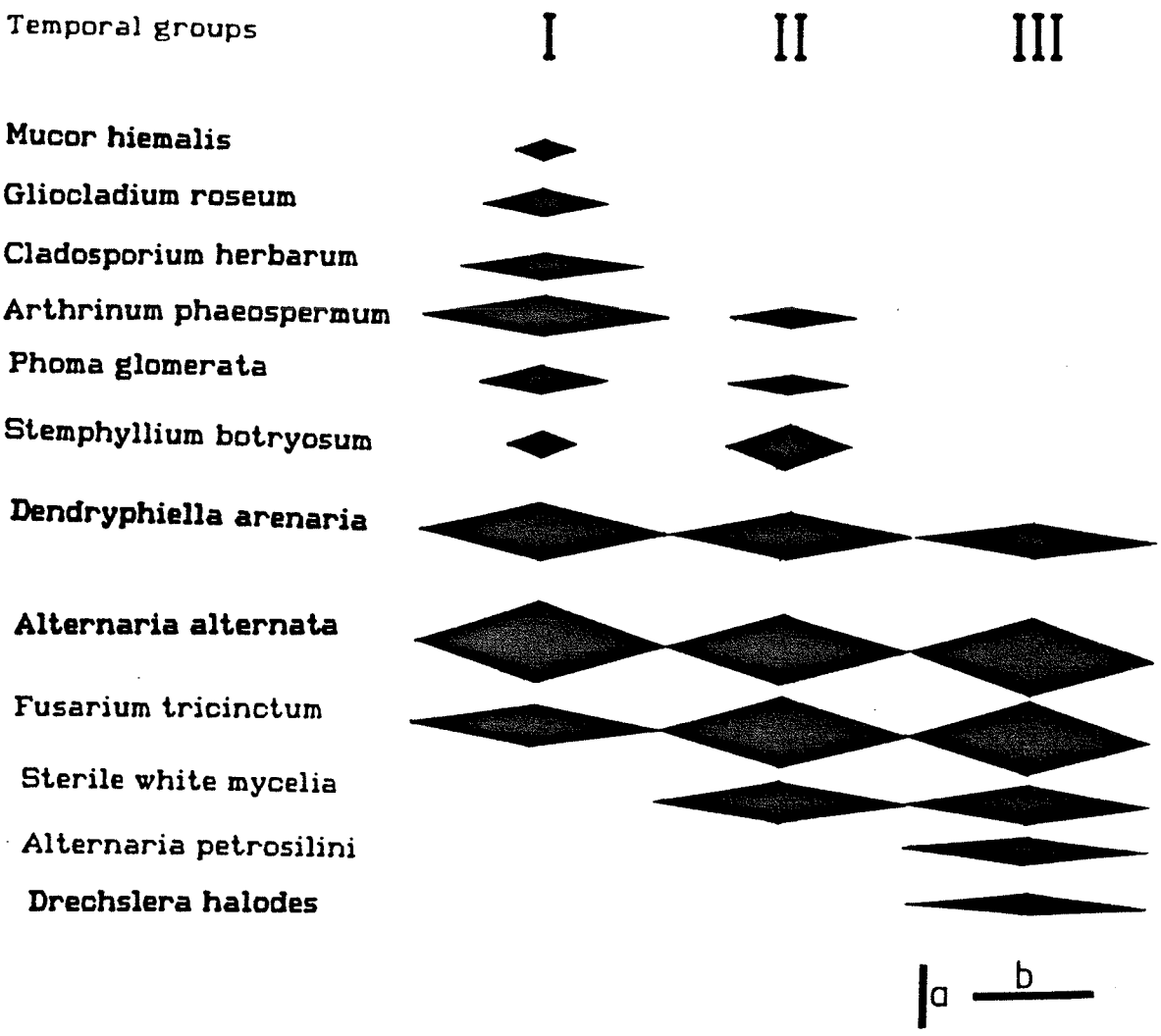

Temporal groups
I
II
III
Alternaria dennisii
Gliocladium roseum
Cladosporium herbarum
Arthrinum phaeospermum
Dendryphiella arenaria
Mucor hiemalis
Alternaria alternata
Fusarium tricinctum
Stemphyllium botryosum
Sterile white mycelia
Scytalidium lignicola
Phoma glomerata
Drechslera halodes
a
b

Fig. 2-13. Spatial groups over time of various fungal taxa on Hordeum jubatum. Vertical bar a = 5% frequency, and horizontal bar b = 50% occurrence as calculated from Appendix 18.


Temporal groups
I
II
III
Mucor hiemalis
Gliocladium roseum
Cladosporium herbarum
Arthrinum phaeospermum
Phoma glomerata
Stemphyllium botryosum
Dendryphiella arenaria
Alternaria alternata
Fusarium tricinctum
Sterile white mycelia
Alternaria petrosilini
Drechslera halodes
a
b

Dominance

The fungal assemblage on Salicornia europaea shows, as previously determined by principal component analysis, four temporal groups (Table 2-7). The community dominance (as calculated from Appendix 19) changes over these groups, i.e., temporal I at 33%; temporal II at 45%; temporal III at 68% and temporal IV at 35%. Alternaria alternata is dominant in periods I, III and IV (Appendix 19). In the first time period, it is codominant with Alternaria phragmospora and Stemphylium botryosum. Alternaria petrosilini is dominant in the second time period. Subdominant and common organisms are different in each of the four temporal groups.

Community dominance (as calculated from Appendix 20) on Suaeda depressa is: 37% in temporal I; 64% in temporal II and 68% in temporal III. Alternaria alternata is codominant with A. dennisii in the first time period (Appendix 20) and dominant in the second and third time periods (Table 2-7). Subdominants include Dendryphiella arenaria, Drechslera halodes, Mucor hiemalis and Stemphylium botryosum, and common organisms are Alternaria citri, A. tenuissima and Phoma glomerata. Both subdominant and common taxa are different for each of the temporal groups.

Alternaria alternata is the dominant organism on Atriplex patula (Table 2-7), and community dominance is: tempor-

TABLE 2-7

Dominance functions, i.e., community dominance and classification of organisms, over the temporal groups for the six plants

	Temporal I	Temporal II	Temporal III	Temporal IV
Salicornia europaea				
Community dominance ...	33%	45%	68%	35%
Dominants	A. alternata A. phragmospora S. botryosum	A. petrosilini	A. alternata	A. alternata
Subdominants	A. chenopodii	A. alternata	A. chlamydospora A. raphani	A. chlamydospora
Common	T. achrasporum	A. chlamydospora	sterile dark mycelia	F. tricinctum
Suaeda depressa				
Community dominance ...	37%	64%	68%	
Dominants	A. alternata A. dennisii	A. alternata	A. alternata	
Subdominants	D. arenaria S. botryosum	M. hiemalis	D. halodes	
Common	P. glomerata	A. citri	A. tenuissima	
Atriplex patula				
Community dominance ...	57%	74%	69%	68%
Dominants	A. alternata	A. alternata	A. alternata	A. alternata
Subdominants	F. tricinctum	F. moniliforme		P. glomerata
Common	M. hiemalis	F. tricinctum	A. raphani	
Glaux maritima				
Community dominance ...	43%	65%	73%	
Dominants		A. alternata	A. alternata	
Subdominants	A. alternata		F. tricinctum	
Common	A. pullulans C. herbarum M. hiemalis	F. tricinctum sterile white mycelia		
Hordeum jubatum				
Community dominance ...	66%	61%	77%	
Dominants	A. alternata			
Subdominants	D. arenaria	A. alternata F. tricinctum	A. alternata F. tricinctum	
Puccinellia nuttalliana				
Community dominance ...	61%	64%	74%	
Dominants	A. alternata	D. arenaria	A. alternata	
Common	D. arenaria	A. alternata	F. tricinctum	

al I at 57%; temporal II at 74%; temporal III at 69% and temporal IV at 68% over all four time periods (Appendix 15). Subdominants, including Fusarium moniliforme, F. tricinctum and Phoma glomerata, are individually restricted to three of the temporal groups. Common taxa, i.e., Alternaria raphani, Fusarium tricinctum and Mucor hiemalis are again singularly restricted to three of the time periods.

On Glaux maritima, community dominance is temporal I at 43%; temporal II at 65% and temporal III at 73% (Appendix 16). On Hordeum jubatum, community dominance is temporal I at 66%; temporal II at 61% and temporal III at 77% (Table 2-7, Appendix 17). Alternaria alternata is the only dominant organism when a dominant is present. Subdominants on this plant are: Alternaria alternata, Dendryphiella arenaria and Fusarium tricinctum. The subdominant combination of A. alternata and F. tricinctum is similar for the second and third temporal groups on H. jubatum.

Fungi on Puccinellia nuttalliana have a community dominance of 61% in the first temporal group; 64% in the second group and 74% in the third group (Table 2-7, Appendix 18). Alternaria alternata is dominant in the first and last time period, and Dendryphiella arenaria is dominant in the middle period. Common taxa, including A. alternata, Dendryphiella arenaria and F. tricinctum, are different for each of the time periods.

Life Spectra

Employing the methods previously mentioned in this study, it is possible to designate, albeit somewhat arbitrarily, the various fungi as to their appropriate life strategies. Competitors include: Alternaria citri, A. dennisii, A. phragmospora, Arthrinum phaeospermum, Fusarium moniliforme, Gliocladium roseum, Monodictys pelagica, Mucor hiemalis, Papulaspora halima and Scytalidium lignicola. The next largest group are the escapers, which include: Alternaria petrosilini, A. raphani, A. tenuissima, Dendryphiella arenaria, Drechslera halodes, Stemphylium botryosum and Trichocladium achrasporum. Survivors are constituted by: Ascochyta chenopodii, Aureobasidium pullulans, Epicoccum purpurascens, Phoma glomerata, sterile dark mycelia and sterile white mycelia. Ruderal fungi are: Acremonium furcatum, Cladosporium herbarum, C. oxysporum and Trichoderma koningii. Finally, the stress-tolerant forms are considered to be: Alternaria alternata, A. chlamydospora and Fusarium tricinctum.

The sums of the distribution intensity index (DII) (derived from Appendices 15-20) within each of these strategies are represented as a series of life spectra (Figs. 2-14 to 19) for the fungi associated with each plant.

Generally, the life spectra are increasingly attenuated

Figs. 2-14 to 19. Life spectra over time of the fungal assemblage on

Atriplex patula (Fig. 2-14)

Glaux maritima (Fig. 2-15)

Hordeum jubatum (Fig. 2-16)

Puccinellia nuttalliana (Fig. 2-17)

Salicornia europaea (Fig. 2-18)

Suaeda depressa (Fig. 2-19).

For each plant, the bars represent the sum of the DII of all fungal species in the respective life strategies as calculated from Appendices 15-20.

Ruderals

Survivors

Escapers

Competitors

Stress-tolerant

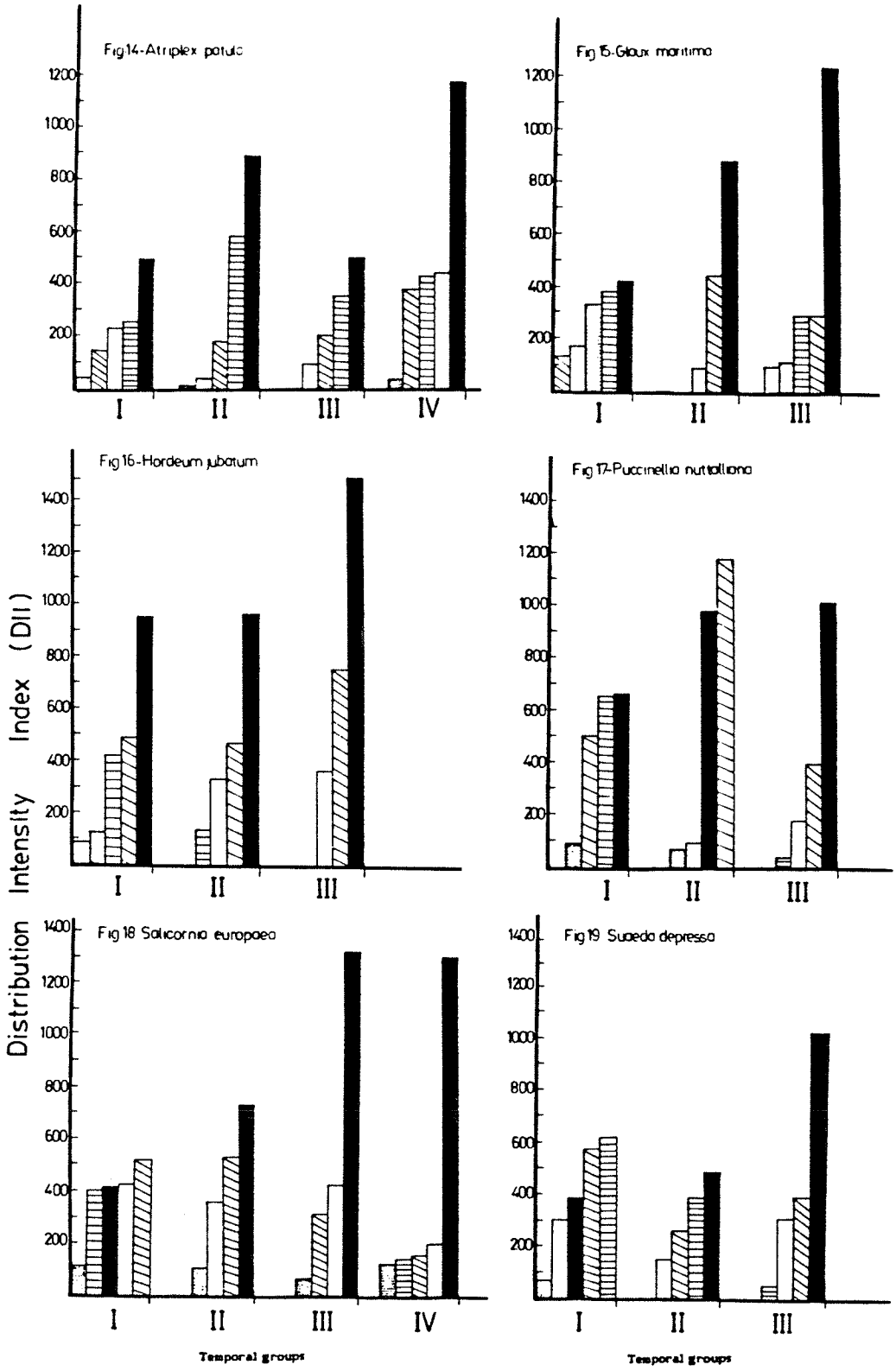


Fig 14-Atriplex patula
Fig 15-Glaux maritima
Fig 16-Hordeum jubatum
Fig 17-Puccinellia nuttalliana
Fig 18 Salicornia europaea
Fig 19 Suaeda depressa
Intensity Index (DII)
Distribution
I
II
III
IV
Temporal groups

over the temporal groups for each of the plants. Stress-tolerant fungi are the most-numerous forms in all the spectra of Atriplex patula, Glaux maritima, Hordeum jubatum and Puccinellia nuttalliana (Figs. 2-14 to 17, respectively). The first spectra of Salicornia europaea (Fig. 2-18) and Suaeda depressa (Fig. 2-19) are most-notably characterized by escapers and competitors, respectively. Escapers are most-frequent in the middle spectrum of P. nuttalliana (Fig. 2-17). When considering the first and the second most-prevalent forms in the spectra, it is seen that spectra III and IV of S. europaea (Fig. 2-18) are similar. This is also true for spectra I through III of A. patula (Fig. 2-14); I and III and II and III of G. maritima (Fig. 2-15), and I through III of H. jubatum (Fig. 2-16).

DISCUSSION

Fungi are more-frequently isolated from Salicornia europaea than any of the other plants. Generally, Glaux maritima, Hordeum jubatum and Puccinellia nuttalliana have noticably lower numbers of isolates than S. europaea, Suaeda depressa and Atriplex patula. This is, in part, a result of fewer collections (the 1982 dates only) for G. maritima, H. jubatum and P. nuttalliana. However, when the percentage isolation is corrected, i.e., % isolation times 1.0 - 7/19, for G. maritima (corrected to 13%), H. jubatum

(corrected to 15.3%) and P. nuttalliana (corrected to 15.8%), the values are still lower than those of S. europaea, S. depressa and A. patula. The markedly varied number of isolations may also be somewhat related to the morphological and physiological nature of the plants. It is reported that surface chemistry (Cutter 1976; Godfrey 1976; Esquerre-Tagaye et al. 1979), surface physical nature (H.B. Johnson 1975), age of the plant (Ruinen 1961) and surface exudates and guttation (Goatly and Lewis 1966) play a role in fungal presence and absence on plants in general. Perhaps the surface of G. maritima, H. jubatum and P. nuttalliana are fundamentally different from those of S. europaea, S. depressa and A. patula.

More possibly the difference in the isolation of fungi from Salicornia europaea, Suaeda depressa and Atriplex patula as compared with Glaux maritima, Hordeum jubatum and Puccinellia nuttalliana may be related to salt levels in the plants and their concomitant osmotic strategy. The salt levels in the tissues and organs of S. europaea, S. depressa and A. patula are greater than in G. maritima, H. jubatum and P. nuttalliana (Williams and Ungar 1972; Ungar 1974; Austenfeld 1974; T.J. Flowers 1975; Albert 1975; Rozema et al. 1978; Ungar et al. 1979; Riehl and Ungar 1982; Cooper 1982). Salicornia europaea, Suaeda depressa and Atriplex patula are euhalophytes (Waisel 1972; Maas and Nieman 1978). The osmotic strategy of the salt-requiring S. europaea and S. depressa is to maintain osmotic balance with the external

environment by accumulating salts (T.J. Flowers 1975; Jefferies 1981). A. patula is salt-resistant and its osmotic strategy is to exclude salts by their accumulation in various plant tissues and structures (Waisel 1972), excretion and elimination of salts (Maas and Nieman 1978), and/or to produce osmotically active compounds (Storey and Wyn Jones 1979; Bennert and Schmidt 1984) such as amino acids, glycine-betaine, organic acids, oxalate and soluble carbohydrates. Glaux maritima is a salt-evading euhalophyte (Waisel 1972). The osmotic strategy of G. maritima is to take up salts and to subsequently exert excessive levels of sodium and chloride. Potassium is maintained at a high and constant internal level, permitting the plant to evade the detrimental effects of sodium and chloride (Rozema and Riphagen 1977). Such plants, which purposefully eliminate salts, may be called "crinohalophytes" (Adriani 1956). H. jubatum and P. nuttalliana are salt-avoiding pseudohalophytes (Waisel 1972) or facultative halophytes (Ungar 1974). This avoidance is accomplished by production of osmotically active amino acids. Proline, such an amino acid, is produced in quantities of 68.4 to 88.5 µmol/gfw in H. vulgare L.; 25.2 µmol/gfw in G. maritima; 7.0 µmol/gfw in Suaeda macrocarpa Mug. and 3.3 µmol/gfw in S. maritima (L.) Dum.; 3.2 µmol/gfw in Atriplex hastata L. and 2.5 µmol/gfw in A. spongiosa F. Muell. and 0.2 to 2.8 µmol/gfw for Salicornia europaea (Stewart and Lee 1974; Storey and Wyn Jones 1979; Tully et al. 1979; Briens

and Larher 1982).

Considering the various pairings of plants, using the similarity indices IS_T and IS_j and the coefficient of association, it may be observed that there is a clear relationship of the fungal assemblages of Salicornia europaea and Suaeda depressa. The relationship of the fungi from Glaux maritima, Hordeum jubatum and Puccinellia nuttalliana is even stronger. Atriplex patula appears to be markedly separated from G. maritima, H. jubatum and P. nuttalliana and not clearly associated with S. europaea and S. depressa when comparing the fungal assemblages. These patterns of similarity conform with the salt levels and osmotic strategies of the plants.

The negative coefficient of association, i.e., V, of Salicornia europaea with most of the plants perhaps results from a greater number of total taxa than on the other plants. Also the high number, i.e., seven, of endemic fungal species on S. europaea would negatively affect the calculated coefficient. Krebs (1978) states that V is more-effective when the number of taxa and the quadrate size are approximately equal.

Four taxa (cf., Alternaria alternata, A. dennisii, Dendryphiella arenaria and Stemphylium botryosum) of the nine species accounting for 75% of all isolates from the six plants, in addition to Alternaria petrosilini and A.

phragmospora, represent the dominant species (Table 2-7, Figs. 2-8 to 13). Alternaria alternata, dominant in most of the temporal groups across the plants, Dendryphiella salina (Suth.) Pugh et Nicot, a species somewhat similar to D. arenaria, and Phoma sp. are known to produce a wide variety of exoenzymes at comparatively high levels (Gessner 1980). Perhaps this wide range of exoenzymes is the basis of the dominance of A. alternata and some of the other fungi in this study. Fungal diversity and dominance are interrelated when considering the six plants.

There are two general diversity patterns over the six plants. The first pattern, typical of the fungi on Salicornia europaea, Suaeda depressa and Atriplex patula, is an early diversity high and a middle season low. Fungi on S. depressa and A. patula are also markedly diminished in their diversity at or near the end of the season. In fact, the diversity lows in A. patula are earlier than in S. depressa. The fungi on Glaux maritima, Hordeum jubatum and Puccinellia nuttalliana generally demonstrate no pronounced diversity high and diversity is low at the end of the season. Generally, dominance is conversely related to diversity in that when diversity is high, dominance is low and when diversity is low, dominance is high. This was generally observed by other workers for various fungal seres (Garrett 1951, 1956, 1963; Swift 1976; Frankland 1981). Finally, fungal diversity and dominance responses seem to follow the general

salts and osmoregulation patterns of the plants.

On each of the plants, the fungal assemblages change over the temporal groups. This is, in part, demonstrated by the species-based principal component analysis (Figs. 2-2 to 7) and the subsequent recognition of the temporal groups. Also the community dominance and taxa of the dominance classes shift over the temporal groups (Table 2-7). Furthermore, the species composition is altered over the temporal groups of each plant, as seen in the presentation of spatial groups (Figs. 2-8 to 13).

Changing diversity, dominance and species composition over time on each of the plants suggests successional changes in the mycota. Two basic types of fungal succession have been described (Park 1968; Swift 1976; Frankland 1981). These types are basically: (1) substrate succession and (2) seral succession. Seral succession may be "primary" or "secondary", depending on whether or not the substrate has been disturbed.

Application of the concept of ecological succession to this study results in denoting the fungal assemblages as seres. The fungi of the various temporal groups are herewith termed "seral communities" where applicable.

The sere of Salicornia europaea is divisible into three communities, i.e., the fungi of temporal I, temporal II and

temporals III and IV combined. These seral communities are based on differences in their dominant and subdominant taxa (Table 2-7) and life spectra (Figs. 2-14 to 19). Fungi of the first three temporal groups and the fourth temporal group delineate the two seral communities on Atriplex patula. Seral communities of Suaeda depressa and Puccinellia nuttalliana are recognizable in each of their temporal groups. The fungi of the first temporal group and the second combined with the third temporal groups delineate the seral communities of Glaux maritima and Hordeum jubatum.

There seems to be a relationship between the seral communities and the osmotic strategies of the plants. For example, the Salicornia europaea sere succeeds to the next stage when salts are reported to build up in the plant, i.e., July (Riehl and Ungar 1982), and it changes again when the salts decrease in the tissues. For comparison, the sere on Suaeda depressa is different in each of the temporal groups. It is interesting to note that the salts continue to increase in the plant tissues until the plant stops growing and dies (Williams and Ungar 1972; T.J. Flowers and Hall 1978).

One feature of seral succession, as seen in this study and previously mentioned (Park 1968; Frankland 1981), is its correlation with biotic events within the substrate. Early seral groups on the Delta Marsh halophytes result from pri-

mary seral succession, but concomitant with salt uptake in some of the plants it is possible that the communities result from secondary seral succession. As the plant dies, the functional form of sere change probably involves substrate succession which is correlated with the availability of nutrient (Swift 1976).

Despite inherent weaknesses in this study, such as: (1) a need for equivalent and increased sampling dates over the field season, (2) the indirect measurement of fungal quantity by frequency of isolation, (3) expression of dominance based on means and standard deviations of frequency rather than density or biomass, and (4) subjective assignments of life strategies to derive life spectra, it is possible to conclude that the fungal seres are different on each of the plants. Secondly, there may be a direct or indirect relationship between the nature of the seres and the osmotic strategies of the plants. Finally, on each plant there are recognizable seral communities based on the dominance functions and the ecological roles (as seen in the life spectra) of the fungi (Pugh 1980; Mueller-Dombois 1981).

CHAPTER 3

COMMUNITY STRUCTURE OF FUNGI ON TREATED *SALICORNIA EUROPAEA* AGG. FROM DELTA MARSH, MANITOBA

INTRODUCTION

The previous chapter (i.e., Chapter 2) indicated that the mycota (sere) on Salicornia europaea agg. can be characterized by levels of diversity, various temporal and spatial groups, specific dominant and subdominant organisms and different ecological strategies based on the life spectra. Ultimately these characteristics are used to derive three seral communities across four temporal groups of the sere.

Frankland (1981) has suggested that little is known about the patterns of spatial relationships and changes within fungal communities over time. She asks: are successional patterns due to the stability of the mycota and/or to changes in the substrate? Although the immediate cause of succession is most probably due to the complex interactions of organisms (fungi in this study), any definite change in the composition of the community is concomitant with a change in the environment (substrate) (Oosting 1956). Certainly any "kick" (Frankland 1981) of the succession of fungi on Salicornia europaea by variously treating the plant should change the physiological and biochemical status of the plant along with the pattern of the fungal community.

Generally, Salicornia europaea treated with sodium nitrate (Jefferies 1977; Jefferies and Perkins 1977), sea salts (Austenfeld 1976; Tiku 1976; Jefferies and Perkins 1977; Jefferies et al. 1979) and irrigated (Cooper 1982) is altered in growth habit, biomass, salt levels, osmoregulatory compounds, water levels and chlorophyll content. Assuming some relationship between fungi on the substrate and the substrate physiology and biochemistry, these treatments may serve to "kick" the normal succession as previously outlined. The purpose of this study is to compare the sere from untreated with those seres from sodium nitrate and sea salt treated and irrigated plants. Any differences in the successional patterns of the seres may establish the role of substrate and mycoflora stability in succession.

METHODS AND MATERIALS

Field Treatments and Fungal Isolations

Plants were collected from 50 x 50 cm permanent plots over 12 collecting dates (June 6 to October 9, 1983). The plots were placed randomly in a low marsh site within the previously described Delta Marsh location (Chapter 2 of this dissertation). Three treatments, i.e., sodium nitrate and Rila sea salt mix additions and irrigation, along with untreated plants were each relegated to four plots. Applica-

tions of the treatments were made on each collecting date. Sodium nitrate solution prepared at a 1.2-M (100 gms/l distilled water) concentration was applied in 100-ml quantities. Rila sea salt mix, herewith termed sea salt, was prepared as a solution of 95% (100 gms/l distilled water) and added in 100-ml quantities. Plants were irrigated using 2.5 l distilled water for each addition.

On each collecting date, 40 plants were gathered from each of the treatments. These were pooled for each treatment and subsequently processed for fungi in University of Manitoba laboratories using methods previously described (Muhsin and Booth 1985).

Data Treatments

After tabulation of fungal isolates from root and shoot pieces under the treatments, various community parameters (i.e., similarity, community dominance, temporal groups, spatial groups, dominance functions and life spectra) were prepared using earlier-described methods (Chapter 2 of this dissertation).

Although not considered in this dissertation, similar methodologies were applied to collections of fungi from Atriplex patula L. and Suaeda depressa (Pursh.) Wats. The reader may wish to consult Appendices 61-82 for the pertinent data.

RESULTS

General Community Structure

Among the 1,156 isolates from 1,080 plated plant pieces, there are 21 different fungal taxa over the three field treatments (Appendices 21-23). At 32.6% for sodium nitrate application, 33.5% for sea salt addition and 33.9% for irrigation, isolations (N/1,156) are almost equivalent over the three treatments. Percentage recovery (N/360) is 104.7% for sodium nitrate, 107.5% for sea salts and 108.9% for irrigation.

Six taxa, Alternaria alternata (Fr.) Keissler at 43.9%, A. chlamydospora Mouchacca at 7.9%, Phoma glomerata (Corda) Wollen. et Hochapfel at 6.8%, Stemphylium botryosum Wallr. at 6.1%, Fusarium tricinctum (Corda) Sacc. at 5.6% and Alternaria phragmospora van Emden at 4.8%, make up a little more than 75% of all the isolates. These six species represent 28.6% of the total mycota on Salicornia europaea under the various treatments. Acremonium furcatum F. et V. Moreau ex Gams, Epicoccum purpurescens Ehrenb. ex Schlecht., Trichocladium achrasporium (Meyers et Moore) Dixon and Trichoderma koningii Oudem are isolated less than 10 times and considered to be very rare. Those species isolated under only one treatment include: Fusarium moniliforme Sheldon for sodium nitrate; Epicoccum purpurescens and Trichochladium achrasporum for sea salt and Alternaria raphani Groves

et Skolko for irrigation.

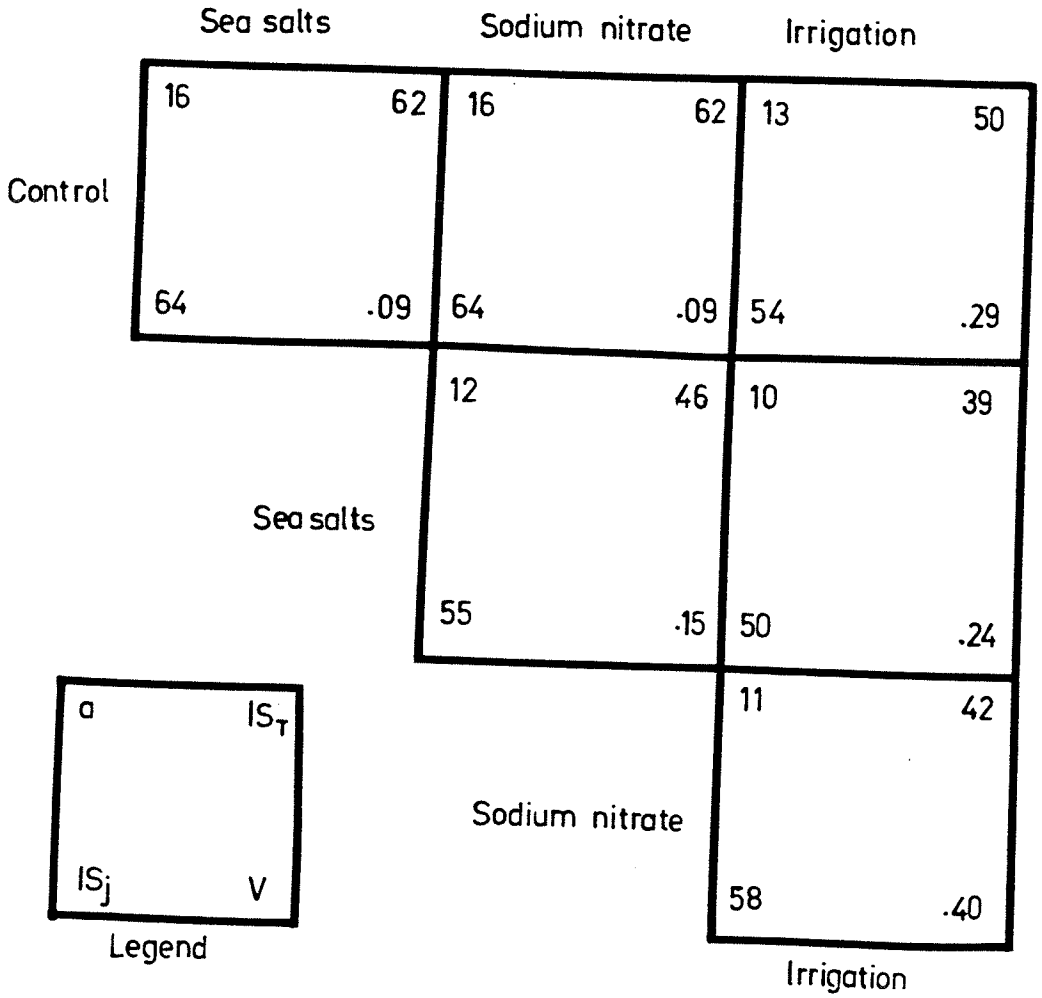
Similarity

Total similarity (IS_T) values for the fungal sere under various treatments are slightly more than one standard deviation above the mean (50.2±9.9) for the combinations of the untreated plants with the sea salt and sodium nitrate treated plants (Fig. 3-1, Appendices 24-25). The IS_T value for the sea salt-irrigation combination is a little more than one standard deviation below the mean value. Jaccard's index is more than one standard deviation above the mean value (57.5±5.7) for the combinations of untreated with sea salts and sodium nitrate. Sea salts combined with irrigation yield an IS_j only slightly a standard deviation below the mean. The coefficient of association (V) between all nine combinations of the treatments is low, and a difference in the probability of association or disassociation is difficult to establish.

Diversity

A total of 25 different fungi are isolated from Salicornia europaea under the various treatments (this includes those fungi on the untreated plants as previously reported in Chapter 2). Under the individual treatments, the number

Fig. 3-1. Similarity indices (i.e., total species in common, a; total similarity, IS_T; Jaccard's index, IS_j; and the coefficient of association, V) of the fungal assemblage on Salicornia europaea under various treatments.


Sea salts
Sodium nitrate
Irrigation
Control
16
62
64
.09
16
62
64
.09
13
50
54
.29
Sea salts
12
46
55
.15
10
39
50
.24
Sodium nitrate
11
42
58
.40
Irrigation
a
IS_T
IS_j
V
Legend

of taxa are: 13 or 52% on the irrigated plants; 17 or 68% on both sodium nitrate and sea salt treated plants; and 24 or 96% on the untreated plants (Appendices 5, 21-23). Simpson's index ranges from .44-.79 ($\bar{X}$ = .67±.13) for the sodium nitrate treatment; from .45-.84 ($\bar{X}$ = .63±.13) for the sea salt treatment; and from .22-.77 ($\bar{X}$ = .46±.16) for the irrigated plants (Table 3-1). Maximum diversity ranges from .67-.86 ($\bar{X}$ = .78±.07) over the isolations from the sodium nitrate plots, and realized diversity is from 60 to 97.5% ($\bar{X}$ = 85.2±11.8) in the same treatments. Values of maximum and realized diversity on the sea salt treated plants are .5-.88 ($\bar{X}$ = .74±.11) and 65.1-95.5% ($\bar{X}$ = 84.2±11.2), respectively. The ranges on the irrigated plants are .7-.83 ($\bar{X}$ = .77±.04) for maximum diversity, and 26.5-93.8% ($\bar{X}$ = 59.3±19.8) for realized diversity.

Low diversity (<$\bar{X}$ minus one standard deviation) occurs during the time periods (T) 7 and 12 on the sodium nitrate treated plants (Table 3-1). According to Simpson's index, there does not seem to be a time of high diversity (>$\bar{X}$ plus one standard deviation) under sodium nitrate treatment. On the sea salt treated plants, high diversity is T_4 and T_5, and low diversity is T_7, T_{10} and T_{11}, while on the irrigated plants, high diversity is T_1 and T_2, and low diversity is T_4 and T_6.

TABLE 3-1

Number of taxa, Simpson's index, maximum diversity (MD) and realized diversity (RD) of fungi on Salicornia europaea under various treatments

Temporal group	Collecting date	No. of taxa	Simpson's index	Maximum diversity (MD)	Realized diversity (RD)	No. of taxa	Simpson's index	Maximum diversity (MD)	Realized diversity (RD)	No. of taxa	Simpson's index	Maximum diversity (MD)	Realized diversity (RD)
		.... Sodium nitrate				..... Sea salt				..... Irrigation			
T_1	6/6	4	0.68	0.75	90.7%	4	0.68	0.75	90.7%	5	0.75	0.80	93.8%
T_2	13/6	7	0.79	0.86	91.9%	4	0.56	0.75	74.7%	5	0.70	0.80	87.5%
T_3	23/6	5	0.78	0.80	97.5%	5	0.74	0.80	92.5%	5	0.40	0.80	50.0%
T_4	3/7	7	0.79	0.86	91.9%	8	0.84	0.88	95.5%	6	0.22	0.83	26.5%
T_5	15/7	6	0.79	0.83	95.2%	7	0.80	0.86	93.0%	3	0.39	0.70	55.7%
T_6	23/7	6	0.78	0.83	93.9%	5	0.66	0.80	82.5%	6	0.26	0.83	31.3%
T_7	6/8	3	0.44	0.67	65.7%	3	0.45	0.67	67.2%	4	0.84	0.75	64.0%
T_8	17/8	4	0.59	0.75	78.7%	6	0.75	0.83	90.4%	4	0.36	0.75	48.0%
T_9	26/8	4	0.67	0.75	89.3%	4	0.54	0.75	65.1%	4	0.55	0.75	73.4%
T_{10}	6/9	5	0.67	0.80	83.8%	3	0.49	0.67	73.2%	4	0.45	0.75	60.0%
T_{11}	17/9	3	0.56	0.67	83.6%	2	0.46	0.50	92.0%	4	0.47	0.75	62.7%
T_{12}	9/10	4	0.45	0.75	60.0%	3	0.63	0.67	94.0%	4	0.44	0.75	58.7%

Temporal Groups

Principal component analysis (Appendices 26-28) of the fungal seres over three treatments demonstrates a temporal separation. Under all three treatments, there are four temporal groups in the fungal assemblage. Sodium nitrate solution addition results in a separation: group I, T_1-T_6 (June 6 to July 23); group II, T_7 and T_8 (August 6 to August 17); group III, T_9 and T_{10} (August 26 to September 6) and group IV, T_{11} and T_{12} (September 17 to October 9) (Fig. 3-2). Temporal groups under sea salt application include: group I, T_1 and T_3-T_5 (June 6 and June 23 to July 15); group II, T_2 (June 13); group III, T_6-T_9 (July 23 to August 26) and group IV, T_{10}-T_{12} (September 6 to October 9) (Fig. 3-3). Groups with irrigation treatment are: group I, T_1-T_5 (June 6 to July 15); group II, T_6 (July 23); group III, T_7 and T_8 (August 6 to August 17) and group IV, T_9-T_{12} (August 26 to October 9) (Fig. 3-4).

Spatial Groups

Under sodium nitrate treatment, several fungi including: Alternaria chlamydospora, A. petrosilini (Neergaard ex Simmons) M.B. Ellis, A. phragmospora, Ascochyta chenopodii Roster, Aureobasidium pullulans (De Bary) Arnand, Cladosporium herbarum (Pers.) Link ex S.F. Gray, Monodictys

Figs. 3-2 to 4. Principal component analysis of the total number of isolations from various fungal taxa on Salicornia europaea under

sodium nitrate (Fig. 3-2)

sea salts (Fig. 3-3)

irrigation (Fig. 3-4).

Time designates and actual dates are given in Appendices 21-23.

Fig.3-2. Sodium nitrate

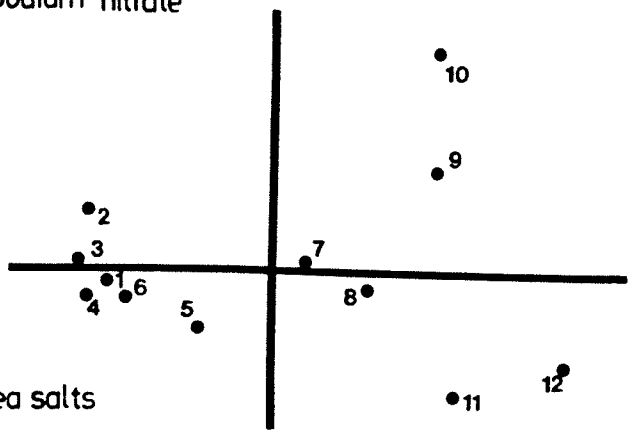


Fig.3-3. Sea salts

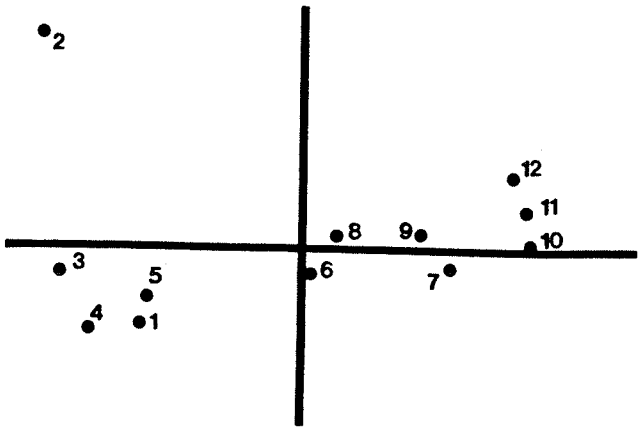
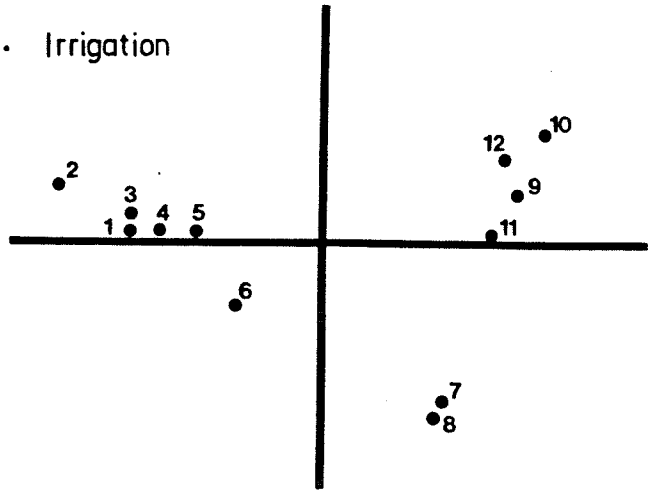


Fig.3-4. Irrigation



pelagica (Johnson) E.B.G. Jones, Stemphylium botryosum and sterile dark mycelia; these are restricted to the early temporal group (Fig. 3-5). Dendryphiella arenaria Nicot, Fusarium tricinctum and Mucor hiemalis Wehmer are found in the early and middle groups, while Trichoderma koningii is found only in the middle group. Sterile white mycelia are present in the early and late temporal groups. Across all four spatial groups, Alternaria alternata and Phoma glomerata are most-frequent in the late groups, and Fusarium moniliforme is found in the middle to late temporal groups.

Alternaria phragmospora, Ascochyta chenopodii, Cladosporium herbarum, Monodictys pelagica and Trichocladium achrasporum are present only in the early temporal group of the sea salt treatment (Fig. 3-6). Early and middle group fungi include: Aureobasidium pullulans, Dendryphiella arenaria, Fusarium tricinctum, Stemphylium botryosum and sterile dark mycelia. Acremonium furcatum, Epicoccum purpurescens and Mucor hiemalis are present only in the middle groups. Most-frequent in the late collections are Alternaria alternata and A. chlamydospora, which occur across all four groups. Alternaria petrosilini is found in the late and middle temporal groups.

Fungi restricted to early collections of irrigated plants are: Acremonium furcatum, Ascochyta chenopodii, Aureobasidium pullulans and Cladosporium herbarum (Fig. 3-7).

Fig. 3-5. Spatial groups over time of various fungal taxa on Salicornia europaea under sodium nitrate treatment. Vertical bar a = 5% frequency, and horizontal bar b = 50% occurrence as calculated from Appendix 29.

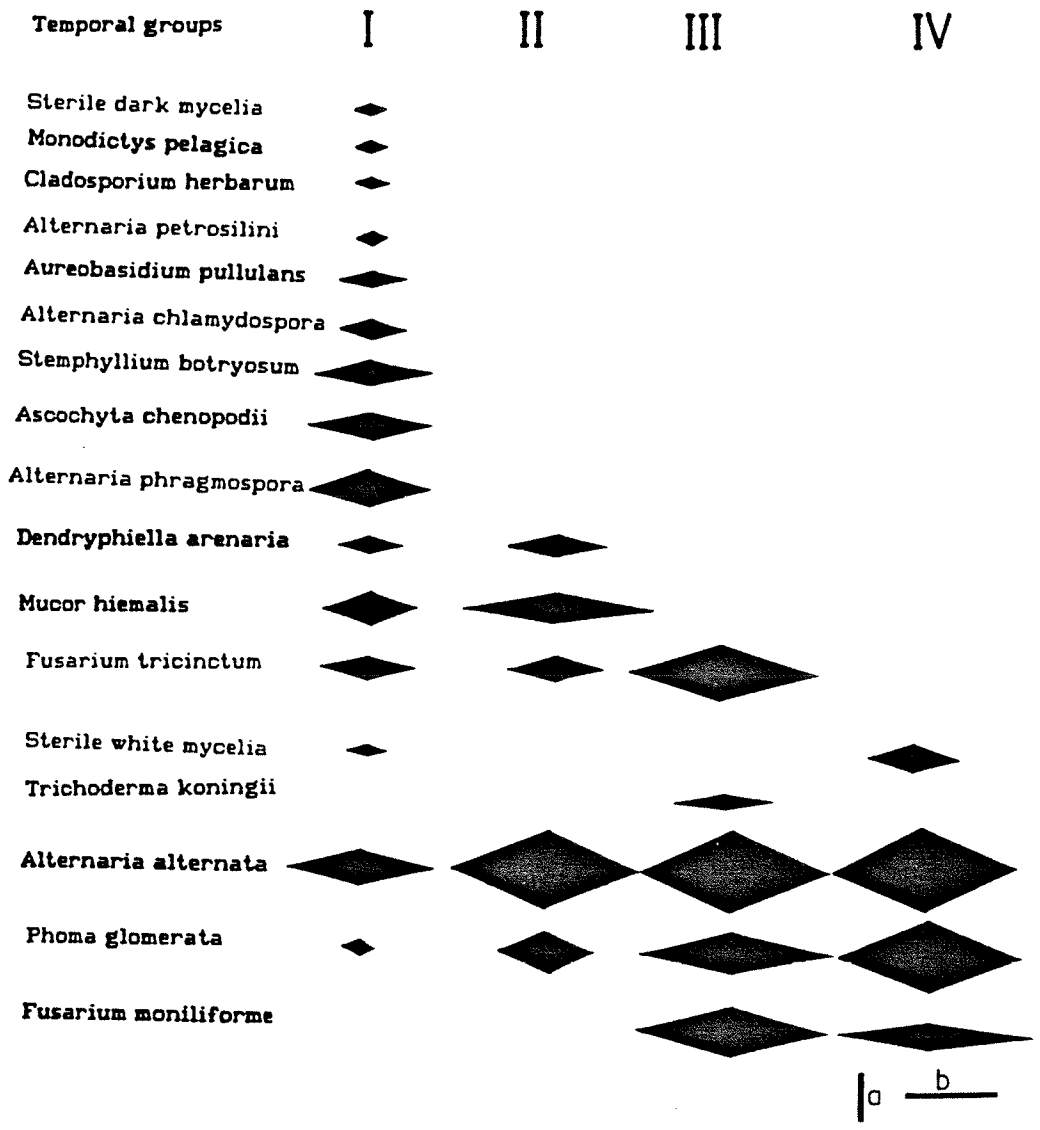

Temporal groups
I
II
III
IV
Sterile dark mycelia
Monodictys pelagica
Cladosporium herbarum
Alternaria petrosilini
Aureobasidium pullulans
Alternaria chlamydospora
Stemphyllium botryosum
Ascochyta chenopodii
Alternaria phragmospora
Dendryphiella arenaria
Mucor hiemalis
Fusarium tricinctum
Sterile white mycelia
Trichoderma koningii
Alternaria alternata
Phoma glomerata
Fusarium moniliforme
a
b

Fig. 3-6. Spatial groups over time of various fungal taxa on Salicornia europaea under sea salts treatment. Vertical bar a = 5% frequency, and horizontal bar b = 50% occurrence as calculated from Appendix 30.

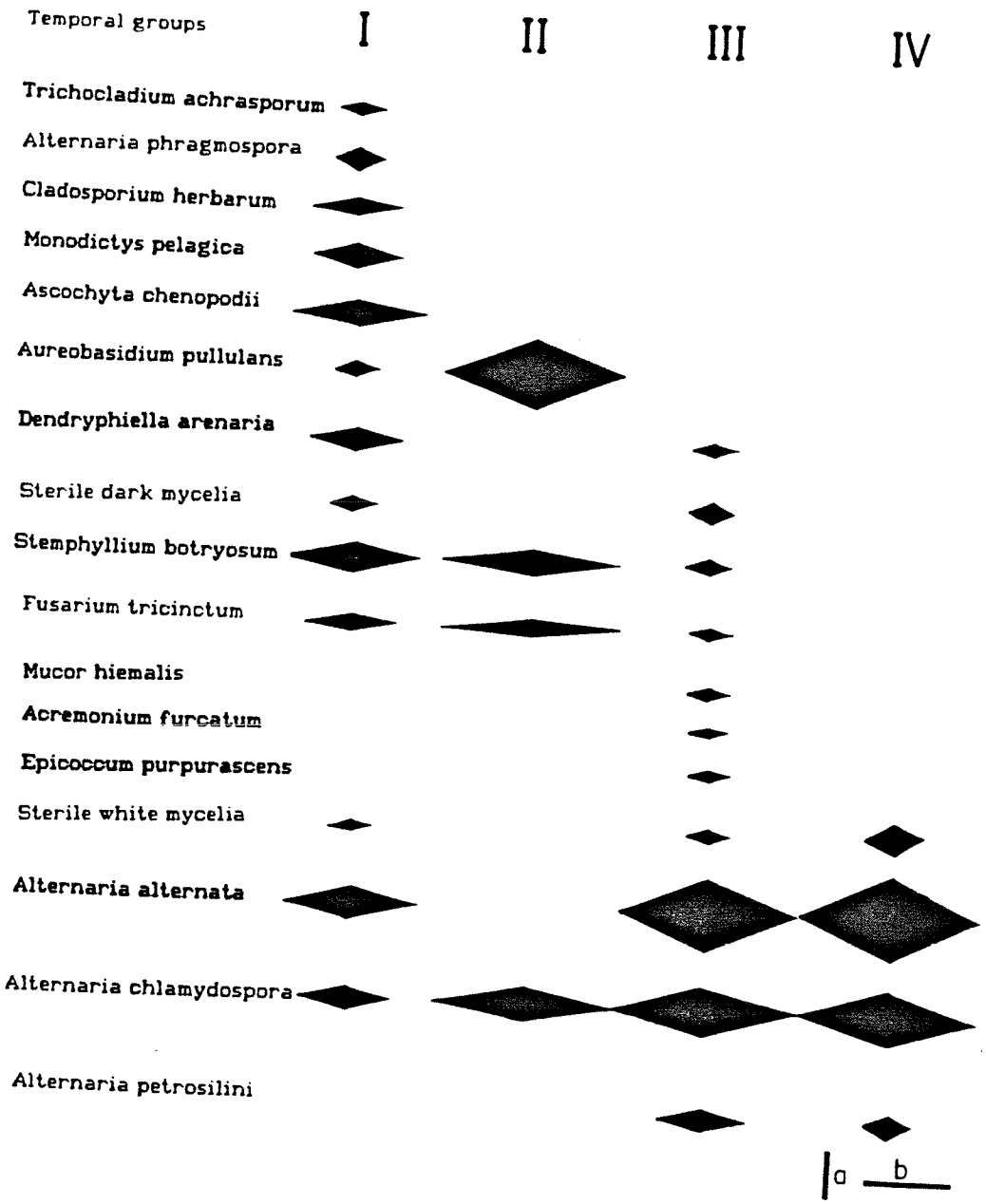
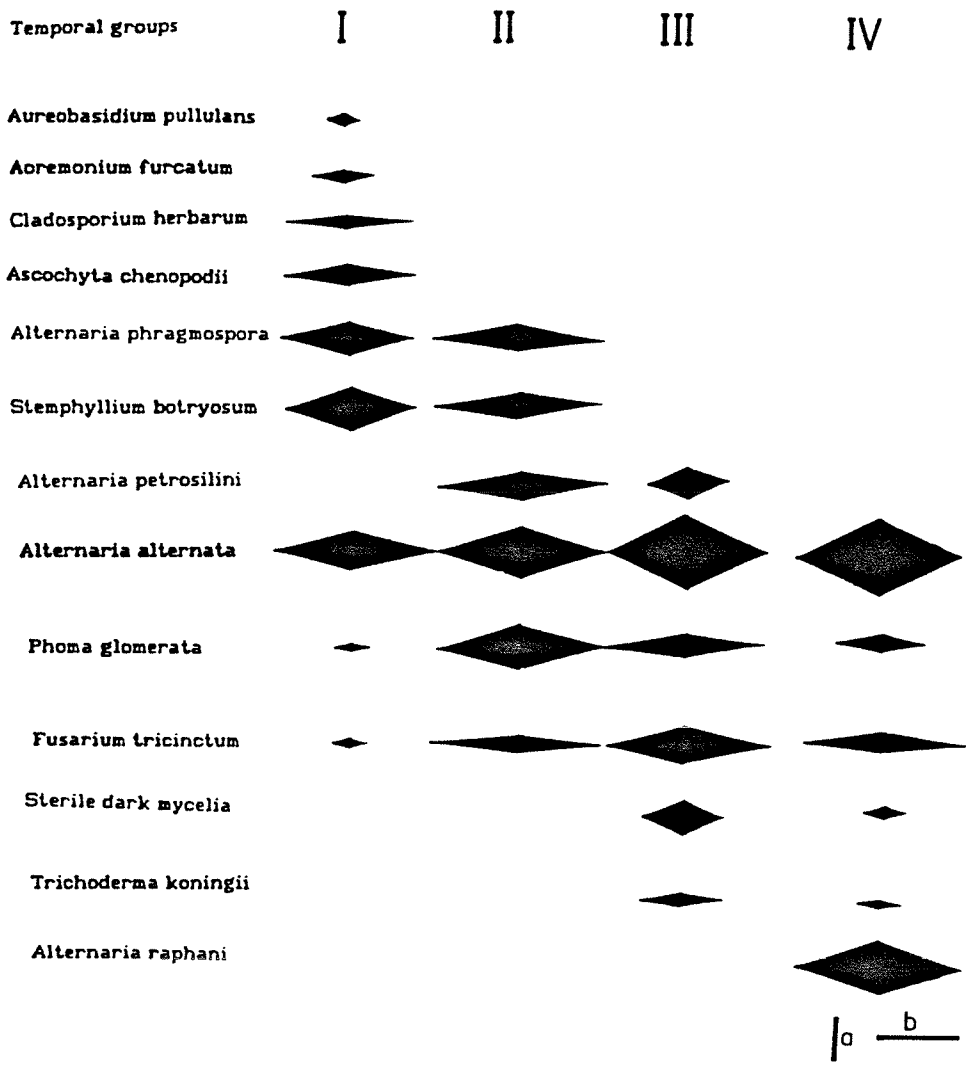

Temporal groups
I
II
III
IV
Trichocladium achrasporum
Alternaria phragmospora
Cladosporium herbarum
Monodictys pelagica
Ascochyta chenopodii
Aureobasidium pullulans
Dendryphiella arenaria
Sterile dark mycelia
Stemphyllium botryosum
Fusarium tricinctum
Mucor hiemalis
Acremonium furcatum
Epicoccum purpurascens
Sterile white mycelia
Alternaria alternata
Alternaria chlamydospora
Alternaria petrosilini
a
b

Fig. 3-7. Spatial groups over time of various fungal taxa on Salicornia europaea under irrigation. Vertical bar a = 5% frequency, and horizontal bar b = 50% occurrence as calculated from Appendix 31.


Temporal groups
I
II
III
IV
Aureobasidium pullulans
Aoremonium furcatum
Cladosporium herbarum
Ascochyta chenopodii
Alternaria phragmospora
Stemphyllium botryosum
Alternaria petrosilini
Alternaria alternata
Phoma glomerata
Fusarium tricinctum
Sterile dark mycelia
Trichoderma koningii
Alternaria raphani
a
b

Alternaria phragmospora and Stemphylium botryosum are present in early and middle temporal groups, and Alternaria petrosilini is found only in middle groups. In all four groups, Alternaria alternata, Fusarium tricinctum and Phoma glomerata are most-frequent in late collections. Sterile dark mycelia and Trichoderma koningii are in late and middle temporal groups, while Alternaria raphani is present only in the late group.

Dominance

Fungal community dominance (as calculated from Appendix 29) on sodium nitrate treated plants sharply increases from temporal I at 38% to the other temporal groups: II at 80%, III at 71% and IV at 91% (Table 3-2). Alternaria alternata is dominant over all four groups, being codominant with A. phragmospora and Mucor hiemalis in the first temporal group. Subdominant and common organisms are generally different over the four temporal groups. On sea salt affected plants, the community dominance (as calculated from Appendix 30) follows the pattern described previously: temporal I at 34%, temporal II at 88%, temporal III at 78% and temporal IV at 87%.

Unlike the sodium nitrate treated plants, Alternaria alternata is only dominant in the first temporal group in sea salt treated plants, with Aureobasidium pullulans dominant in the second group. There are no dominants in the

TABLE 3-2

Dominance functions, i.e., community dominance and classification of organisms, over the temporal groups for *Salicornia europaea* under various treatments

	Temporal I	Temporal II	Temporal III	Temporal IV
SODIUM NITRATE				
Community dominance ...	38%	80%	71%	91%
Dominants	A. alternata A. phragmospora M. hiemalis	A. alternata	A. alternata	A. alternata
Subdominants	A. chenopodii F. tricinctum	P. glomerata	F. tricinctum	
Common	A. chlamydospora S. botryosum	M. hiemalis	F. moniliforme	P. glomerata
SEA SALT				
Community dominance ...	34%	88%	78%	87%
Dominants	A. alternata M. pelagica S. botryosum	A. pullulans		
Subdominants	A. chlamydospora A. phragmospora A. chenopodii D. arenaria	A. chlamydospora	A. chlamydospora	A. chlamydospora
Common	F. tricinctum		A. petrosilini sterile dark mycelia	
IRRIGATION				
Community dominance ...	61%	66%	70%	90%
Dominants	A. alternata S. botryosum	A. alternata	A. alternata	A. alternata
Subdominants	A. phragmospora	P. glomerata	A. petrosilini F. tricinctum sterile dark mycelia	A. raphani
Common	A. chenopodii			F. tricinctum

third and fourth temporals. Among the subdominants, Alternaria chlamydospora is in all four temporal groups along with A. phragmospora, Ascochyta chenopodii and Dendryphiella arenaria in temporal I.

Unlike the general pattern in community dominance across the temporals of the sodium nitrate and sea salt treated plants, community dominance (as calculated from Appendix 31) on the irrigated plants sharply increases only in the last temporal group, i.e., 61% in temporal I, 66%in temporal II, 70% in temporal III, 90% in temporal IV. Alternaria alternata is dominant in all four temporal groups. It is codominant with Stemphylium botryosum in the first temporal. The subdominants are notably different across the temporal groups.

Life Spectra

Over the temporal groups on sodium nitrate treated and irrigated plants, the life spectra are increasingly attenuated from the first through the third temporal group, and less attenuated in the fourth group (Figs. 3-8,10). On sea salt treated plants, the attenuation of the spectra increases through the fourth temporal group (Fig. 3-9). Stress-tolerant fungi are generally the most-frequently encountered forms over all the treatments and temporal groups. The exception is the survivors strategy in the second temporal of the sea salt treated plants (Fig. 3-9). Consideration of

Fig. 3-8. Life spectra over time of the fungal assemblage on Salicornia europaea under sodium nitrate treatment.

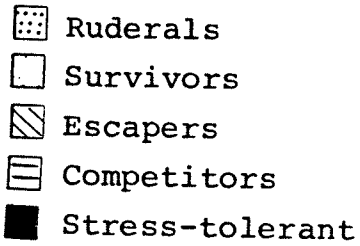


Fig. 3-9. Life spectra over time of the fungal assemblage on Salicornia europaea under sea salts treatment.

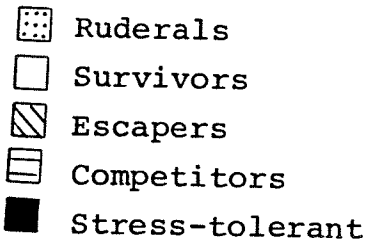
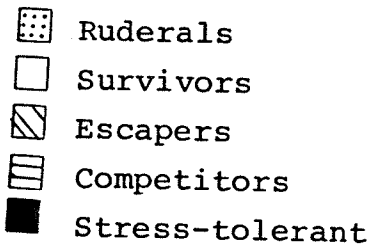
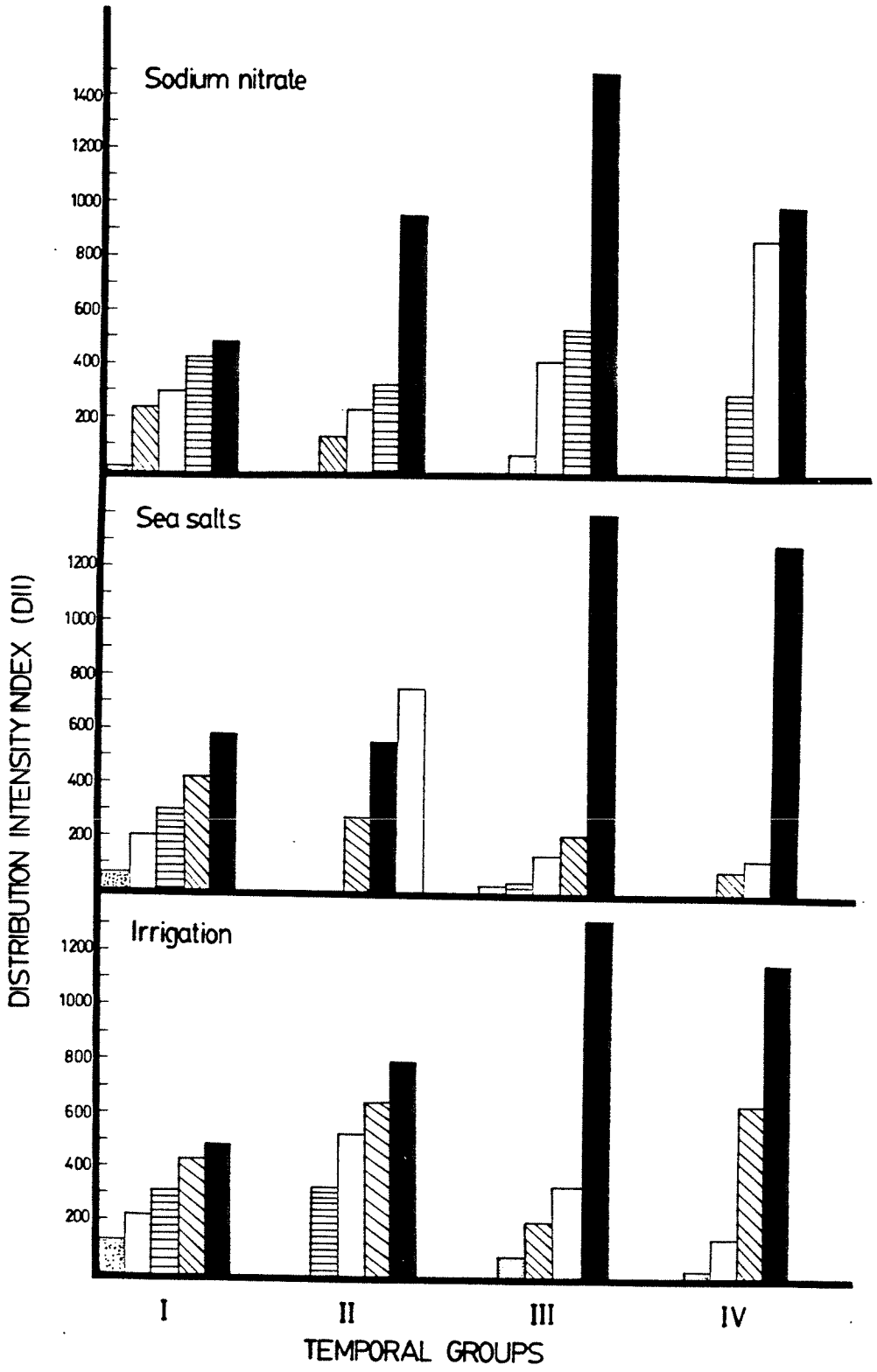


Fig. 3-10. Life spectra over time of the fungal assemblage on Salicornia europaea under irrigation.




Sodium nitrate
Sea salts
Irrigation
DISTRIBUTION INTENSITY INDEX (DII)
TEMPORAL GROUPS
I
II
III
IV

the two most-frequently encountered strategies in the spectra indicates similarity of the spectra of temporals I and II of the sodium nitrate treated plants (i.e., stress-tolerant and competitor strategies) (Fig. 3-8). Escapers and stress-tolerant strategies are also similarly important for temporals I and III of the sea salt treated plants (Fig. 3-9) and temporals I, II and IV of the irrigated plants (Fig. 3-10). Similarity of the spectra over temporals I through III of the sodium nitrate treated plants is highlighted by the order of the survivor, competitor, and stress-tolerant strategies.

DISCUSSION

As implied by the equivalent percentage isolation and recovery over the three treatments and the untreated plants (isolation at 28.7% and recovery at 111.2% from Chapter 2 of this dissertation), there are no differences in the seres in terms of total fungal isolates. Thus, any differences between the seres are more likely attributed to patterns of change within the mycota involving similarity, diversity, dominance, spatial groups and life strategies.

Although there are various fungal taxa which are restricted to the sodium nitrate, sea salt and irrigation treatments, inclusion of the untreated plant results suggests that no species are unique to sea salt treated and

irrigated plants. Fusarium moniliforme is found only on sodium nitrate treated plants, and Alternaria citri Ellis et Pierce, Gliocladium roseum Bain., Papulaspora halima Anastasiou and Scytalidium lignicola Pessante occur strictly on the untreated plants. These results imply that the seres on the treated plants are mostly indistinguishable on the basis of restricted fungal taxa.

Similarity, IS_T and IS_j values indicate a positive relationship between the fungal sere of untreated and that of sea salt treated plants. Also there is a positive similarity in the mycota of sea salt and sodium nitrate treated plants. There appears to be a dissimilarity in the fungi of sea salt treated plants when compared with those of irrigated plants. However, these similarities and dissimilarities are not representative of patterns of change in the seres, but they are representative of numbers of fungi in common in the paired comparisons of the mycota under various treatments.

Patterns of change exist in the times of diversity highs and lows and the inversely related community dominance over the untreated and treated plants. The untreated and irrigated plants demonstrate an early diversity high and a middle season low (time of the highs and lows are earlier on the irrigated plants than on the untreated plants). There is no diversity high on the sodium nitrate treated plants and

the lows are middle and end of the season. On sea salt treated plants, the diversity high is middle season, and this is followed by middle and end of the season lows.

Community dominance generally is low when diversity is high except on irrigated plants, where it is never low and only high at the end of the season. These patterns suggest that the seres may be different from one another in terms of diversity and community dominance.

However, this is only partially the case. Considering the dominant and subdominant forms over the untreated and treated plants of the first temporal group, the seres on all the plants are most probably the same as the dominants, and subdominants are similar. This is also the case for the seres of the second temporal group on irrigated and sodium nitrate treated plants. In the same temporal group, the seres of the untreated and sea salt treated plants are different from the others and each other, based on dominant and subdominant taxa. Seres of the third and fourth temporal groups are all different across the untreated and treated plants.

These similarities and differences between the seres of the treatments and the untreated plants are perhaps related to the physiological and biochemical changes by adding nitrates, salts or irrigation. For example, an increase in the size of Salicornia europaea plants with addition of

sodium nitrate is previously reported (Jefferies and Perkins 1977). Addition of sodium nitrate to the growth medium of S. europaea and Suaeda maritima (L.) Dum. results in an increase in the production of nitrate reductase (Stewart et al. 1972; Jefferies 1977). These workers have also established that high marsh plants produce lower levels of nitrate reductase than low marsh plants. Also, low marsh S. europaea plants are more-robust and produce a more-extensive root system (Jefferies 1977). It is known that low marsh S. europaea is tetraploid, while high marsh plants are diploid (Jefferies et al. 1981).

Sodium chloride additions reduce the chlorophyll levels in the tissues of Salicornia europaea (Tiku 1976). Increasing salts in the growth medium of halophytes increases their production of osmotically active substances in the cytoplasm of the cells (Jefferies et al. 1979b). One of these osmotically active substances, produced by S. europaea, is oxalate which is derived from glycolate with mediation of the enzyme glycolate oxidase (Austenfeld 1974, 1976). High levels of sodium chloride reduce the enzyme's activity while sodium sulfate increases the enzyme's activity. Additions of sodium chloride are also known to increase the levels of total amino acid production in Suaeda maritima (T.J. Flowers and Hall 1978). When this plant is grown in a non-saline medium or a medium low in sodium chloride, these amino acids, mainly proline, are produced at very low levels

(Flowers and Hall 1978). Proline is known to be an osmotically active substance as are some of the other amino acids.

In comparison of irrigated with non-irrigated Atriplex hymenelytra (Torr.) Wats. plants, it is seen that carbohydrates, various ions such as sodium and chloride, amino acids and imino acids (i.e., glycinebetaine) are at much lower levels in the irrigated plants (Bennert and Schmidt 1984). Biomass of Salicornia europaea grown on irrigated soil is nearly 50% of that for plants grown on salt-treated soils (Cooper 1982). Also the sodium level in irrigated plants is 45% of the level in salt-treated plants.

Temporal and spatial groups suggest that each sere may be separable into distinct stages or seral communities when considering the mycota of each treatment over the temporal groups. However, combining the dominance function, i.e., dominant and subdominant taxa, and the order of the ecological strategies in the life spectra yields clearer delimitation of seral groups in the treatment seres. The pattern of dominance groups and spectra of life strategies is the same for the untreated and sea salt treated seres. There are seral communities in the first temporal, second temporal and third and fourth temporals combined. (The dominant and subdominant taxa and life spectra are different in temporal groups I and II, and these groups are distinct from groups III and IV which are similar for the two community para-

meters.) The seral communities of the sodium nitrate and irrigation treated plants are separate for each of the temporal groups.

This similarity of pattern for the untreated plant sere with the sea salt treated plant sere and the sodium nitrate treated plant sere with the irrigated plant sere may be related to the magnitude of the "kick" caused by the treatments (Frankland 1981). Irrigated Salicornia europaea plants are markedly inhibited in growth and sodium chloride uptake in contrast to untreated plants (Cooper 1982). A similar response is also found in Atriplex hymenehytra (Bennert and Schmidt 1984). Formation of osmotically active substances by A. hymenelytra and Suaeda maritima is also much inhibited by irrigation (T.J. Flowers and Hall 1978; Bennert and Schmidt 1984).

Salicornia europaea and Suaeda maritima are reported to demonstrate much greater than normal growth when treated by sodium nitrate (Stewart et al. 1972; Jefferies and Perkins 1977; Jefferies et al. 1979a). Although there seems to be no reports of more than normal levels of salts and osmotically active substances in sodium nitrate treated halophytes, these phenomena are implied by Waisel (1972).

CHAPTER 4

POSSIBLE RELATIONSHIPS OF SALT LEVELS IN *SALICORNIA EUROPAEA* AGG. WITH FUNGAL ISOLATIONS AND COMMUNITY ORGANIZATION

INTRODUCTION

Salicornia europaea agg. is a succulent annual halophyte which is widely distributed in salt marshes throughout North America and Canada (Chapman 1974; Ungar 1974; Jufferies et al. 1979a). As a pioneer species of saline habitats, it is highly salt-stress tolerant (S. Flowers 1934; Waisel 1972). Soil salinity is the major factor affecting the growth of this plant (Ungar 1978; Ungar et al. 1979; Jefferies et al. 1979b).

Salt-resistant mechanism of Salicornia europaea has been discussed by Jennings (1968), Stewart and Lee (1974), Trichel (1979) and Pearcy and Ustin (1984). Waisel (1972) stated that salt levels are asymmetrically distributed in halophytic plants. However, little is known about the ionic level in roots and shoots of S. europaea. Riehl and Ungar (1982) observed that shoots of S. europaea have greater ionic content than the roots. They also found the level of ions is fluctuated throughout the season following the soil conductivity pattern. Cooper (1982) reported that the salt levels within the roots and shoots of S. europaea are higher under saline conditions than those under waterlogged conditions. He also stated that the growth of this species

is suppressed by waterlogging.

Several investigations indicated that Salicornia supports a diverse group of fungi (Pugh 1960, 1974, 1979; Gessner and Lamore 1978; Kohlmeyer and Kohlmeyer 1979). Although the salinity effect on fungi inhabiting saline environments has been discussed (T.W. Johnson and Sparrow 1961; Jones and Jennings 1964), little is known about the effects of this factor on salt marsh fungi. Gessner (1977) and Crabtree and Gessner (1982) examined the growth of some species, isolated from Spartina, under different salinities in vitro.

The objectives of this study are (1) to examine the physical, chemical and biological changes (particularly in total salts, ionic concentration, growth habit, phenological stages, and water content) of the roots and shoots of Salicornia europaea growing under control and treatment conditions in the field, (2) to relate these changes to relevant climatic and edaphic factors, and (3) to examine changes in the fungal pattern on the roots and shoots of this halophyte.

METHODS AND MATERIALS

Field Work

Random plots (50 x 50 cm) for sampling of Salicornia

europaea were established within a saline area of Delta Marsh (Chapter 2 of this dissertation). Three treatments, sodium nitrate, Rila sea salt mix, and irrigation with distilled water, were applied at intervals to the plots. Untreated plots were also established (Chapter 3).

Air temperature (C^{o}) at 1-m height above the ground, soil surface temperature (by laying a thermometer on the ground for one minute), and 10 cm below the soil surface (by inserting the thermometer into the soil for one minute) were measured at each collecting date between 11:00 and 12:00 a.m. using a YSI-Tele-thermometer, Model 42SC. Daily precipitation (mm) levels and minimum and maximum air temperatures were provided by the Environment Canada Weather Station at the University Field Station at Delta Marsh. Cumulative precipitation levels over 10-day intervals were calculated during the collecting season of 1983.

Soil samples from each of the treatment plots were collected at a 5-cm depth from the soil surface using a soil core (5 cm in diameter). Samples were placed in polyethylene bags and brought back to the laboratory, where soil moisture level and conductivity were determined. At the same time, plant material from each treatment was gathered, placed in polyethylene bags, and brought back to the laboratory where measurement of length of roots and shoots, determination of water content, fungal isolation and chemi-

cal analysis were made.

Laboratory Work

Plant Characteristics

Lengths (cm) of roots and shoots of Salicornia europaea were measured to characterize the growth rate of treated and untreated plants. Water content of the roots and shoots was also determined. Root and shoot samples for each collecting date were weighed, oven-dried at 80°C for 48 hours, and reweighed. Constant weights were obtained by redrying and reweighing the samples until values stabilized. Water content was expressed as the amount of water (gm) per fresh weight (gm) of roots and shoots.

Root and shoot samples were analyzed for cations (Na^+, K^+, Ca^{++}, and Mg^{++}) and anions (Cl^- and $SO_4^=$) following Riehl and Ungar (1982). This involved oven-drying root and shoot samples, previously washed in distilled water, at 80°C. Following this, samples were blended using a 1-mm mesh size. The blended material was weighed into 12-ml glass vials and combusted in a furnace at 550°C for 24 hours. Ten ml of deionized distilled water was then added to the ashed sample. Ashed samples were allowed to dissolve over 48 hours with periodic shaking. Appropriate dilutions were made as required, and the final diluted samples were analyzed for ionic content.

Cation levels were determined using Flame Atomic Absorption Spectroscopy (Perkin-Elmer 403) and anions using Ion-Chromatography. Ionic values are expressed as mg/gm dw (after Cooper 1982). (Equivalents as $\mu eq.\ ml^{-1} \times 10^{-2}$ are given in Appendices 57-60.)

Soil Analysis

Fresh soil samples were weighed, oven-dried at 80°C for 48 hours, then reweighed. Water content was expressed as weight (gm) per dry weight soil (gm). In addition, soil samples from each treatment were air-dried at room temperature. These were then passed through a 2-mm sieve and mixed with distilled water (1:1 volume ratio) followed by shaker agitation for two hours. The soil solutions were vacuum-filtered through Whatman No. 2 filter paper using a Buchner funnel. The filtrate was used for the measurement of electrical conductivity with a Radiometer CDM2D conductivity meter.

Fungal Isolation

Isolation and counting of fungi from roots and shoots of Salicornia europaea under various treatments were carried out using previously described techniques (Muhsin and Booth 1985).

Data Treatment

Total salt content of the roots and shoots was calculated by summing all ionic values at each sampling date. The ratio of divalent to monovalent ions was also calculated.

Comparisons of air and soil temperatures, soil conductivity, root and shoot lengths, root and shoot water content, and soil water moisture of various treatments over time were undertaken using the analysis of variance.

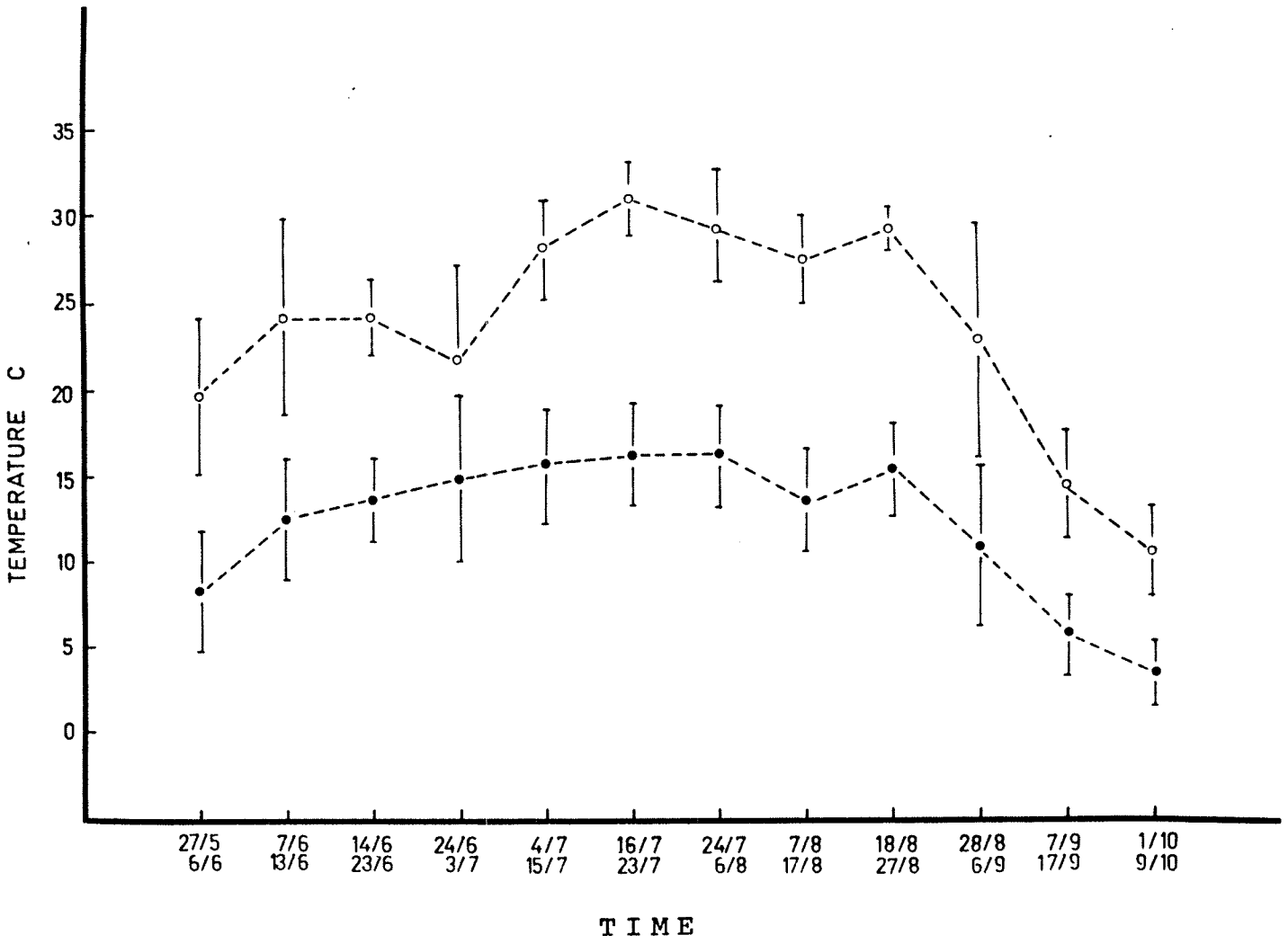
The product-moment correlation coefficient was calculated between the total fungal isolations and the ionic level of roots and shoots at each collecting date. Corelation between the individual ions and the total fungal isolates on roots and shoots of each treatment was also calculated.

RESULTS

Climatic and Edaphic Factors

The seasonal air temperature regime is seen in the ranges, means and standard deviations of the maximum and minimum readings from continuous time periods (Fig. 4-1, Appendix 32). The ranges in maximum and minimum air temperatures overlap for the collecting period. This is also

Fig. 4-1. Mean maximum o---o and minimum •-----• temperatures (°C) with ranges and standard deviations. Means, ranges and standard deviations based on indicated time periods.


TEMPERATURE C
35
30
25
20
15
10
5
0
27/5
6/6
7/6
13/6
14/6
23/6
24/6
3/7
4/7
15/7
16/7
23/7
24/7
6/8
7/8
17/8
18/8
27/8
28/8
6/9
7/9
17/9
1/10
9/10
TIME

the situation for range means. Seasonal variation is greater for the means of maximum temperature ranges than for minimum temperature range means. Generally the maximum temperature range means appear to be divisible into three parts, with an early cooler period from May 27 to July 3, a warmer period from July 4 to August 26, followed by a cooler to cold period from August 27 to October 10. Air, soil-surface and below-ground collecting time temperatures follow exactly the same three-part pattern (Fig. 4-2, Appendix 33). It is interesting to observe that the mean and standard deviation of air temperature are 21.9±6.3°C; those of soil-surface temperature are 22.9±6.3°C; and those of below-ground temperature are 19.6±5.4°C. Collections of July 23 and August 26 were made with air, soil-surface and below-ground temperatures more than one standard deviation above the mean. (The means of the maximum temperature range are the highest for the two dates, i.e., July 23 and August 26 as seen in Fig. 4-1.) Air, soil-surface and below-ground temperatures were more than one standard deviation below the mean on the last two collecting dates, i.e., September 17 and October 9. (The means of maximum temperature range, as well as minimum temperature range, were the lowest of the season for the previously mentioned dates, i.e., September 17 and October 9.) Analysis of variance of the different types of temperatures and the temperatures over time shows that air, soil-surface and below-ground

temperatures were different from one another ($F = 80.16$ and $P<0.001$) and each were different over each of the collecting dates ($F = 252.6$ and $P<0.001$) (Appendix 34). The temperatures were most-changeable over the time periods at the end of the season (September 6 to October 9). However, the air, soil-surface and below-ground temperatures were quite similar (Fig. 4-2).

Daily precipitation values range from 0 to 25 mm over the collecting period (Table 4-1). Total precipitation levels before and on each of the collecting dates are:

(1) June 1 to June 6 at 10.5 mm, or an average of 1.75 mm/day;

(2) June 7 to June 13 at 10.4 mm, or an average of 1.5 mm/day;

(3) June 14 to June 23 at 47 mm, or an average of 4.7 mm/day;

(4) June 24 to July 3 at 38 mm, or an average of 3.8 mm/day;

(5) July 4 to July 15 at 4.6 mm, or an average of 0.4 mm/day;

(6) July 16 to July 23 at 4 mm, or an average of 0.5 mm/day;

(7) July 24 to August 6 at 52.4 mm, or an average of 3.7 mm/day;

(8) August 7 to August 17 at 0.1 mm, or an

Fig. 4-2. Air ●....●, soil surface Δ——Δ, and below ground ▲----▲ temperatures over 1983 collecting dates.

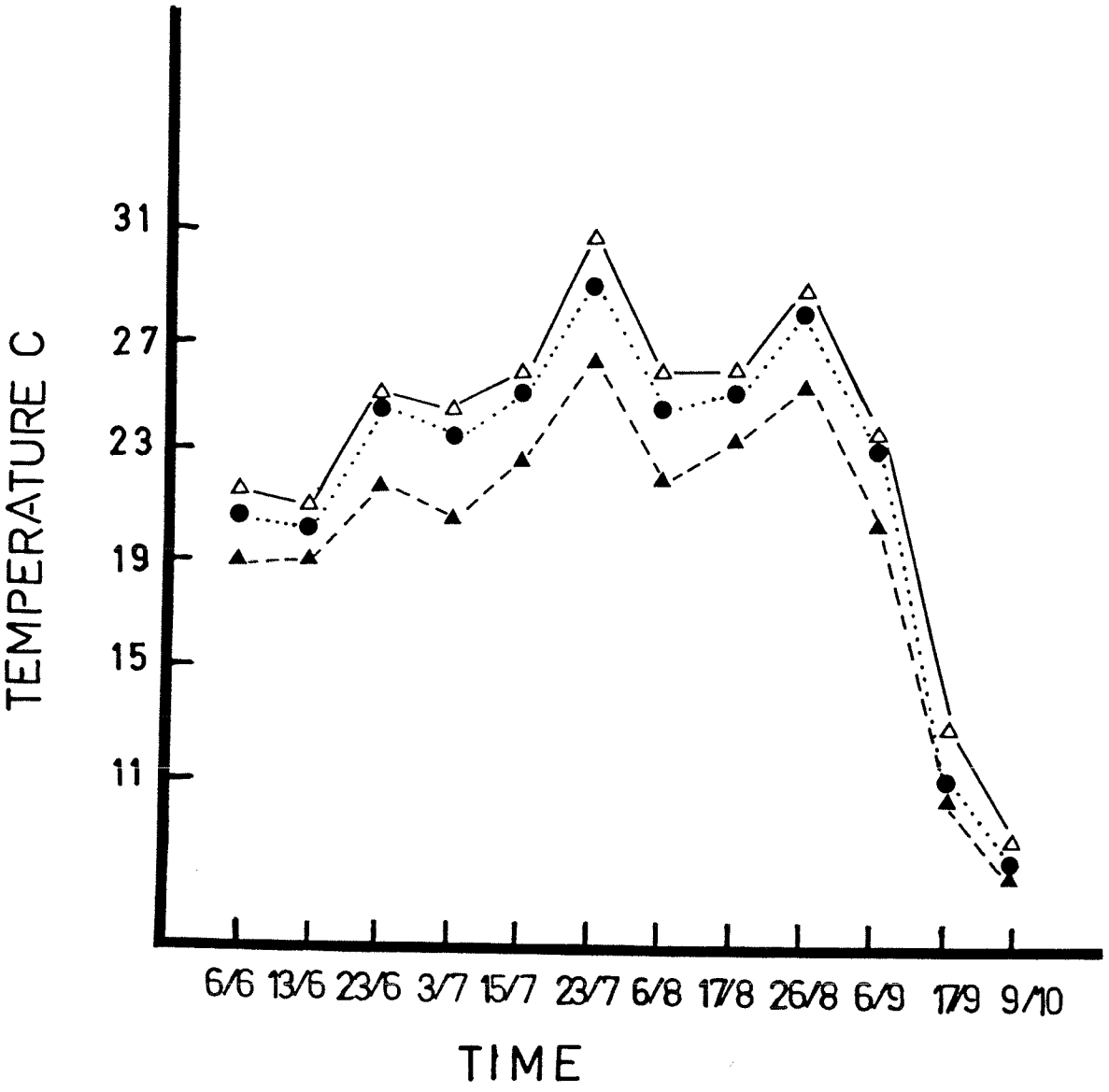

TEMPERATURE C
31
27
23
19
15
11
6/6 13/6 23/6 3/7 15/7 23/7 6/8 17/8 26/8 6/9 17/9 9/10
TIME

TABLE 4-1

Daily precipitation (ppt.) values for June 1 to October 10 of 1983

Date	ppt. (mm)	Date	ppt. (mm)	Date	ppt. (mm)	Date	ppt. (mm)	Date	ppt. (mm)
June 1		July 1	6.0	August 1	0.4	September 1		October 1	
2	1.1	2	0.2	2	0.5	2		2	2.4
3	6.8	3*	19.0	3	0.2	3		3	0.4
4	2.5	4	1.8	4		4		4	4.0
5		5		5	15.4	5	2.2	5	
6*	0.1	6		6*		6*	3.0	6	0.5
7		7	0.4	7		7	0.2	7	trace
8	3.2	8		8		8	0.4	8	
9		9		9		9	0.6	9*	0.4
10	0.9	10	2.0	10	0.8	10		10	0.4
11		11	0.4	11	0.2	11			
12		12		12		12	1.0		
13*	6.3	13		13		13	1.0		
14	7.4	14		14		14	5.2		
15	9.3	15*		15		15	0.8		
16	0.2	16	2.8	16		16			
17		17		17*		17*			
18		18		18		18			
19	trace	19		19	3.4	19	0.4		
20	3.2	20	0.4	20		20	1.0		
21	1.5	21	0.8	21	18.2	21	0.4		
22	0.4	22		22	0.2	22			
23*	25.0	23*		23		23			
24	1.8	24		24	14.0	24			
25	0.2	25	0.3	25	1.2	25			
26	trace	26		26*	0.2	26			
27		27		27	0.2	27	1.5		
28		28		28	15.6	28			
29		29		29	2.8	29	2.6		
30	10.8	30	19.8	30		30	25.0		
		31	15.8	31					

*Collecting dates

average of 0.01 mm/day;

(9) August 18 to August 26 at 21.8 mm, or an average of 3.6 mm/day;

(10) August 27 to September 6 at 39.4 mm, or an average of 2.8 mm/day;

(11) September 7 to September 17 at 9.2 mm, or an average of 0.9 mm/day; and

(12) September 18 to October 9 at 38 mm, or an average of 1.7 mm/day.

Corresponding with the three-part temperature pattern, precipitation totals are: 105.9 mm (3.2 mm/day on average) for May 27 through July 3; 83.8 mm (1.6 mm/day) for July 4 through August 26; and 63.9 mm (1.3 mm/day) for August 27 through October 10.

Soil moisture content varies from 29.6 to 70.1% (Fig. 4-3, Appendix 35). The values are significantly different between treatments ($F = 30.7$ and $P < 0.001$) and over time ($F = 12.2$ and $P < 0.001$) (Appendix 36). Soils where irrigation occurs are higher in percentage moisture than those under the other treatments (Fig. 4-3). Generally in all treatments there is an early season (June 6 through July 4) increase, followed by a middle season (July 5 through August 26) low and high; and an end of season (August 27 through October 10) increase.

During the early part of the season, June 6 to July 3,

Fig. 4-3. Soil water content [% water/soil dry weight (gm/gm] for each treatment.

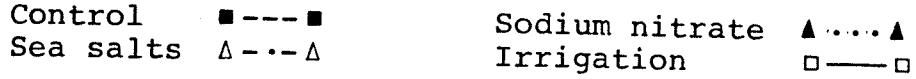
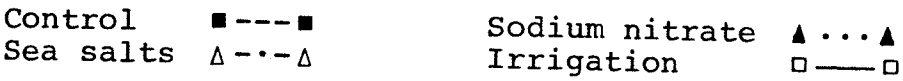
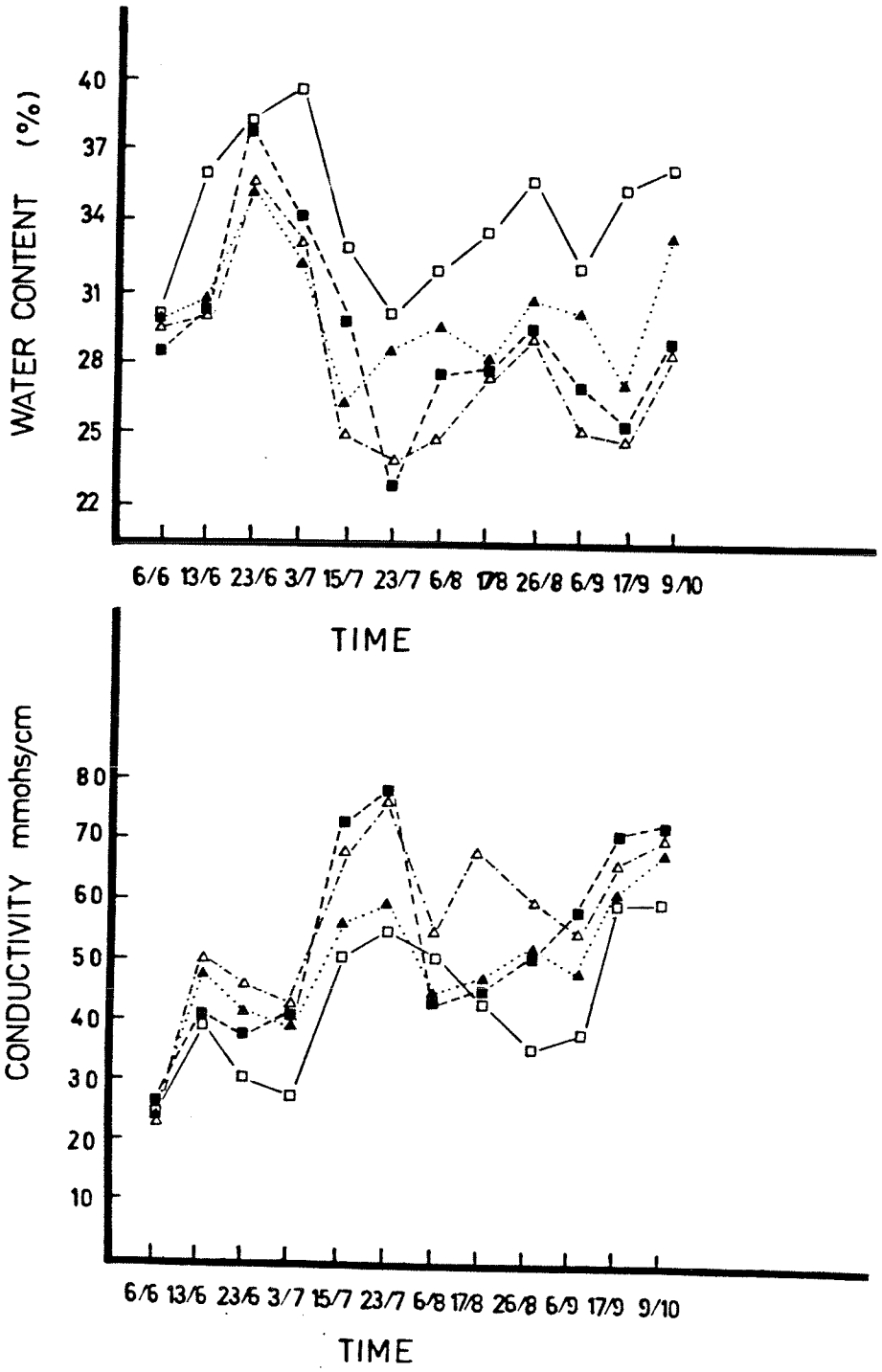


Fig. 4-4. Soil conductivity (mmhos/cm) for Salicornia europaea under various treatments.




WATER CONTENT (%)
40
37
34
31
28
25
22
6/6 13/6 23/6 3/7 15/7 23/7 6/8 17/8 26/8 6/9 17/9 9/10
TIME
CONDUCTIVITY mmohs/cm
80
70
60
50
40
30
20
10
6/6 13/6 23/6 3/7 15/7 23/7 6/8 17/8 26/8 6/9 17/9 9/10
TIME

soil conductivity increases slightly (Fig. 4-4, Appendix 37). A pronounced increase (July 15 and 23), followed by a sharp decline (August 6), preceeds an increase in conductivity to the end of the collecting season. Analysis of variance for soil conductivity under the treatments over time shows that it is significantly different for the treatments ($P<0.001$) and over time ($P<0.001$) (Appendix 38). Under irrigation the conductivity is lowest (Fig. 4-4). Both the control and sea salt treated plots have the highest conductivity (78 mmohs/cm). Generally the sharp increase in conductivity (July 15 and 23) is typical of the control and sea salt treatments. Over the season, soils with sea salt application have a higher conductivity in general than the control soils. Soils in the sodium nitrate treated plots demonstrate a conductivity intermediate between the control and irrigated plots. Although there is a high conductivity in the soils of the sodium nitrate treated and irrigated plots on July 15 and 23, the increase from the early season (June 6 through July 3) conductivities is not as nearly pronounced as in the soils of the control and sea salt treated plots.

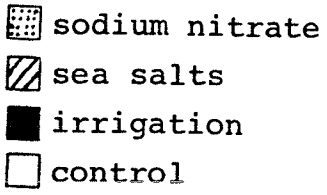
Plant Characteristics

Root and shoot lengths generally increase over the season until July 23 or August 6. A stationary phase follows

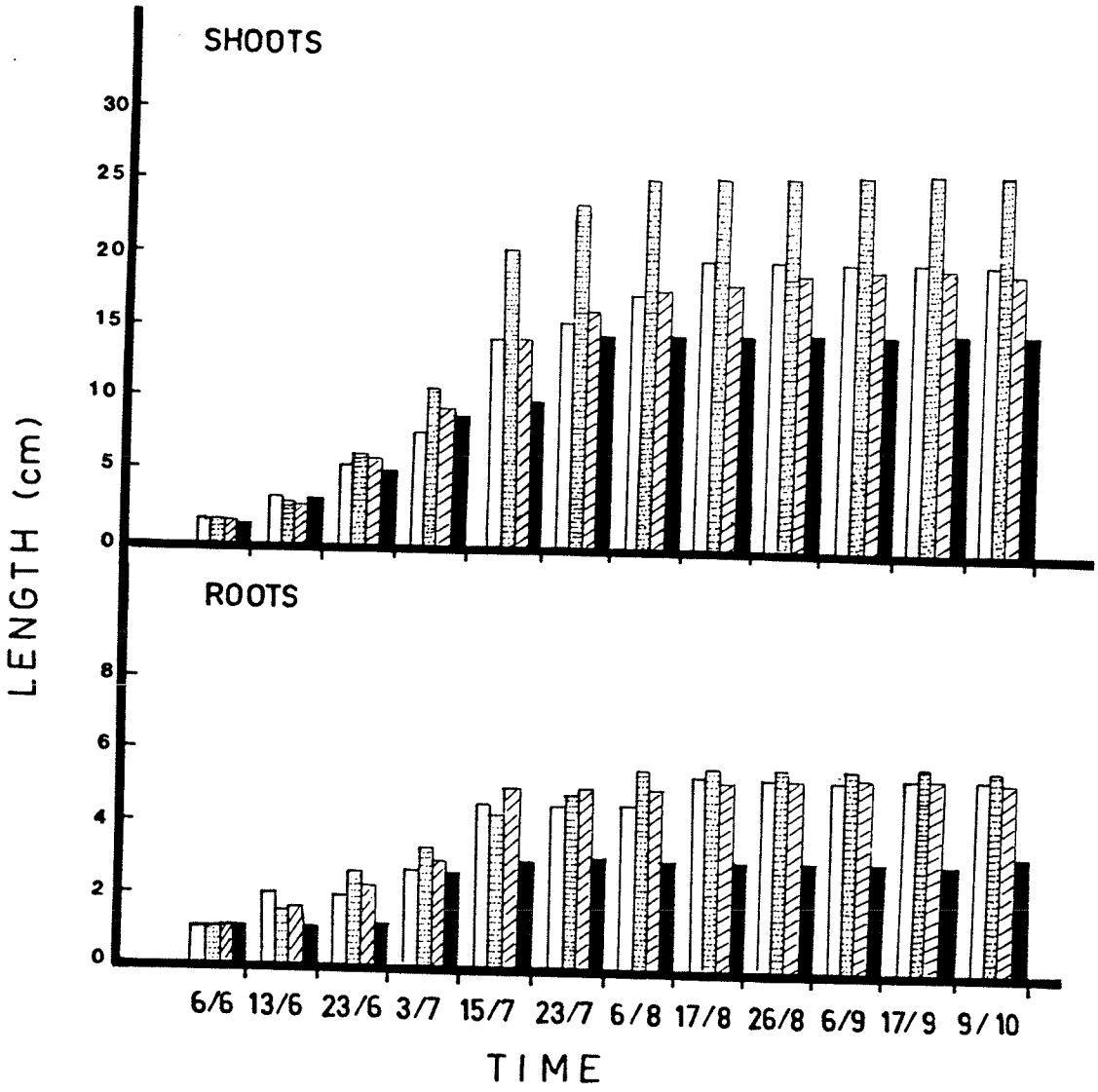
the growth period (Fig. 4-5, Appendix 39). Root and shoot lengths are significantly different over treatments ($P<0.001$) as well as time ($P<0.001$) (Appendices 40-41). Root growth on sodium nitrate treated plants becomes stationary later (August 6) than on the control, irrigated or sea salt treated plants. Control and sea salt treated plants are stationary for root growth on July 15, and the stationary phase for irrigated plants begins on July 3. Roots developed under sodium nitrate treatment are slightly longer than those of an equivalent length formed on control and sea salt treated plants. Irrigation results in plants with much-shorter roots. Basically, the shoot lengths under the treatments follow the same pattern as the roots. The sodium nitrate treated plants produce much-longer shoots than the equivalent in length of control and sea salt grown plants. Irrigated plants have much-shorter shoots than those of control, sodium nitrate treated and sea salt treated plants. The stationary phase of the shoot growth for irrigated plants begins on July 23. Sodium nitrate treated plants are stationary on August 6, while the stationary phase in control and sea salt treated plants seems to start on August 17.

Percentage water in roots is generally more-variable between the collecting dates under each treatment than for percentage water in shoots (Figs. 4-6 to 9, Appendix 42). Analysis of variance results (Appendix 43) indicate that

Fig. 4-5. Mean length of Salicornia europaea roots and shoots under



treatments over the collecting dates.


SHOOTS
30
25
20
15
10
5
0
ROOTS
8
6
4
2
0
LENGTH (cm)
6/6 13/6 23/6 3/7 15/7 23/7 6/8 17/8 26/8 6/9 17/9 9/10
TIME

Figs. 4-6 to 9. Water content of roots (o----o) and shoots (• ——— •) and phenological stages of Salicornia europaea under

control (Fig. 4-6)

sodium nitrate (Fig. 4-7)

sea salts (Fig. 4-8)

irrigation (Fig. 4-9)

treatments over the collecting dates.

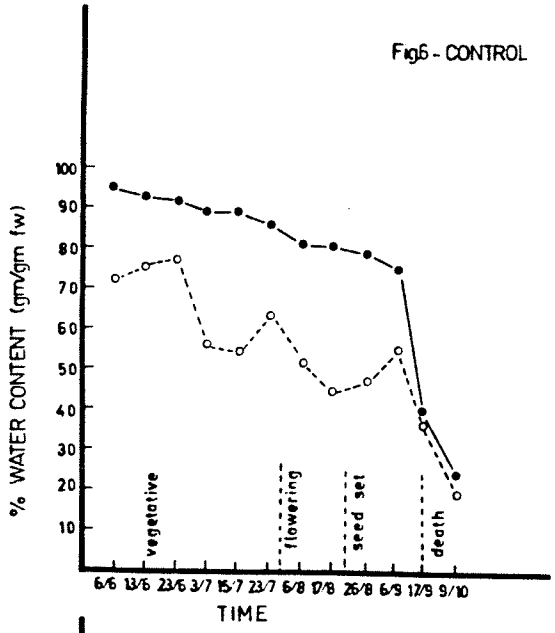


Fig6 - CONTROL
% WATER CONTENT (gm/gm f.w)
100
90
80
70
60
50
40
30
20
10
vegetative
flowering
seed set
death
6/6 13/6 23/6 3/7 15/7 23/7 6/8 17/8 26/8 6/9 17/9 9/10
TIME

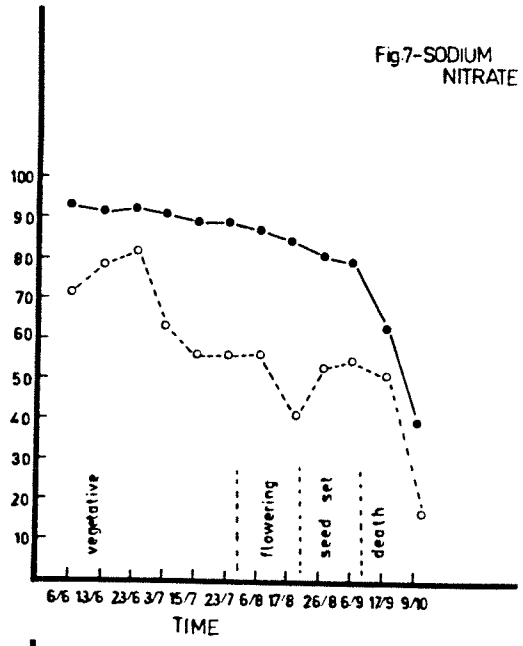


Fig.7-SODIUM NITRATE
100
90
80
70
60
50
40
30
20
10
vegetative
flowering
seed set
death
6/6 13/6 23/6 3/7 15/7 23/7 6/8 17/8 26/8 6/9 17/9 9/10
TIME

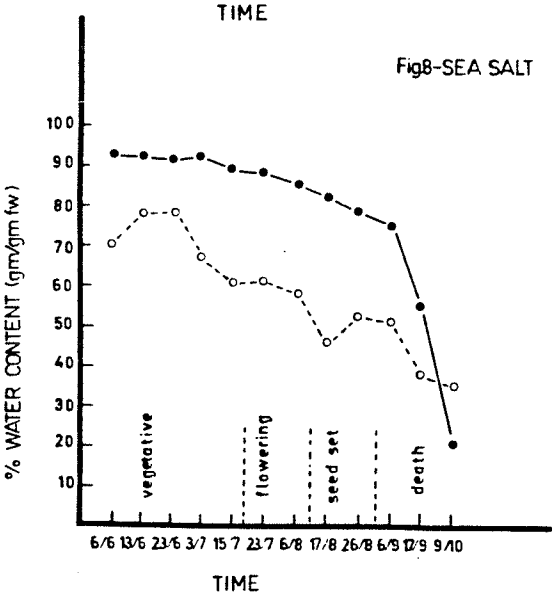


Fig8-SEA SALT
% WATER CONTENT (gm/gm f.w)
100
90
80
70
60
50
40
30
20
10
vegetative
flowering
seed set
death
6/6 13/6 23/6 3/7 15 7 23/7 6/8 17/8 26/8 6/9 17/9 9/10
TIME

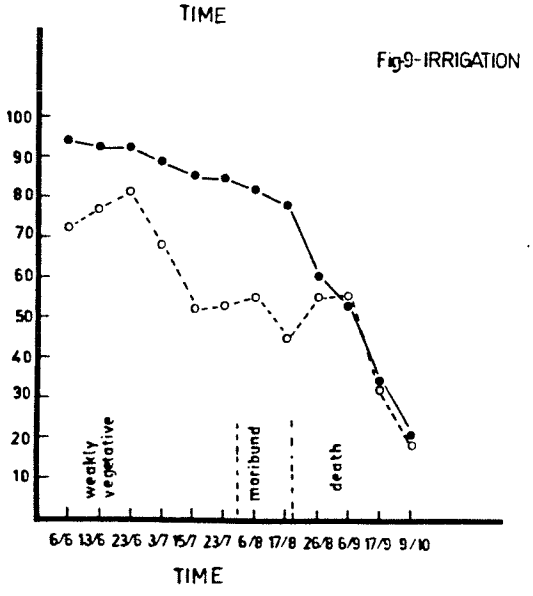


Fig9-IRRIGATION
100
90
80
70
60
50
40
30
20
10
weakly vegetative
moribund
death
6/6 13/6 23/6 3/7 15/7 23/7 6/8 17/8 26/8 6/9 17/9 9/10
TIME

the differences between the water levels in roots ($P = 0.183$) are not significant when comparing treatments. The general trend in the root moisture percentages within each treatment is for a general seasonal decline. The general decline is accompanied by variations in the moisture. Differences between shoot water levels over the treatments and significant ($P<0.002$) (Appendix 43). Shoots show only slightly declining moisture levels until the end of the season, which is characterized by an abrupt drop in water percentage. Time differences within the roots ($P<0.001$) and shoots ($P<0.001$) are significant. Highest root water levels, i.e., 75.6 to 83.3%, are found for all treatments in June 23 collections. Lowest quantities of root moisture, i.e., 16.2 to 34.6%, are generally encountered on September 17 and October 9. There is, however, a noticeable dip in root water content over all treatments on August 17. In the control and sea salt and sodium nitrate treated plants, shoot water generally stays higher than 75% until the last two collecting dates. The decline below this level occurs earlier, i.e., August 26, in the shoots of irrigated plants.

The patterns of phenological changes under the various treatments (Figs. 4-6 to 9) include rapid vegetative growth, flowering, seed set and maturation and senescence and death stages. These stages also relate to the growth and stationary phases previously mentioned. Timing of the phenological stages is the same for control and sodium nitrate treated

plants, i.e., June 6 to July 23 vegetative growth; August 6 to 17 flowering; August 26 to September 6 seed set and maturation; and September 17 to October 9 senescence and death. Vegetative growth under sea salt treatment continues from June 6 through July 15. Timing of the other stages is: July 23 to August 6 flowering; August 17 to 26 seed set and maturation; and September 6 to October 9 senescence and death. Irrigated plants remain weakly vegetative from June 13 to July 23. The senescence stage, i.e., July 23, is followed by a moribund and dying stage, i.e., August 6 to 17. By August 26 the plants are dead.

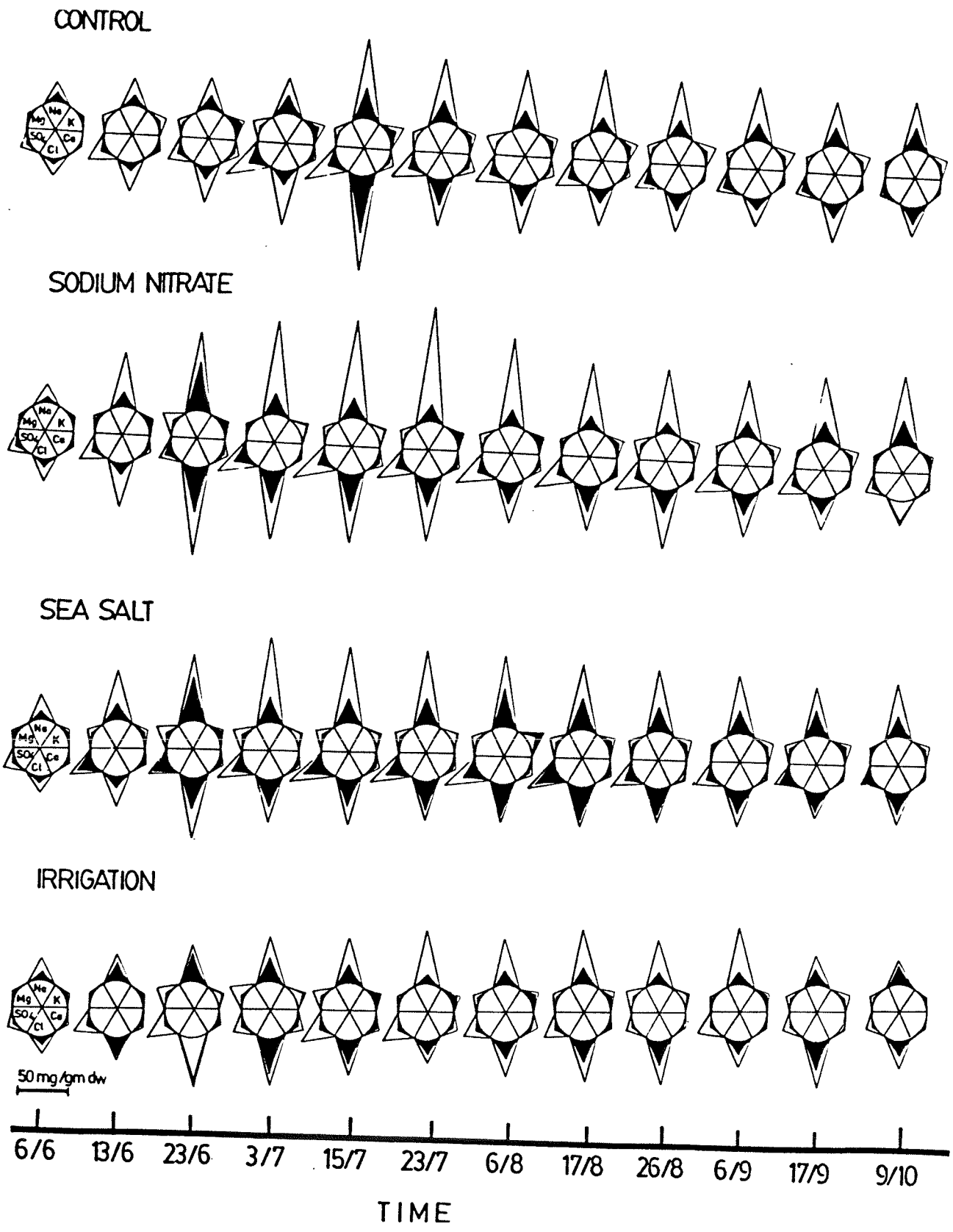
Concentrations (from Appendices 44-47), mg/gm dw, for all shoot ions and root ions exclusive of Ca^{++} and Mg^{++} are significantly different ($P = 0.002 - <0.001$) over time (Figs. 4-10 to 13, Appendices 48-49) for each of the treatments. Na^{+}, Cl^{-} and $SO_4^{=}$ are the dominant ions over all the treatments and over all dates. On roots, Mg^{++} and $SO_4^{=}$ are the only ions significantly different ($P = 0.002$ and <0.001, respectively) between the treatments (Appendix 48). Significant differences ($P<0.001$) are seen for K^{+}, Na^{+} and $SO_4^{=}$ ions among the treatments (Appendix 49). It is generally observed that the highest Na^{+} concentrations are in sodium nitrate treated plants (Fig. 4-11). Na^{+} levels from the control (Fig. 4-10) and sea salt (Fig. 4-12) treated plants are about equal and less than in sodium nitrate treated plants. The lowest levels of Na^{+} among the treat-

Fig. 4-10. Concentrations (mg/gm dw) of various ions from roots (dark areas) and shoots (white areas) of Salicornia europaea under control conditions. (Values are read by applying the scale bar from the circle periphery to the extremes.)

Fig. 4-11. Concentrations (mg/gm dw) of various ions from roots (dark areas) and shoots (white areas) of Salicornia europaea under sodium nitrate treatment.

Fig. 4-12. Concentrations (mg/gm dw) of various ions from roots (dark areas) and shoots (white areas) of Salicornia europaea under sea salts treatment.

Fig. 4-13. Concentrations (mg/gm dw) of various ions from roots (dark areas) and shoots (white areas) of Salicornia europaea under irrigation.


CONTROL
Na
K
Ca
Cl
SO4
Mg
SODIUM NITRATE
SEA SALT
IRRIGATION
50 mg/gm dw
6/6
13/6
23/6
3/7
15/7
23/7
6/8
17/8
26/8
6/9
17/9
9/10
TIME

ments is in irrigated plants (Fig. 4-13). The time of Na^+ ion build-up is earlier under sodium nitrate and sea salt treated and irrigation than on the control plants. Highest total salts in any single collection (July 15) of plant material is found in the control plants (Fig. 4-14). However, taking into account an earlier increase in total salts (June 23) and a sustained high level (July 23 to August 6), it is possible to observe that the seasonal level of salt may be highest for sodium nitrate (Fig. 4-15) and sea salt (Fig. 4-16) treated plants. Total salts are at low concentration in irrigated plants (Fig. 4-17), particularly for the roots.

The percentage root ions to shoot ions varies over the collecting dates and between the treatments. The range of ratio of root to shoot ions for the control is 32-41.6±6.8-55% when expressed as a percentage. The percentages of roots to shoots under the treatments are: 29-37±8.0-59% on the sodium nitrate treated plants; 42-55.1±8.8-67% on the sea salt treated plants; and 32-50.1±13.6-71% on the irrigated plants.

Fungal Patterns

On control plants the total fungal isolates can be used to predict the total salts in the growing and stationary plants (Appendix 50). Shoot and root total isolates are

Fig. 4-14. Total number of fungal isolations and total salt levels on

roots ▨
shoots □

of Salicornia europaea under control conditions.

Fig. 4-15. Total number of fungal isolations and total salt levels on

roots ▨
shoots □

of Salicornia europaea under sodium nitrate treatment.

Fig. 4-16. Total number of fungal isolations and total salt levels on

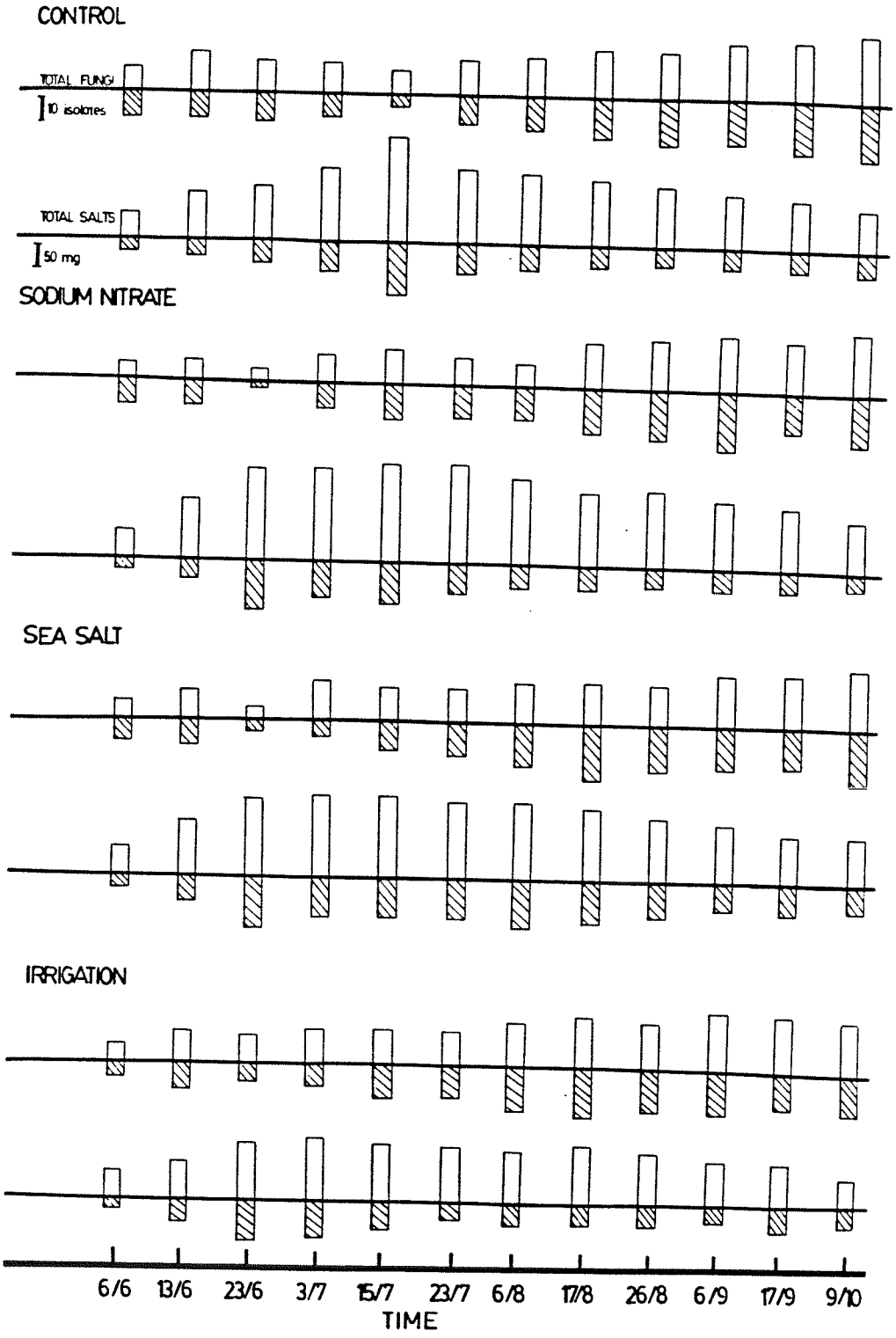
roots ▨
shoots □

of Salicornia europaea under sea salt treatment.

Fig. 4-17. Total number of fungal isolations and total salt levels on

roots ▨
shoots □

of Salicornia europaea under irrigation.


CONTROL
TOTAL FUNGI
10 isolates
TOTAL SALTS
50 mg
SODIUM NITRATE
SEA SALT
IRRIGATION
6/6
13/6
23/6
3/7
15/7
23/7
6/8
17/8
26/8
6/9
17/9
9/10
TIME

correlated with the salts of their respective plant parts for both the growing and stationary phases. In the stationary phase, the number of shoot isolates can serve to predict the divalent/monovalent ratio. Diversity on the divalent/monovalent ratio is correlated. On sodium nitrate treated plants, the shoot fungal isolate numbers can be applied on the shoot salts to predict the salt levels. Shoot salt levels can be predicted from total shoot isolates in stationary sea salt treated plants. Also, there is correlation of shoot isolates with the divalent/monovalent ratio.

When considering the treatments, there are significant variations in total root and shoot isolates (Figs. 4-14 to 17) over the treatments and time ($P = 0.003$ to <0.001) (Appendix 51). There is significant correlation of total fungal isolates (Appendix 5 or 52) combining root and shoot results with total salts (Fig. 4-14, Appendix 44) during the growing phase ($Y = 38.4-.06X$, $r = -.93$, $n = 5$) and the stationary phase ($Y = 103.7-.34X$, $r = -.97$, $n = 6$). Also, total fungal isolates from shoots correlate with total shoot salts in the growth phase ($Y = 21.1-.05X$, $r = -.91$, $n = 5$) and the stationary phase ($Y = 91.1-.38X$, $r =-.99$, $n = 6$). Regression of total isolates from roots on total root salts is significant in the growth phase ($Y = 16.95-0.9X$, $r = -.86$, $n = 5$) and the stationary phase ($Y = 38.4-.41X$, $r = -.82$, $n = 5$). Under sodium nitrate treatment, total fungal

isolates (root + shoot isolates from Appendices 21 or 53) regressed on total salts (root and shoot results combined from Fig. 4-15, Appendix 45) are somewhat correlated during the stationary phase ($Y = 88.1-23X$, $r = -.73$, $n = 6$). Total shoot isolates correlated with total shoot salts ($Y = 52.2-.21X$, $r = -.86$, $n = 6$) on sodium treated plants. Weak correlation ($Y = 62.7-.1X$, $r = -.66$, $n = 7$) of total fungal isolates (root + shoot isolates from Appendices 22 or 54) regressed on total salts (Fig. 4-16, Appendix 46) occurs in the stationary phase of sea salt treated plants. Total shoot isolates from sea salt treated plants correlate with total shoot salts ($Y = 37.52-.12X$, $r = -.86$, $n = 7$) in the stationary phase. On irrigated plants, the fungal root isolates (Appendix 55) are correlated ($Y = 21.3-.14X$, $r = -.83$, $n = 4$) with root salts (Fig. 4-17, Appendix 47) during the growth phase. Other combinations of total isolates and root or shoot isolates on total salts and root or shoot salts during the growth and stationary phases were not correlated above $r = \pm.65$. Finally, all correlations above this level were negative.

Regression of total fungal isolates on root and shoot ions for the growth and stationary plant phases are significant ($>r = .8$) for various combinations of treatments, times, plant parts and ions (Table 4-2). There are fewer significant correlations between total fungal isolates and ions for the sodium nitrate and sea salt treatments and irrigation than for the control plants.

TABLE 4-2

Regression of total fungal isolates and various ionic concentrations on roots and shoots of *Salicornia europaea* over treatments and temporal groups*

Treatment	Ions		Temporal Groups	Temporal Groups
			I (13/6-23/7) n=5	II-IV (6/8-9/10) n=6
CONTROL	Na^+	roots	Y = 19.26 - .29X, r = -.85	
	K^+	roots		Y = 27.95-2.19X, r = -.80
	Cl^-	roots	Y = 14.28 - .14X, r = -.90	
	Ca^{++}	shoots	Y = 23.83-1.49X, r = -.88	Y = 29.32-1.84X, r = -.84
	Mg^{++}	shoots		Y = 32.24-1.27X, r = -.93
	Cl^-	shoots	Y = 18.61 - .10X, r = -.93	Y = 46.62 - .64X, r = -.85
	$SO_4^=$	shoots		Y = 40.22 - .89X, r = -.97
			I (13/6-23/7) n=5	II-IV (6/8-9/10) n=6
SODIUM NITRATE	Na^+	roots	Y = 18.73 - .31X, r = -.81	
	Na^+	shoots		Y = 55.82 - .51X, r = -.83
	$SO_4^=$	shoots	Y = 1.84 + .31X, r = .96	Y = 35.70 - .54X, r = -.81
			I,II (13/6-15/7) n=4	III,IV (23/7-9/10) n=7
SEA SALTS	Mg^{++}	roots	Y = 20.00-3.26X, r = -.93	
	Na^+	shoots		Y = 41.50 - .35X, r = -.85
	$SO_4^=$	shoots	Y = -3.41 + .60X, r = .87	Y = 24.44 - .35X, r = -.87
			I (13/6-15/7) n=4	II-IV (23/7-9/10) n=7
IRRIGATION	Na^+	roots	Y = 23.19 - .50X, r = -.83	
	Cl^-	roots	Y = 17.28 - .21X, r = -.83	
	Ca^{++}	shoots	Y = 9.44 + .68X, r = .94	
	$SO_4^=$	shoots	Y = 19.47 + .27X, r = .94	

*Regression lines based on ion values from ashing at 550°C and distilled water extraction. Ionic concentrations expressed in mg/gm dw.

As the total number of isolates are not significantly different (P = .285) over the treatments (Appendix 56), the numbers under control conditions are representative of the seasonal pattern. Total isolates (combining root and shoot results) over the 1982 and 1983 collecting seasons are seen (Fig. 4-18) to change somewhat equally in magnitude and time.

DISCUSSION

Climatic and Edaphic Factors

Soil moisture and salinity are co-determinants of soil water potential (Waisel 1972). Soil water potential determines the water relations of halophyte cells (Dainty 1979; Jefferies 1981; Riehl and Ungar 1982). Generally, in order to establish a water gradient from the soil into the plant, cell water potential must be lower than the external environment (Waisel 1972). This implies that halophytes take up salts and/or produce and maintain osmoregulatory substances (Dainty 1979; Jefferies 1981).

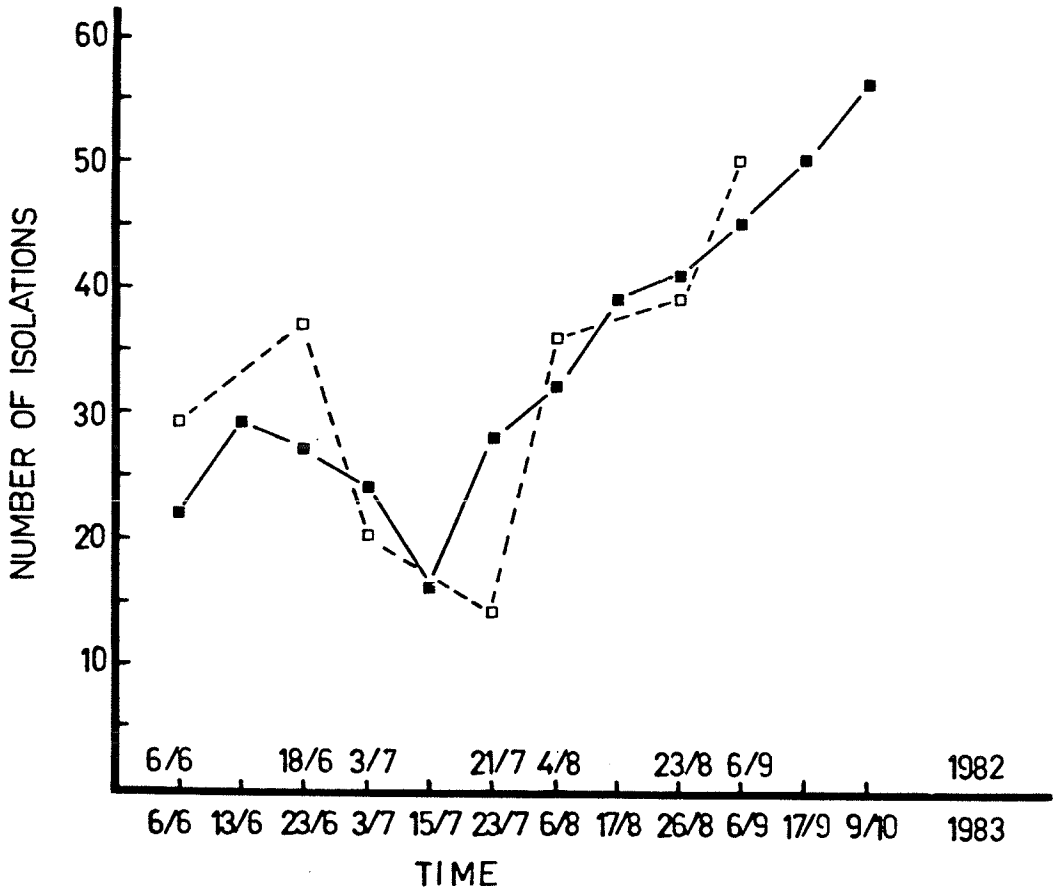
There is a seasonal variation is soil salinity which is influenced by the fluctuation in soil moisture (Waisel 1972; Ungar 1974; McMahon and Ungar 1978). Using soil conductivity as a measure of salinity, the results from Delta Marsh (Fig. 4-4) demonstrate the seasonal

Fig. 4-18. Total number of fungal isolations on Salicornia europaea under control conditions over

1982 □----□

1983 ■——■

collecting dates.


NUMBER OF ISOLATIONS
60
50
40
30
20
10
6/6
18/6
3/7
21/7
4/8
23/8
6/9
1982
6/6
13/6
23/6
3/7
15/7
23/7
6/8
17/8
26/8
6/9
17/9
9/10
1983
TIME

salinity variation. At the beginning of the season, soil salinity remains low as the soil water content markedly increases. With a drying of the soils in the middle of the season, the salinity greatly increases. The subsequent salinity decrease is concomitant with a soil water increase. Even though there is soil moisture increase at the end of the season, the salinity increases. This may be partly due to salt retransportation to the roots (Waisel 1972) and their loss from dead tissue.

Salinity, as conductivity, varied in relation to precipitation which is reported to wash salts from the soil (Hill 1908; Waisel 1972). Heavy rainfall (i.e., August 6 to September 6) brought the salinity sharply down while dry periods caused a sharp rise in salinity. Where sea salts are added, a pronounced dry period (i.e., August 17) caused a noticeable increase in salinity. (Irrigated soils show no such salinity increase on August 17.) The relationship between salinity and precipitation is perhaps overly simplistic.

Sporadic rainfall and high evapotranspiration during the growing season are known to affect the degree of salinity stress by causing fluctuations in the salt concentration of the soil (Ungar 1974). The three factors inherent in affecting soil salinity are: temperature, precipitation and soil moisture. In general terms, this study indicates an

early cool period combined with spring runoff and rain water. This results in a fairly low soil salinity (conductivity) during this period, i.e., June 6 through July 3. Middle season is warmer with low precipitation levels and high salinity levels. Precipitation is varied in this period, and soil water additions are somewhat mediated by the higher temperatures. The precipitation levels must be high in order to affect a noticeable soil moisture change due to increased evaporation. This, in turn, affects the degree of change in the soil salinity. At the end of the season, i.e., September 6 through October 9, lower temperatures are concomitant with decreased precipitation, a slight soil moisture increase from middle season and sharp rise in salinity. With lower temperatures, less precipitation is required to raise the soil moisture. Despite the rise in soil moisture, there is an accompanying rise in conductivity and hence salinity. As previously stated, this may be due to the release of salts from senescent, moribund and dead tissues. It is known that living plants will excrete salts from the root tissues (Waisel 1972).

Plant Characteristics

Plant salt content increases with soil salinity (Albert 1975; T.J. Flowers 1975; Cooper 1982; Riehl and Ungar 1982; Bennert and Schmidt 1984). In this study, control plants

demonstrated this pattern. Salt content levels in sodium nitrate and sea salt treated plants and irrigated plants may increase as the soil conductivity decreases. This may perhaps result from the obligate halophytic nature of Salicornia europaea (Austenfeld 1974; Tiku 1976; Jefferies and Perkins 1977; Jefferies et al. 1979a).

The plants responded directly to the increased levels of sodium nitrate and sea salt treatments. Thus, if a hydrostatic detector system (Hastings and Gutknecht 1976; Jefferies 1981) is present in S. europaea it would respond positively to a salt increase in the soil. Soil salinity must increase to a critical level, or certain ionic concentrations and combinations must be present, to facilitate salt uptake into the plant. In irrigated plants, where the soil conductivity is diminished by additions of distilled water, the uptake of salts occur earlier in the season than the control. Salts in the irrigated plots are leached away with the unexpected result that internal salt levels increase. Perhaps this further demonstrates the obligatory halophytic nature of S. europaea. Furthermore, the salt uptake and osmoregulatory system of the plant is complex and may, when considering the results of the irrigation experiments, act on negative as well as positive hydrostatic signals.

Complexity of the system is seen when considering

sodium levels in the plants. Although there is a rise within the tissues of sodium nitrate and sea salt treated plants at the same time, Na^+ levels in the later plants are lower than in the sodium nitrate treated plants. This may result from ionic competition (Waisel 1972; Albert 1975; T.J. Flowers 1975) as sea salt treatment involves a wide spectrum of ionic types. Also Na^+ uptake is seen to depend on the concentration of this ion in the external soil solution (T.J. Flowers 1975). Finally, the effect of sodium concentration on the uptake of Na^+ is dependent upon anionic interactions.

In halophytic systems it is reported that salts are asymmetrically distributed in order to ensure a favorable water potential gradient for the plant (Waisel 1972). Basically the water potential in halophytic plant shoots is lower than in the roots. Root cell water potential is, in turn, lower than in the soil. This study affirms this pattern with respect to the ratio of total root salts to shoot salts.

Interpretation of total salts and individual ion levels in the plant is problematical. Water extraction of ashed material results in an underestimation of the ions of calcium, magnesium and sulphate. In ashed material a portion of the Ca^{++} and Mg^{++} are combined in carbonates and are insoluable in water. At high temperatures sulphates combine

with carbon to form sulphides. These compounds are unstable at high temperatures and hydrogen sulphide gas is driven off.

Thus, it is appropriate to state that the results for calcium, magnesium and sulphate ions, in particular, are semiquantitative. It has been suggested (Ungar personal communication) that water extraction of ions may effectively represent the active osmotic component in the plant. Acid extraction of ash does account for ions incorporated into the cell wall and various membranes as well.

In Atriplex inflata F. Muell. and A. nummularia Lindl. the ratio of Na^+/K^+ is approximately the same in expressed cell sap and acid extraction of ash from plants grown in complete Hoogland's solution (Ashby and Beadle 1957). Wet ashed and acid extraction from Salicornia europaea produced less sodium to potassium ions (Na^+/K^+ = 2.0, Cooper 1982) than in oven-dried (95°C), boiled and water extracted S. prostrata Pall. (Na^+/K^+ ≃ 4.0-6.0, Albert 1975). The sodium to potassium ions ratio for young seedlings and mid-season mature plants is about the same in this study as in previous results (Riehl and Ungar 1982) using S. europaea and similar methodology.

Temporally, calcium, chlorine, potassium, sodium and sulphate ion levels show somewhat similar pattern for dry ashed-water extraction (Riehl and Ungar 1982) and oven dried-boiling in distilled water extraction (Albert 1975).

It is interesting to note that in Riehl and Ungar's Ohio collections where the soils are higher in Cl^- than Na^+, the amount of chlorides is greater than sodium in the plants. At Delta Marsh, the soils are higher in Na^+ than Cl^-, and the plants incorporate more sodium than chlorine into the cells.

Despite the limitations of the methodology employed, the general patterns of ion ratios and levels of this study are similar to the results of the previously mentioned work. The types of methods used do not appear to greatly alter the general pattern.

It is generally known that the growth of Salicornia europaea is enhanced by an increase in salts in its tissues (Ungar et al. 1979; Cooper 1982; Riehl and Ungar 1982). Stimulation of the growth of S. europaea and other halophytes has been previously reported (Ashby and Beadle 1957; Boucard and Ungar 1976; Jefferies 1977; Jefferies and Perkins 1977; Storey and Wyn Jones 1979; Pearcy and Ustin 1984). Also it is already known that irrigation of S. europaea inhibits growth (Cooper 1982). The growth period of roots is longer on sodium nitrate treated plants than on plants under the other treatments. Irrigated roots and shoots grow for the most-limited time period. Shoots grow for longer periods under control conditions and sea salt treatment than on plants treated with sodium nitrate. Perhaps it is not

simply the rate of growth that is important to the plant's survival in the environment but also the duration of the growth period.

Phenological stages in Salicornia europaea are very definitely affected by the duration of the growth period. For example, irrigated plants stopped growing and such normal stages as flowering and seed set with maturation never occurred. Water content of the stem also may be related to definite phenological stages such as the moribund and death conditions. The timing of the various phenological stages is the same for control plants as for sodium nitrate treated plants. Flowering occurs earlier in sea salt treated plants than in any plants under the other treatments. Irrigated plants remain as stated earlier in the vegetative condition or they are dead.

Fungal Patterns

Irrespective of the treatment, the general pattern of total fungal isolates over time is for a decrease in isolates during the growing phase of the plant. During the growth period, the plant is taking up salts, and in the stationary phase the salts decrease and root-shoot salt asymmetry decreases. The general fungal pattern in this phase is for an increase in fungal isolate numbers. There is a general increase in the fungi as salts decrease. How-

ever, the patterns in the growth and stationary phases are not different because of fungal isolate decline or rise but rather the rapid increase in the salts of the actively growing plants against the more-gradual decline in salts over the stationary and dead phases. The fungi developing in the growth phase are on plants with pronounced salt variation while those developing on stationary plants are associated with a gradual change in salts. This suggests that there may be a major dichotomy in the fungi developing on roots and shoots of Salicornia europaea. Perhaps as indicated earlier (Chapters 2 and 3), there are different types of succession in the two general, i.e., growing and stationary, phenological stages. As seral succession functions in a regime of biotic substrate changes (Frankland 1981), it is possible that there are definite seral stages on the growing plants. On the more-environmentally stable stationary plants, with a gradual change in salts, the pattern of fungal change may represent substate succession. As secondary succession involves a disturbance of habitat (Park 1968; Pugh 1980; Frankland 1981), it is possible to suggest that sodium nitrate treatment, sea salt addition and irrigation resulted in modifying the substrate. These modifications involve (1) plant growth; (2) phenological stages; (3) time of the onset of the stationary period; (4) total salt levels; (5) ionic concentration and symmetry; and (6) decline in shoot water levels. On this background the fungi demonstrate changing

diversity, dominance, life strategies, and successional patterns.

Although it is extremely difficult to establish clear cause and effect for any of the plant characteristics and the number of fungal isolates, it is instructive to discern patterns of fungal numbers in the light of events within the plant. Such a comparison may be seen to relate the plant's phenological stages to the changes in the fungal community. Interestingly enough, the temporal groups based on principal component analysis of taxa isolates over time, very closely correspond with the phenological stages. This is generally the case for each of the sere on plants of each treatment type. It appears that plant phenological events and fungal community changes may, with further research, permit the construction of a predictive model.

Another possible area of comparison of fungal pattern and plant activities involves the ionic levels in the latter. Recognizing the possibility of successional strategy differences within the fungal communities on each of the treatments, it is possible to consider the correlation of total fungal isolates on total salts, and root and shoot salts; shoot fungi on shoot salts; root fungi on root salts; total shoot isolates on the divalent/monovalent ratio; diversity on total salts and diversity on the divalent/monovalent ratio. If at high levels of correlation ($r>.8$) the regressions may be of some predic-

tive value. That is, it may be possible to make predictions on some of the listed comparisons based on numbers of total isolates.

Assuming that dominant and subdominant fungi represent a large percentage of the total of the isolates on a collecting date under the various treatments, it is possible to associate fungi with ionic patterns in the growing and stationary phases of the plant. For example, under control conditions there are a wide variety of ions in the growing plant which are strongly correlated with the total number of fungal isolates. The dominant and subdominant organisms are Alternaria alternata (Fr.) Keissler, A. phragmospora van Emden, Ascochyta chenopodii Roster, and Stemphylium botryosum Wallr. Nearly the same organisms, i.e., A. alternata, A. phragmospora and S. botryosum, are dominants and subdominants on irrigated growing plants. As in the case of the growing plants demonstrate a wide variety of ions correlating with total numbers of fungi. On the sodium nitrate treated plants, the dominant fungi are A. alternaria, A. phragmospora, A. chenopodii, and Fusarium tricinctum (Corda) Sacc. for the growing plants. On the sodium nitrate treated stationary plants the dominants are A. alternata, F. tricinctum and Phoma glomerata. The only ions correlated with total isolates are Na^{+} and $SO_4^{=}$. Dominants on sea salt treated plants on the growing plants, i.e., A. alternata, A. chlamydospora, A. phragmospora, A. chenopodii, Dendryphiella

arenaria Nicot, Monodictys pelagica (Johnson) E.B.G. Jones, and S. botryosum, perhaps correlate with Mg^{++} and $SO_4^{=}$. On the stationary plants, the dominant and subdominant fungi, i.e., Aureobasidium pullulans (De Bary) Arnand, and Alternaria chlamydospora Mouchacca, perhaps correlate with Na^{+} and $SO_4^{=}$.

There are major trends in life strategies which are related to the ecological conditions of food (stress) and perturbation (disturbance) (Pugh 1980). Relating ecological conditions with the treatment, it was observed (Table 4-3) that fungi on the control are perhaps exposed to the combinations of high stress with high disturbance and high stress alone (Table 4-3). Perhaps the high disturbance is related to the variety and type of ions as well as other factors. High stress seems to act on fungi on Salicornia europaea to be a general. In all probability, the root and shoot surfaces of S. europaea are high stress habitats. Contrarily, the life strategies of fungi growing on sodium nitrate treated plants show characteristics of organisms growing in low disturbance sites. Interestingly, there are only two ions, i.e., Na^{+} and $SO_4^{=}$, which correlate with total fungal isolates.

Although the plant ions may not be directly acting on the fungi, they do indicate various physiological and biochemical patterns which could act on the fungi.

TABLE 4-3

Principal life strategies under various treatments and on growth and stationary phases of Salicornia europaea*

Treatment	Growth Phase	Stationary Phase
	Temporal I	Temporals II-IV
CONTROL	Escapers Survivors (High stress, high disturbance)	Stress tolerant Escapers Survivors (High stress)
	Temporal I	Temporals II-IV
SODIUM NITRATE	Stress tolerant Competitors (Low disturbance)	Stress tolerant Competitors (Low disturbance)
	Temporals I,II	Temporals III-IV
SEA SALTS	Stress tolerant Escapers Survivors (High stress)	Stress tolerant Escapers Survivors (High stress)
	Temporal I	Temporals II-IV
IRRIGATION	Stress tolerant Escapers (High stress)	Stress tolerant Escapers Survivors (High stress)

*This table derived from Chapter 2, Fig. 2-18 and Chapter 3, Figs. 3-8 to 10.

GENERAL CONCLUSIONS

This study demonstrates that living and dead halophytic plants support various fungal groups. The total numbers of fungal isolates may vary from one plant species to another. Salicornia europaea was seen to render the majority of fungal taxa when compared with other halophytes. The differences in the number of fungal isolates and taxa were probably related to the nature, salt levels and osmotic strategies of the plants.

An examination of the fungal community structures of salt marsh halophytes showed that there is a clear similarity in the fungal assemblages of the obligate halophytes (e.g., Salicornia europaea and Suaeda depressa) and of the facultative halophytes (e.g., Hordeum jubatum and Puccinellia nuttalliana). Generally, diversity was seen to be inversely related to dominance, i.e., when diversity is high, dominance is low, and vice versa. It is also shown that there are two general diversity patterns among the six species studied. The diversity pattern on S. europaea, S. depressa and Atriplex patula, is different from the pattern on H. jubatum, P. nuttalliana and Glaux maritima.

On each of the plants, the fungal assemblage changed with time. The change in the fungal community structures (i.e., diversity, dominance, spatial groups and life strategies) suggests successional changes over the temporal groups. Two types of fungal successions can be recognized, seral and substrate successions. The seral successional pattern is mostly related to the plant biotic events during its growth stages. The second successional type is seen to be a function of the stationary phase of plant growth.

Climatic and edaphic factors varied throughout the growing season. Soil salinity was affected by precipitation, temperature and water moisture. High soil salinity was often observed during the dry period. Plant salt level was concomitant with the soil salinity pattern. Additions of sodium nitrate, sea salts and irrigation resulted in physical and chemical changes of the plant roots and shoots. Sodium nitrate and sea salts caused an increase in the ionic levels of the plant tissues. Irrigated plants, however, showed a relatively low level of salts. As a consequence the fungal assemblages were also changed. The fungal seres of the treated and untreated plants were similar during the earlier growth stages. However, differences in the seres were noticeable over later growth stages.

This investigation also demonstrates that the life strategies of fungi are related to ecological conditions

(i.e., stress and disturbance). It appears that treatments cause either a stressed or disturbed environment which affects the plant growth strategy as well as the associated mycota.

As the salt levels increased in the plant roots and shoots, the total number of fungal isolates decreased. Comparison between fungal patterns and plant ionic levels demonstrates a correlation between the total salts and total fungal isolates throughout the growth and stationary phases. Furthermore, regression analyses indicate that Na^{+}, Mg^{++} and $SO_4^{=}$ are the ions within plant tissue most highly correlated with fungi on Salicornia europaea. Since the correlations were high, it is suggested that such may be used as the basis of a predictive model.

Further research is needed to elucidate the relationship of fungal patterns and ionic levels in salt marsh halophytes using the dominant and subdominant taxa to predict the salt levels within the plant tissues. Study of the association of the mycota and halophytic plants may also provide an understanding of the ecology of salt marsh halophytes and their fungi.

APPENDICES

APPENDIX 1. Total number of isolates for various fungal taxa from Atriplex patula under control conditions over 1982 and 1983 collecting dates.

Taxa	1982							1983											
	T_1* 6/6	T_2 18/6	T_4 3/7	T_6 21/7	T_7 4/8	T_9 23/8	T_{10} 6/9	T_1 6/6	T_2 13/6	T_3 23/6	T_4 3/7	T_5 15/7	T_6 23/7	T_7 6/8	T_8 17/8	T_9 26/8	T_{10} 6/9	T_{11} 17/9	T_{12} 9/10
Alternaria alternata (Fr.) Keissler		6	12	15	7	9	22	4	5	10	14	16	15	14	8	15	17	22	30
A. raphani Groves et Skolko			2	2	6	6	1					2	2					4	6
A. tenuissima (Kunze ex Pers.) Wiltshire						2			2			1		8					
Ascochyta chenopodii Roster		4	3	2			2			3	1								
Cladosporium oxysporum Berk. et Curt.			1	1					1										1
Dendryphiella arenaria Nicot		1							2										1
Fusarium moniliforme Sheldon		1	1	7	2		3		1			3	12	2	3	3	9		2
F. tricinctum (Corda) Sacc.		5	3	2			2	5	3	4	8	2	3	1		1	2	5	3
Mucor hiemalis Wehmer		2	9	2		6	4	3	2					4	1	1	1	2	1
Phoma glomerata (Corda) Wollen. et Hochapfel		3	3				6		2	1		1						4	4
Stemphylium botryosum Wallr.										4		1							
sterile dark mycelia					2							1							
Trichoderma koningii Oudem										1									
Total number of taxa		7	8	7	4	4	7	3	8	6	3	8	4	5	3	4	4	5	8
Total number of isolates		22	34	31	17	23	40	12	18	23	23	27	32	29	12	20	29	37	48

*No collection made on this date

APPENDIX 2. Total numbers of isolates for various fungal taxa from Glaux maritima under control conditions over 1982 collecting dates.

Taxa	T_1 6/6	T_2 18/6	T_4 3/7	T_6 21/7	T_7 4/8	T_9 23/8	T_{10} 6/9
Alternaria alternata (Fr.) Keissler	4	3	7	4	8	18	24
Arthrinum phaeospermum (Corda) M.B. Ellis	2	2					1
Aureobasidium pullulans (De Bary) Arnand	6	5					
Cladosporium herbarum (Pers.) Link ex S.F. Gray	4	7	4				3
C. oxysporum Berk. et Curt.		1	1				
Dendryphiella arenaria Nicot				2	2		
Drechslera halodes (Drechsler) Subram. et Jain							5
Fusarium tricinctum (Corda) Sacc.			1	2	7	4	6
Gliocladium roseum Bain.	3						
Mucor hiemalis Wehmer		6	7	3		1	2
Phoma glomerata (Corda) Wollen. et Hochapfel	1						
Stemphylium botryosum Wallr.			3	2	1	5	
sterile white mycelia					5	2	
Total number of taxa	6	6	6	5	5	5	6
Total number of isolates	20	24	23	13	23	30	43

APPENDIX 3. Total numbers of isolates for various fungal taxa from *Hordeum jubatum* under control conditions over 1982 collecting dates.

Taxa	T_1 6/6	T_2 18/6	T_4 3/7	T_6 21/7	T_7 4/8	T_9 23/8	T_{10} 6/9
Alternaria alternata (Fr.) Keissler	10	14	16	10	8	9	17
A. petrosilini (Neergaard ex Simmons) M.B. Ellis							2
Arthrinum phaeospermum (Corda) M.B. Ellis	3	2	4	2	1		
Cladosporium herbarum (Pers.) Link ex S. F. Gray	1	2	1				
Dendryphiella arenaria Nicot	3	6	7	9	5	1	3
Drechslera halodes (Drechsler) Subram. et Jain							1
Fusarium tricinctum (Corda) Sacc.	3	2	6	3	8	6	16
Gliocladium roseum Bain.		2		2			
Mucor hiemalis Wehmer				2			
Phoma glomerata (Corda) Wollen. et Hochapfel	2			2		1	
Stemphylium botryosum Wallr.				2	5		
sterile white mycelia					2	2	4
Total number of taxa	6	6	5	8	6	5	6
Total number of isolates	22	28	34	32	29	19	43

APPENDIX 4. Total numbers of isolates for various fungal taxa from Puccinellia nuttalliana under control conditions over 1982 collecting dates.

Taxa	T_1 6/6	T_2 18/6	T_4 3/7	T_6 21/7	T_7 4/8	T_9 23/8	T_{10} 6/9
Alternaria alternata (Fr.) Keissler	9	10	12	5	16	16	20
A. dennisii M.B. Ellis	2						
A. petrosilini (Neergaard ex Simmons) M.B. Ellis						3	5
Arthrinum phaeospermum (Corda) M.B. Ellis	6	5	1				
Cladosporium herbarum (Pers.) Link ex S.F. Gray		2	2				
Dendryphiella arenaria Nicot	4	11	9	16	6	1	
Drechslera halodes (Drechsler) Subram. et Jain							3
Fusarium tricinctum (Corda) Sacc.		2	4	6		5	8
Gliocladium roseum Bain.	4						
Mucor hiemalis Wehmer			1	2			
Phoma glomerata (Corda) Wollen. et Hochapfel							4
Scytalidium lignicola Pesante					3	1	
Stemphylium botryosum Wallr.			2	4	7		
sterile white mycelia					1		
Total number of taxa	5	5	7	5	5	5	5
Total number of isolates	25	30	31	33	33	26	40

APPENDIX 5. Total number of isolates for various fungal taxa from *Salicornia europaea* under control conditions over 1982 and 1983 collecting dates.

Taxa	1982							1983											
	T_1 6/6	T_2 18/6	T_4 3/7	T_6 21/7	T_7 4/8	T_9 23/8	T_{10} 6/9	T_1 6/6	T_2 13/6	T_3 21/6	T_4 3/7	T_5 15/7	T_6 23/7	T_7 6/8	T_8 17/8	T_9 26/8	T_{10} 6/9	T_{11} 17/9	T_{12} 9/10
Acremonium furcatum F. et V. Moreau ex Gams	2	2			3	2		2										1	2
Alternaria alternata (Fr.) Keissler	2	4	1		10	18	14	5	9	9	6	2	4	23	22	23	27	24	27
A. citri Ellis et Pierce		3																	
A. chlamydospora Mouchacca			2	3	1	2	12						8	4	1	7	3	15	15
A. petrosilini (Neergaard ex Simmons) M.B. Ellis					6	5							9	2		1			
A. phragmospora van Emden	5	5	3	4				5	1		1	1							
A. raphani Groves et Skolko					2	2	3									5	10		
Ascochyta chenopodii Roster	5	2	4				10	7	3	4	5								
Aureobasidium pullulans (De Bary) Arnaud									2										
Cladosporium herbarum (Pers.) Link ex S.F. Gray		3	1						2										
Dendryphiella arenaria Nicot	3	2	3				3			2		1							1
Epicoccum purpurascens Ehrenb. ex Schlecht.	4	2				3										2	1		
Fusarium tricinctum (Corda) Sacc.	2	2			3	2	4	1						2	1	2	3	6	3
Gliocladium roseum Bain.		2					3	2											
Monodictys pelagica (Johnson) E.B.G. Jones			1								2	1							
Mucor hiemalis Wehmer									2										
Papulaspora halima Anastasiou						2	1		2										
Phoma glomerata (Corda) Wollen. et Hochapfel	3	3	1	3	5	3				2					1			4	6
Scytalidium lignicola Pesante		2																	
Stemphylium botryosum Wallr.		2	3	2					4	6	6	11	6						
sterile dark mycelia													1	1	13				
sterile white mycelia				2	6										1				2
Trichocladium achrasporum (Meyers et Moore) Dixon	6	3	1						2	4									
Trichoderma koningii Oudem											2					1	1		
Total number of taxa	9	14	10	5	8	9	8	6	9	6	6	5	5	5	6	7	6	5	7
Total number of isolates	29	37	20	14	36	39	50	22	29	27	24	16	28	32	39	41	45	50	56

APPENDIX 6. Total number of isolates for various fungal taxa from Suaeda depressa under control conditions over 1982 and 1983 collecting dates.

	1982							1983											
	T_1 6/6	T_2 18/6	T_4 3/7	T_6 21/7	T_7 4/8	T_9 23/8	T_{10} 6/9	T_1^* 6/6	T_2 13/6	T_3 23/6	T_4 3/7	T_5 15/7	T_6 23/7	T_7 6/8	T_8 17/8	T_9 26/8	T_{10} 6/9	T_{11} 17/9	T_{12} 9/10
Alternaria alternata (Fr.) Keissler	2	3	8	2	9	13	21		6	5	5		2	8	4	10	23	28	29
A. citri Ellis et Pierce			5	3	4							3		1					
A. dennisii M.B. Ellis	5	5	10	8	1	6			3	5	9	4		1					
A. tenuissima (Kunze ex Pers.) Wiltshire		2	2	3							3	2		2	1	3	10	3	
Arthrinum phaeospermum (Corda) M.B. Ellis			4	2	1	3							2						
Ascochyta chenopodii Roster	1	2					1			2			1	1	1				2
Cladosporium herbarum (Pers.) Link ex S.F. Gray	3	2									1								
Dendryphiella arenaria Nicot	2	2	4	8	2	1	2		1	2		1	2	2					
Drechslera halodes (Drechsler) Subram. et Jain							8											4	12
Epicoccum purpurasens Ehrenb. ex Schlecht.		3					3											1	
Fusarium tricinctum (Corda) Sacc.	2	3				2	1				2			2		1	3	1	1
Mucor hiemalis Wehmer	2	3								4			18	2		1			
Phoma glomerata (Corda) Wollen. et Hochapfel	3	4							6		2	4			2			2	3
Stemphylium botryosum Wallr.		2							1	3	7	13							
sterile white mycelia	2	2				4	2			3						5			
sterile dark mycelia			1				3							4					
Trichoderma koningii Odeum												1							1
Total number of taxa	9	12	7	6	5	6	8		5	7	7	7	5	9	4	5	3	6	6
Total number of isolates	22	33	34	26	17	29	41		17	24	29	28	25	23	8	20	36	39	48

*No collection made on this date

APPENDIX 7. Fungal species common to the 15 different paired combinations of the six salt marsh halophytes over 1982 and 1983 collecting dates.

	SUAEDA DEPRESSA	ATRIPLEX PATULA	GLAUX MARITIMA	PUCCINELLIA NUTTALLIANA	HORDEUM JUBATUM
SALICORNIA EUROPAEA (24)	Alternaria alternata A. citri Ascochyta chenopodii Cladosporium herbarum Dendryphiella arenaria Epicoccum purpurascens Fusarium tricinctum Mucor hiemalis Phoma glomerata Stemphylium botryosum sterile dark mycelia sterile white mycelia Trichoderma koningii	Alternaria alternata A. raphani Ascochyta chenopodii Dendryphiella arenaria Fusarium tricinctum Mucor hiemalis Phoma glomerata Stemphyllum botryosum sterile dark mycelia Trichoderma koningii	Alternaria alternata Aureobasidium pullulans Cladosporium herbarum Dendryphiella arenaria Fusarium tricinctum Gliocladium roseum Mucor hiemalis Phoma glomerata Stemphylium botryosum sterile white mycelia	Alternaria alternata A. petrosilini Cladosporium herbarum Dendryphiella arenaria Fusarium tricinctum Gliocladium roseum Mucor hiemalis Phoma glomerata Scytalidium lignicola Stemphylium botryosum sterile white mycelia	Alternaria alternata A. petrosilini Cladosporium herbarum Dendryphiella arenaria Fusarium tricinctum Gliocladium roseum Mucor hiemalis Phoma glomerata Stemphylium botryosum sterile white mycelia
SUAEDA DEPRESSA (17)		Alternaria alternata A. tenuissima Ascochyta chenopodii Dendryphiella arenaria Fusarium tricinctum Mucor hiemalis Phoma glomerata Stemphyllum botryosum sterile dark mycelia Trichoderma koningii	Alternaria alternata Arthrinum phaeospermum Cladosporium herbarum Dendryphiella arenaria Drechslera halodes Fusarium tricinctum Mucor hiemalis Phoma glomerata Stemphylium botryosum sterile white mycelia	Alternaria alternata A. dennisii Arthrinum phaeospermum Cladosporium herbarum Dendryphiella arenaria Drechslera halodes Fusarium tricinctum Mucor hiemalis Phoma glomerata Stemphylium botryosum sterile white mycelia	Alternaria alternata Arthrinum phaeospermum Cladosporium herbarum Dendryphiella arenaria Drechslera halodes Fusarium tricinctum Mucor hiemalis Phoma glomerata Stemphylium botryosum sterile white mycelia
ATRIPLEX PATULA (13)			Alternaria alternata Cladosporium oxysporum Dendryphiella arenaria Fusarium tricinctum Mucor hiemalis Phoma glomerata Stemphylium botryosum	Alternaria alternata Dendryphiella arenaria Fusarium tricinctum Mucor hiemalis Phoma glomerata Stemphylium botryosum	Alternaria alternata Dendryphiella arenaria Fusarium tricinctum Mucor hiemalis Phoma glomerata Stemphylium botryosum
GLAUX MARITIMA (13)				Alternaria alternata Arthrinum phaeospermum Cladosporium herbarum Dendryphiella arenaria Fusarium tricinctum Gliocladium roseum Mucor hiemalis Phoma glomerata Stemphylium botryosum sterile white mycelia	Alternaria alternata Arthrinum phaeospermum Cladosporium herbarum Dendryphiella arenaria Drechslera halodes Fusarium tricinctum Gliocladium roseum Mucor hiemalis Phoma glomerata Stemphylium botryosum sterile white mycelia
PUCCINELLIA NUTTALLIANA (14)					Alternaria alternata A. petrosilini Arthrinum phaeospermum Cladosporium herbarum Dendryphiella arenaria Drechslera halodes Fusarium tricinctum Gliocladium roseum Mucor hiemalis Phoma glomerata Stemphylium botryosum sterile white mycelia
HORDEUM JUBATUM (12)					

Figures in parentheses indicate total number of fungal taxa recovered from each plant species over the collecting period.

APPENDIX 8. Number of fungal taxa in common (a), number of taxa present only on the horizontally listed plants (b), number of taxa present only on the vertically listed plants (c), and number of taxa not present on either of the higher plants (d) in each of the 15 paired plant combinations.

	SUAEDA DEPRESSA	ATRIPLEX PATULA	GLAUX MARITIMA	PUCCINELLIA NUTTALLIANA	HORDEUM JUBATUM
SALICORNIA EUROPAEA (24)	13 12 4 1	10 15 3 2	10 15 3 2	11 14 3 2	10 15 2 3
SUAEDA DEPRESSA (17)		10 7 3 10	11 6 2 11	11 6 3 10	10 7 2 11
ATRIPLEX PATULA (13)			7 6 6 11	6 7 8 9	6 7 6 11
GLAUX MARITIMA (13)				11 2 3 14	11 2 1 16
PUCCINELLIA NUTTALLIANA (14)					12 2 0 16
HORDEUM JUBATUM (12)					

LEGEND

a	b
c	d

a = taxa in common
b = taxa on plant 1
c = taxa on plant 2
d = taxa not found on plant 1 and 2

APPENDIX 9. Principal component analyis coordinates derived from the total number of fungal isolates on Atriplex patula over the 1982 and 1983 collecting periods. The total number of fungal isolates is extracted from Appendix 1 in this dissertation.

Point	Coordinates	
	Axis 1	Axis 2
1	-2.3874640	-0.3685151
2	-2.0638978	-0.1989694
3	-0.9541385	-0.3769021
4	-4.6253036	-0.4792054
5	0.6379215	0.2404962
6	0.6836308	2.1756303
7	-0.0395302	-0.1597131
8	-1.3371242	0.5520661
9	0.3151856	0.3725358
10	0.9877449	1.5393472
11	2.1117408	-1.0482466
12	4.1264897	-0.6980832
13	-1.8061737	-0.4418423
14	-0.3884915	-1.0672636
15	0.4858994	0.9611225
16	-1.4316622	0.2580595
17	-1.0890671	-0.7091645
18	2.1535619	-0.5513525

Origin is at x = -3.6218100 and y = 4.3979122

APPENDIX 10. Principal component analysis coordinates derived from the total number of fungal isolates on Glaux maritima over the 1982 collecting period. The total number of fungal isolates is extracted from Appendix 2 in this dissertation.

Point	Coordinates	
	Axis 1	Axis 2
1	-2.8767817	0.6479154
2	-3.5572421	1.9000093
3	-1.3733735	0.6802049
4	-2.0271348	-1.4010439
5	0.1817730	-2.7398376
6	3.6204607	-0.7085100
7	6.0322983	1.6212620

Origin is at x = 1.3304608 and y = 6.6523041

APPENDIX 11. Principal component analysis coordinates derived from the total number of fungal isolates on Hordeum jubatum over the 1982 collecting period. The total number of fungal isolates is extracted from Appendix 3 in this dissertation.

Point	Coordinates	
	Axis 1	Axis
1	-1.4797071	-0.4495936
2	-1.4392713	1.4747320
3	0.1187035	2.0865052
4	-2.0670691	0.2521065
5	0.0692069	-1.9886700
6	-1.9518966	-1.7635952
7	4.8000889	0.3885149

Origin is at x = 0 and y = 4.4903053

APPENDIX 12. Principal component analysis coordinates derived from the total number of fungal isolates on Puccinellia nuttalliana over the 1982 collecting period. The total number of fungal isolates is extracted from Appendix 4 in this dissertation.

Point	Coordinates	
	Axis 1	Axis 2
1	0.4363351	-3.2369139
2	2.1435728	-0.9992550
3	0.9793274	0.4080127
4	4.7742071	2.3170007
5	-0.7819946	-0.2874538
6	-2.8487520	0.1760900
7	-4.7026958	1.6225193

Origin is at x = 2.6609216 and y = 1.4635069

APPENDIX 13. Principal component analysis coordinates derived from the total number of fungal isolates on Salicornia europaea over the 1982 and 1983 collecting periods. The total number of fungal isolates is extracted from Appendix 5 in this dissertation.

Point	Coordinates	
	Axis 1	Axis 2
1	-1.9626998	-0.0558029
2	-1.2042961	-0.6124746
3	-1.3322738	-0.5498447
4	-1.9249402	-0.3298757
5	-2.8211273	-0.2852058
6	-1.5469874	1.2296215
7	2.4913006	-0.7296469
8	2.2219095	-2.2235190
9	2.8321958	-0.2559674
10	3.5472654	-1.4234904
11	3.6383962	1.7220494
12	4.2095099	1.5363456
13	-2.5606224	-0.0140514
14	-2.1991877	-0.1011665
15	-2.7276113	0.4504427
16	-2.6975010	0.5782960
17	-0.3637374	-0.2124005
18	1.3502296	-0.6832953
19	1.0501773	1.9599860

Origin is at x = 5.6369524 and y = 3.4311884

APPENDIX 14. Principal component analysis coordinates derived from the total number of fungal isolates on Suaeda depressa over the 1982 and 1983 collecting periods. The total number of fungal isolates is extracted from Appendix 6 in this dissertation.

Point	Coordinates	
	Axis 1	Axis 2
1	-0.9134713	-0.3220146
2	-1.3908474	0.3088200
3	-1.4893083	-1.3765258
4	-2.6506934	-1.4327130
5	-2.2372412	3.8174928
6	-0.3771340	0.4123029
7	-1.1415642	0.1502278
8	0.2295236	0.3004133
9	3.2662899	-0.2118217
10	4.5173080	2.6934338
11	5.1944832	0.1947315
12	-1.9441935	0.0505108
13	-1.7050535	0.1959196
14	-0.8263634	-1.0445983
15	-2.1054569	-0.8262554
16	-0.1627470	-0.0567824
17	0.5913401	-0.4250169
18	3.1451291	0.2626159

Origin is at x = -2.5870072 and y = 6.5968682

APPENDIX 15. Total isolates, frequency, square root of frequency, occurrence, distribution intensity index and dominance function of various fungal taxa from Atriplex patula over the 1982 and 1983 collecting dates.

Taxa	Total isolates	Frequency (f)	√frequency	Occurrence	Distribution intensity index (DII)*	Dominance function**	Total isolates	Frequency (f)	√frequency	Occurrence	Distribution intensity index (DII)*	Dominance function**	Total isolates	Frequency (f)	√frequency	Occurrence	Distribution intensity index (DII)*	Dominance function**	Total isolates	Frequency (f)	√frequency	Occurrence	Distribution intensity index (DII)*	Dominance Function**
	Temporal I						Temporal II						Temporal III						Temporal IV					
Alternaria alternata	60	28.6	5.4	100.0	534.5	D	75	41.7	6.5	100.0	645.5	D	15	25.0	5.0	100	500.0	D	64	71.1	8.4	100.0	843.3	D
A. raphani	8	3.8	2.0	28.6	55.8	R	6	3.3	1.8	50.0	91.3	VR	6	10.0	3.2	50	158.1	C	11	12.2	3.5	100.0	349.6	R
A. tenuissima	4	1.9	1.4	28.6	39.5	VR	9	5.0	2.2	33.3	74.5	R												
Ascochyta chenopodii	11	5.2	2.3	57.1	130.7	R	2	1.1	1.1	16.7	17.6	VR							2	2.2	1.5	33.3	49.6	VR
Cladosporium oxysporum	2	0.95	0.97	28.6	27.9	VR	1	0.6	0.8	16.7	12.5	VR							1	1.1	1.1	33.3	35.1	VR
Dendryphiella arenaria	3	1.4	1.2	28.6	33.5	VR													1	1.1	1.1	33.3	35.1	VR
Fusarium moniliforme	3	1.4	1.2	42.8	51.2	VR	36	20.0	4.5	100.0	447.2	SD	5	8.3	2.9	100	288.7	R	5	5.6	2.4	66.7	157.2	VR
F. tricinctum	28	13.3	3.7	87.5	319.5	SD	11	6.1	2.5	100.0	247.2	C							10	11.1	3.3	100.0	333.3	R
Mucor hiemalis	22	10.5	3.2	62.5	202.3	C	8	4.4	2.1	66.7	140.6	R	1	1.7	1.3	50	64.6	VR	7	7.8	2.8	100.0	278.9	R
Phoma glomerata	9	4.3	2.1	50.0	103.5	R	1	0.6	0.8	16.7	12.5	VR							14	15.6	3.9	100.0	394.4	SD
Stemphylium botryosum	4	1.9	1.4	14.3	20.0	VR	1	0.6	0.8	16.7	12.5	VR												
sterile dark mycelia							1	0.6	0.8	16.7	12.5	VR	2	3.3	1.8	50	91.3	R						
Trichoderma koningii	1	0.5	0.7	14.3	9.9	VR																		
Number of starts	210						180						60						90					
	$\bar{X}_1, s_1$ = 23.0±18.1						$\bar{X}_1, s_1$ = 24.2±27.3						$\bar{X}_1, s_1$ = 8.7±5.5						$\bar{X}_1, s_1$ = 18.5±22.5					
	$\bar{X}_2, s_2$ = 15.6± 8.9						$\bar{X}_2, s_2$ = 14.0±12.4						$\bar{X}_2, s_2$ = 5.5±0.7						$\bar{X}_2, s_2$ = 9.4± 3.5					
	$\bar{X}_3, s_3$ = 12.5± 6.5						$\bar{X}_3, s_3$ = 8.5± 2.1						$\bar{X}_3, s_3$ = 3.5±2.1						$\bar{X}_3, s_3$ = 8.3± 2.8					

*Values derived from unrounded √frequency

**D = dominant; SD = subdominant; C = common; R = rare; VR = very rare

APPENDIX 16. Total isolates, frequency, square root of frequency, occurrence, distribution intensity index and dominance function of various fungal taxa from Glaux maritima over the 1982 collecting dates.

Taxa	Total isolates	Frequency (f)	√frequency	Occurrence	Distribution intensity index (DII)*	Dominance function**	Total isolates	Frequency (f)	√frequency	Occurrence	Distribution intensity index (DII)*	Dominance function**	Total isolates	Frequency (f)	√frequency	Occurrence	Distribution intensity index (DII)*	Dominance function**
	..... Temporal I						..... Temporal II						..... Temporal III					
Alternaria alternata	18	15.0	3.9	100	387.3	SD	8	26.7	5.2	100	516.7	D	42	70.0	8.4	100	836.7	D
Arthrinum phaeospermum	2	1.7	1.3	50	65.2	VR							1	1.7	1.3	50	65.2	R
Aureobasidium pullulans	11	9.2	3.0	50	151.7	C												
Cladosporium herbarum	15	12.5	3.5	75	265.2	C							3	5.0	2.2	50	111.8	R
C. oxysporum	2	1.7	1.3	50	65.2	VR												
Dendryphiella arenaria	2	1.7	1.3	25	32.5	VR	2	6.7	2.6	100	258.8	R						
Drechslera halodes													5	8.3	2.9	50	144.1	R
Fusarium tricinctum	3	2.5	1.6	25	39.5	R	4	13.3	3.7	100	364.7	C	10	16.7	4.1	100	408.7	SD
Gliocladium roseum	3	2.5	1.6	25	39.5	R												
Mucor hiemalis	16	13.3	3.7	75	273.5	C							3	5.0	2.2	100	223.6	R
Phoma glomerata	1	0.8	0.9	25	22.4	VR												
Stemphylium botryosum	5	4.2	2.1	50	102.5	R	1	3.3	1.8	100	181.7	R	5	8.3	2.9	50	144.1	R
sterile white mycelia							5	16.7	4.1	100	408.7	C	2	3.3	1.8	50	90.8	R
Number of starts	120						30						60					
	$\bar{X}_1, s_1$ = 13.0±5.2						$\bar{X}_1, s_1$ = 5.7±2.1						$\bar{X}_1, s_1$ = 15.5±17.8					
	$\bar{X}_2, s_2$ = 11.8±4.9						$\bar{X}_2, s_2$ = 4.5±0.71						$\bar{X}_2, s_2$ = 6.7± 2.9					
	$\bar{X}_3, s_3$ = 3.7±1.2						$\bar{X}_3, s_3$ = 1.5±0.71						$\bar{X}_3, s_3$ = 5.0± 0.0					

*Values derived from unrounded $\sqrt{\text{frequency}}$

**D = dominant; SD = subdominant; C = common; R = rare; VR = very rare

APPENDIX 17. Total isolates, frequency, square root of frequency, occurrence, distribution intensity index and dominance function of various fungal taxa from Hordeum jubatum over the 1982 collecting dates.

Taxa	Total isolates	Frequency (f)	√frequency	Occurrence	Distribution intensity index (DII)*	Dominance function**	Total isolates	Frequency (f)	√frequency	Occurrence	Distribution intensity index (DII)*	Dominance function**	Total isolates	Frequency (f)	√frequency	Occurrence	Distribution intensity index (DII)*	Dominance function**
	..... Temporal I						..... Temporal II						..... Temporal III					
Alternaria alternata	50	41.7	6.5	100	645.8	D	13	10.8	3.3	100	328.6	SD	17	14.2	3.8	100	376.8	SD
A. petrosilini													2	1.7	1.3	100	130.4	VR
Arthrinum phaeospermum	11	9.2	3.0	100	303.3	R	1	0.8	0.9	50	44.7	VR						
Cladosporium herbarum	4	3.3	1.8	75	136.2	R												
Dendryphiella arenaria	25	20.8	4.6	100	456.1	SD	6	5.0	2.2	100	223.6	R	3	2.5	1.6	100	158.1	R
Drechslera halodes													1	0.8	0.9	100	89.4	VR
Fusarium tricinctum	11	9.2	3.0	100	303.3	R	14	11.7	3.4	100	342.1	SD	16	13.3	3.7	100	364.7	SD
Gliocladium roseum	4	3.3	1.8	50	90.8	R												
Mucor hiemalis	2	1.7	1.3	25	32.6	VR												
Phoma glomerata	4	9.2	3.0	50	151.7	R	1	0.8	0.9	50	44.7	VR						
Stemphylium botryosum	2	1.7	1.3	25	32.6	VR	5	4.2	2.1	50	102.5	R						
sterile white mycelia							4	3.3	1.8	100	181.7	VR	4	3.3	1.8	100	181.7	R
Number of starts	120						60						30					
	$\bar{X}_1, s_1$ = 24.3±18.4						$\bar{X}_1, s_1$ = 9.5±4.7						$\bar{X}_1, s_1$ = 16.5±0.71					
	$\bar{X}_2, s_2$ = 15.7± 8.1						$\bar{X}_2, s_2$ = 9.5±4.7						$\bar{X}_2, s_2$ = 16.5±0.71					
	$\bar{X}_3, s_3$ = 7.5± 4.1						$\bar{X}_3, s_3$ = 5.5±0.7						$\bar{X}_3, s_3$ = 3.5±0.71					

*Values derived from unrounded $\sqrt{\text{frequency}}$

**D = dominant; SD = subdominant; C = common; R = rare; VR = very rare

APPENDIX 18. Total isolates, frequency, square root of frequency, occurrence, distribution intensity index and dominance function of various fungal taxa from Puccinellia nuttalliana over the 1982 collecting dates.

Taxa	Total isolates	Frequency (f)	√frequency	Occurrence	Distribution intensity index (DII)*	Dominance function**	Total isolates	Frequency (f)	√frequency	Occurrence	Distribution intensity index (DII)*	Dominance function**	Total isolates	Frequency (f)	√frequency	Occurrence	Distribution density index (DII)*	Dominance function**
	Temporal I						Temporal II						Temporal III					
Alternaria alternata	19	31.7	5.6	100	563.0	D	17	28.3	5.3	100	531.9	C	52	57.8	7.6	100.0	760.0	D
A. dennisii	2	3.3	1.8	50	90.8	VR												
A. petrosilini													8	8.8	2.9	66.7	197.9	R
Arthrinum phaeospermum	11	18.3	4.3	100	427.8	R	1	1.7	1.3	50	65.2	VR						
Cladosporium herbarum	2	3.3	1.8	50	90.8	VR	2	3.3	1.8	50	90.8	VR						
Dendryphiella arenaria	15	25.0	5.0	100	500.0	C	25	41.7	6.5	100	645.8	D	1	1.1	1.1	33.3	34.9	VR
Drechslera halodes													3	3.3	1.8	33.3	60.5	VR
Fusarium tricinctum	2	3.3	1.8	50	90.8	VR	10	20.0	4.5	100	447.2	R	13	14.5	3.8	66.7	253.9	C
Gliocladium roseum	4	6.7	2.6	50	129.4	VR												
Mucor hiemalis							3	5.0	2.2	100	223.6	VR						
Phoma glomerata													4	4.4	2.1	66.7	139.9	VR
Scytalidium lignicola													1	1.1	1.1	33.3	34.9	VR
Stemphylium botryosum							6	10.0	3.2	100	316.2	R	7	7.8	2.8	33.3	93.0	R
sterile white mycelia													1	1.1	1.1	33.3	34.9	VR
Number of starts	60						60						90					
	$\bar{X}_1, s_1 = 12.3 \pm 5.7$						$\bar{X}_1, s_1 = 15.0 \pm 8.1$						$\bar{X}_1, s_1 = 24.3 \pm 24.1$					
	$\bar{X}_2, s_2 = 10.0 \pm 5.6$						$\bar{X}_2, s_2 = 11.7 \pm 5.5$						$\bar{X}_2, s_2 = 10.5 \pm 3.5$					
	$\bar{X}_3, s_3 = 7.5 \pm 4.9$						$\bar{X}_3, s_3 = 9.0 \pm 4.3$						$\bar{X}_3, s_3 = 6.0 \pm 2.8$					

*Values dervied from unrounded $\sqrt{\text{frequency}}$

**D = dominant; SD = subdominant; C = common; R = rare; VR = very rare

APPENDIX 19. Total isolates, frequency, square root of frequency, occurrence, distribution intensity index and dominance function of various fungal taxa from Salicornia europaea over the 1982 and 1983 collecting dates.

Taxa	Temporal I						Temporal II						Temporal III						Temporal IV					
	Total isolates	Frequency (f)	√frequency	Occurrence	Distribution intensity index (DII)*	Dominance function**	Total isolates	Frequency (f)	√frequency	Occurrence	Distribution intensity index (DII)*	Dominance function**	Total isolates	Frequency (f)	√frequency	Occurrence	Distribution intensity index (DII)*	Dominance function**	Total isolates	Frequency (f)	√frequency	Occurrence	Distribution intensity index (DII)*	Dominance function**
Acremonium furcatum	6	2.2	1.5	33.0	49.6	R	3	5.0	2.2	50	110	VR	2	1.3	1.14	20.0	22.8	VR	3	3.3	1.8	66.7	120.9	VR
Alternaria alternata	38	14.1	3.8	88.9	337.8	D	14	23.3	4.8	50	240	SD	113	75.3	8.68	100.0	867.9	D	5	72.2	8.49	100.0	849.8	D
A. citri	3	1.11	1.05	11.1	11.7	VR																		
A. chlamydospora	5	1.8	1.35	22.2	30.2	R	9	15.0	3.9	100	390	C	17	11.3	3.36	100.0	336.7	SD	42	46.7	6.83	100.0	683.4	SD
A. petrosilini							15	5.0	2.2	100	220	D	8	5.3	2.3	80.0	184.8	R						
A. phragmospora	29	10.7	3.3	88.9	293.4	D																		
A. raphani							2	3.8	1.8	50	90	VR	17	11.3	3.36	40.0	134.7	SD	3	3.3	1.8	25.0	45.6	VR
Ascochyta chenopodii	27	12.0	3.2	77.8	248.9	SD													10	11.1	3.33	25.0	83.9	R
Aureobasidium pullulans	2	0.74	0.86	11.1	9.6	VR																		
Cladosporium herbarum	6	2.2	1.5	33.3	49.6	R																		
Dendryphiella arenaria	11	4.1	2.0	55.6	111.2	R													4	4.5	2.12	50.0	106.0	VR
Epicoccum purpurascens	6	2.2	1.5	22.3	33.1	R							6	4.0	2.00	75.0	150.0	R						
Fusarium tricinctum	5	1.8	1.3	33.3	43.3	R	3	5.0	2.2	50	110	VR	8	5.3	2.3	100.0	230.9	R	13	14.5	3.8	100.0	380.0	C
Gliocladium roseum	4	1.5	1.2	22.2	26.6	VR													3	3.3	1.8	25.0	45.6	VR
Monodictys pelagica	4	1.5	1.2	33.3	39.9	VR																		
Mucor hiemalis	2	0.75	0.86	11.1	9.6	VR																		
Papulaspora halima	2	0.7	0.8	11.1	8.8	VR													3	3.3	1.8	50.0	90.8	VR
Phoma glomerata	12	4.5	2.1	55.6	117.0	R	5	8.3	2.9	50	145	R	4	2.7	1.64	60.0	98.4	VR	10	11.3	3.3	25.0	83.3	R
Scytalidium lignicola	2	0.7	0.8	11.1	8.8	VR																		
Stemphylium botryosum	34	12.6	3.6	77.8	280.0	D	6	10.0	3.2	50	160	R												
sterile dark mycelia							1	1.7	1.3	50	65	VR	14	9.3	3.04	50.0	152.5	C						
sterile white mycelia	2	0.7	0.8	11.1	8.8	VR	6	10.0	3.2	50	160	R	1	0.7	0.83	40.0	33.5	VR	2	2.2	1.5	25.0	37.3	VR
Trichocladium achrasporum	16	5.9	2.4	55.6	133.4	C																		
Trichoderma koningii	2	0.7	0.8	11.1	8.8	VR							2	1.3	1.14	20	45.6	VR						
Number of starts	270						60						150						90					
	$\bar{x}_1, s_1 = 16.3 \pm 12.1$						$\bar{x}_1, s_1 = 9.2 \pm 4.9$						$\bar{x}_1, s_1 = 26.2 \pm 38.6$						$\bar{x}_1, s_1 = 28.0 \pm 24.7$					
	$\bar{x}_2, s_2 = 10.6 \pm 7.6$						$\bar{x}_2, s_2 = 8.0 \pm 3.4$						$\bar{x}_2, s_2 = 11.7 \pm 4.9$						$\bar{x}_2, s_2 = 18.8 \pm 15.6$					
	$\bar{x}_3, s_3 = 8.4 \pm 4.1$						$\bar{x}_3, s_3 = 6.5 \pm 1.7$						$\bar{x}_3, s_3 = 9.0 \pm 3.5$						$\bar{x}_3, s_3 = 11.0 \pm 1.8$					

*Values derived from unrounded √frequency

**D = dominant; SD = subdominant; C = common; R = rare; VR = very rare

APPENDIX 20. Total isolates, frequency, square root of frequency, occurrence, distribution intensity index and dominance function of various fungal taxa from Suaeda depressa over the 1982 and 1983 collecting dates.

Taxa	Total isolates	Frequency (f)	√frequency	Occurrence	Distribution intensity index (DII)*	Dominance function**	Total isolates	Frequency (f)	√frequency	Occurrence	Distribution intensity index (DII)*	Dominance function**	Total isolates	Frequency (f)	√frequency	Occurrence	Distribution intensity index (DII)*	Dominance function**
	..... Temporal I						..... Temporal II						..... Temporal III					
Alternaria alternata	33	13.8	3.7	88.9	326.3	D	31	25.8	5.1	100	508.3	D	114	76.0	8.7	100	871.8	D
A. citri	11	4.6	2.14	33.0	70.7	R	8	6.7	2.6	50	129.1	C						
A. dennisii	49	20.4	4.5	88.9	401.7	D	2	1.7	1.3	25	32.3	VR	6	4.0	2.0	20	40.0	R
A. tenuissima	12	5.0	2.24	55.6	124.3	R	6	5.0	2.2	75	167.7	R	13	8.7	2.9	40	117.7	C
Arthrinum phaeospermum	8	3.3	1.83	33.3	60.8	R	1	0.8	0.9	25	22.8	VR	3	2.0	1.4	20	28.3	VR
Ascochyta chenopodii	6	2.5	1.6	44.5	70.4	R	3	2.5	1.6	50	79.1	VR	3	2.0	1.4	40	56.6	VR
Cladosporium herbarum	6	2.5	1.6	33.3	53.3	R												
Dendryphiella arenaria	22	9.2	3.03	88.9	269.2	SD	4	3.3	1.8	50	91.3	VR	3	2.0	1.4	40	56.6	VR
Drechslera halodes													24	16.0	4.0	60	240.0	SD
Epicoccum purpurascens	3	1.25	1.1	11.1	12.4	VR							4	2.7	1.6	40	65.3	VR
Fusarium tricinctum	7	2.9	1.7	33.3	56.9	R	3	2.5	1.6	50	79.1	VR	8	5.3	2.8	80	184.8	R
Mucor hiemalis	9	3.8	1.9	44.5	86.2	R	20	16.7	4.1	50	204.1	SD						
Phoma glomerata	19	7.9	2.8	55.6	156.4	C	2	1.7	1.3	25	32.3	VR	5	3.3	1.8	40	73.0	R
Stemphylium botryosum	26	10.8	3.3	55.6	183.0	SD												
sterile white mycelia	7	2.9	1.7	33.3	56.9	R							11	7.3	2.7	40	108.3	R
sterile dark mycelia	1	0.4	0.65	11.1	7.2	VR	4	3.3	1.8	25	45.0	VR	3	2.0	1.4	20	28.3	R
Trichoderma koningii	1	0.4	0.65	20.0	13.0	VR							1	0.7	0.8	20	16.3	VR
Number of starts	240						120						150					
	$\bar{X}_1, s_1 = 16.9 \pm 13.1$						$\bar{X}_1, s_1 = 16.4 \pm 11.6$						$\bar{X}_1, s_1 = 23.6 \pm 3.7$					
	$\bar{X}_2, s_2 = 12.1 \pm 7.0$						$\bar{X}_2, s_2 = 11.4 \pm 7.6$						$\bar{X}_2, s_2 = 10.7 \pm 6.5$					
	$\bar{X}_3, s_3 = 9.5 \pm 4.2$						$\bar{X}_3, s_3 = 7.0 \pm 1.4$						$\bar{X}_3, s_3 = 8.5 \pm 3.0$					

*Values derived from unrounded $\sqrt{\text{frequency}}$

**D = dominant; SD = subdominant; C = common; R = rare; VR = very rare

APPENDIX 21. Total number of fungal isolates on *Salicornia europaea* under sodium nitrate treatment.

Taxa	T_1 6/6	T_2 13/6	T_3 23/6	T_4 3/7	T_5 15/7	T_6 23/7	T_7 6/8	T_8 17/8	T_9 26/8	T_{10} 6/9	T_{11} 17/9	T_{12} 9/10
Alternaria alternata	4	1		3	9	5	18	22	22	23	19	29
A. chlamydospora				1		7						
A. petrosilini						5						
A. phragmospora	6	3		8	6							
Ascochyta chenopodii	7	2	2	4								
Aureobasidium pullulans		3	1									
Cladosporium herbarum				2								
Dendryphiella arenaria					2	2	3					
Fusarium moniliforme									7	10	3	2
F. tricinctum	1	7	2					4	8	14		
Monodictys pelagica				2								
Mucor hiemalis		3			7	7	4	2				
Phoma glomerata					4			12	7	3	18	16
Stemphylium botryosum			2	3	3	1						
sterile dark mycelia		1										
sterile white mycelia			1									3
Trichoderma koningii										1		
Total number of isolates	18	20	8	23	31	27	25	40	44	51	40	50

APPENDIX 22. Total number of fungal isolates on *Salicornia europaea* under sea salts treatment.

Taxa	T_1 6/6	T_2 13/6	T_3 23/6	T_4 3/7	T_5 15/7	T_6 23/7	T_7 6/8	T_8 17/8	T_9 26/8	T_{10} 6/9	T_{11} 17/9	T_{12} 9/10
Acremonium furcatum									1			
Alternaria alternata	6			3	5	15	25	15	22	28	29	25
A. chlamydospora		4		1	7	7	6	11	13	9	12	13
A. petrosilini							6		2	5		
A. phragmospora	7											
Ascochyta chenopodii	4			4	1							
Aureobasidium pullulans		17	2									
Cladosporium herbarum			1	1								
Dendryphiella arenaria				5	1	2						
Epicoccum purpurascens						1						
Fusarium tricinctum	1	1	3					3				
Monodictys pelagica				5	5							
Mucor hiemalis								2				
Stemphylium botryosum		2	4	4	6	4						
sterile dark mycelia					3			9				
sterile white mycelia			1					3				13
Trichocladium achrasporum				2								
Total number of isolates	18	24	11	25	28	29	37	43	38	42	41	51

APPENDIX 23. Total number of fungal isolates on *Salicornia europaea* under irrigation.

Taxa	T_1 6/6	T_2 13/6	T_3 23/6	T_4 3/7	T_5 15/7	T_6 23/7	T_7 6/8	T_8 17/8	T_9 26/8	T_{10} 6/9	T_{11} 17/9	T_{12} 9/10
Acremonium furcatum	1			3								
Alternaria alternata	3	2	6	8	13	11	25	23	26	25	25	23
A. petrosilini						3	9					
A. phragmospora	5	9		4	5	3						
A. raphani									11	16	8	14
Ascochyta chenopodii	4	2	1	3								
Aureobasidium pullulans		3										
Cladosporium herbarum			1	1								
Fusarium tricinctum	2					1	4	7	1	3	2	1
Phoma glomerata			1			8		4		1	4	
Stemphylium botryosum		10	11	6	12	3						
sterile dark mycelia								10				3
Trichoderma koningii							1		1			
Total number of isolates	15	26	20	25	30	29	39	44	39	45	39	41

APPENDIX 24. Fungal species common to the nine different paired combinations of *Salicornia europaea* under various treatments.

	SEA SALT	SODIUM NITRATE	IRRIGATION
CONTROL	*Acremonium furcatum* *Alternaria alternata* *A. chlamydospora* *A. petrosilini* *A. phragmospora* *Ascochyta chenopodii* *Aureobasidium pullulans* *Cladosporium herbarum* *Epicoccum purpurascens* *Fusarium tricinctum* *Monodictys pelagica* *Mucor hiemalis* *Stemphylium botryosum* *Trichocladium achrasporum* sterile dark mycelia sterile white mycelia	*Alternaria alternata* *A. chlamydospora* *A. petrosilini* *A. phragmospora* *Ascochyta chenopodii* *Aureobasidium pullulans* *Cladosporium herbarum* *Dendryphiella arenaria* *Fusarium tricinctum* *Monodictys pelagica* *Mucor hiemalis* *Phoma glomerata* *Stemphylium botryosum* *Trichoderma koningii* sterile dark mycelia sterile white mycelia	*Acremonium furcatum* *Alternaria alternata* *A. petrosilini* *A. phragmospora* *A. raphani* *Ascochyta chenopodii* *Aureobasidium pullulans* *Cladosporium herbarum* *Fusarium tricinctum* *Phoma glomerata* *Stemphylium botryosum* *Trichoderma koningii* sterile dark mycelia
SEA SALT		*Alternaria alternata* *A. chlamydospora* *A. petrosilini* *A. phragmospora* *Ascochyta chenopodii* *Aureobasidium pullulans* *Fusarium tricinctum* *Monodictys pelagica* *Mucor hiemalis* *Stemphylium botryosum* sterile dark mycelia sterile white mycelia	*Acremonium furcatum* *Alternaria alternata* *A. petrosilini* *A. phragmospora* *Ascochyta chenopodii* *Aureobasidium pullulans* *Cladosporium herbarum* *Fusarium tricinctum* *Stemphylium botryosum* sterile dark mycelia
SODIUM NITRATE			*Alternaria alternata* *A. petrosilini* *A. phragmospora* *Ascochyta chenopodii* *Aureobasidium pullulans* *Cladosporium herbarum* *Fusarium tricinctum* *Phoma glomerata* *Stemphylium botryosum* *Trichoderma koningii* sterile dark mycelia
			IRRIGATION

APPENDIX 25. Number of fungal taxa in common (a), number of taxa present only on the horizontally listed conditions (b), number of taxa present only on the vertically listed conditions (c), and number of taxa not present on either of the conditions (d) in each of the nine conditions for Salicornia europaea.

	SEA SALTS	SODIUM NITRATE	IRRIGATION
CONTROL	16 8 1 1	16 8 1 1	13 11 0 2
SEA SALTS	12 5 5 4	10 7 3 6	
SODIUM NITRATE	11 6 2 7		
IRRIGATION			

LEGEND

a	b
c	d

APPENDIX 26. Principal component analysis coordinates derived from the total number of fungal isolates on Salicornia europaea under sodium nitrate treatment. The total number of fungal isolates is extracted from Appendix 21 in this dissertation.

Point	Coordinates	
	Axis 1	Axis 2
1	-3.4011940	-0.1813164
2	-3.7789500	1.0530400
3	-3.9791346	0.0305297
4	-3.7552343	-0.5367478
5	-1.5828938	-1.0975522
6	-3.0040912	-0.5220672
7	0.5169031	0.1104517
8	3.3701969	-0.7666824
9	3.1677610	1.8147524
10	3.1816613	4.1663338
11	3.5187531	-2.2790485
12	5.7462223	-1.7916927

Origin is at x = -2.0178656 and y = -7.7610215

APPENDIX 27. Principal component analysis coordinates derived from the total number of fungal isolates on Salicornia europaea under sea salt treatment. The total number of fungal isolates is extracted from Appendix 22 in this dissertation.

Point	Coordinates	
	Axis 1	Axis 2
1	-3.0004245	-1.4166130
2	-5.1252518	3.8340924
3	-4.7309939	-0.4819872
4	-3.9432860	-1.7135820
5	-2.7655417	-0.8785434
6	0.1328699	-0.5009921
7	3.0846451	-0.3964179
8	0.7405268	0.2438568
9	2.8496681	0.2550776
10	4.1675199	-0.1130236
11	4.5999048	0.2048094
12	3.9903634	0.9633231

Origin is at x = -1.7074247 and y = -6.2088172

APPENDIX 28. Principal component analysis coordinates derived from the total number of fungal isolates on Salicornia europaea under irrigation. The total number of fungal isolates is extracted from Appendix 23 in this dissertation.

Point	Coordinates	
	Axis 1	Axis 2
1	-3.6113929	0.1501976
2	-5.0932662	0.9847620
3	-3.5882586	0.3966658
4	-2.9540011	0.2191368
5	-2.2634309	0.1381143
6	-1.6565603	-1.0775196
7	2.3489841	-2.6024227
8	2.0785572	-2.9746532
9	3.7917601	1.0075640
10	4.2342030	2.0404817
11	3.2178312	0.0435313
12	3.4955745	1.6741422

Origin is at x = 3.8805107 and y = 2.7163575

APPENDIX 29. Total isolates, frequency, square root of frequency, occurrence, distribution intensity index and dominance function of various fungal taxa from *Salicornia europaea* under sodium nitrate treatment.

Taxa	Total isolates	Frequency (f)	√frequency	Occurrence	Distribution intensity index (DII)*	Dominance function**	Total isolates	Frequency (f)	√frequency	Occurrence	Distribution intensity index (DII)*	Dominance function**	Total isolates	Frequency (f)	√frequency	Occurrence	Distribution intensity index (DII)*	Dominance function**	Total isolates	Frequency (f)	√frequency	Occurrence	Distribution intensity index (DII)*	Dominance function**
	..... Temporal I						..... Temporal II						..... Temporal III						..... Temporal IV					
Alternaria alternata	22	12.3	3.5	83.3	291.6	D	40	67.2	8.2	100	820	D	45	75.7	8.7	100	870	D	48	79.2	8.9	100	890	D
A. chlamydospora	8	4.4	2.1	33.3	69.9	C																		
A. petrosilini	5	2.9	1.7	16.7	28.4	R																		
A. phragmospora	25	13.7	3.7	66.7	246.8	D																		
Ascochyta chenopodii	15	8.3	2.9	66.7	193.4	D																		
Aureobasidium pullulans	4	2.3	1.5	33.3	49.9	R																		
Cladosporium herbarum	2	1.2	1.1	16.7	18.4	R																		
Dendryphiella arenaria	4	2.3	1.5	33.3	49.9	R	3	5.3	2.3	50	125	R												
Fusarium moniliforme													17	28.1	5.3	100	530	C	5	8.4	2.9	100	290	R
F. tricinctum	10	5.8	2.4	50.0	120.0	SD	4	6.8	2.6	50	130	R	22	37.2	6.1	100	610	SD						
Monodictys pelagica	2	1.2	1.1	16.2	18.4	R																		
Mucor hiemalis	17	9.6	3.1	50.0	155.0	D	6	10.2	3.2	100	320	C												
Phoma glomerata	4	2.3	1.5	16.7	25.1	R	12	20.3	4.5	50	225	SD	10	16.8	4.1	100	410	R	34	56.3	7.5	100	750	C
Stemphylium botryosum	9	5.3	2.3	66.7	153.0	C																		
sterile dark mycelia	1	0.6	0.8	16.7	12.5	VR																		
sterile white mycelia	1	0.6	0.8	16.7	12.5	VR													3	5.3	2.3	50	155	R
Trichoderma koningii													1	1.7	1.3	50	65	VR						
Number of starts	180						60						60						60					
			$\bar{x}_1, s_1$ = 8.6±7.1						$\bar{x}_1, s_1$ = 13.0±18.2						$\bar{x}_1, s_1$ = 19.0±15.2						$\bar{x}_1, s_1$ = 22.5±21.9			
			$\bar{x}_2, s_2$ = 5.4±3.6						$\bar{x}_2, s_2$ = 6.3± 4.3						$\bar{x}_2, s_2$ = 12.5± 6.0						$\bar{x}_2, s_2$ = 14.7±20.5			
			$\bar{x}_3, s_3$ = 4.0±2.1						$\bar{x}_3, s_3$ = 4.3± 1.4						$\bar{x}_3, s_3$ = 9.3± 4.9						$\bar{x}_3, s_3$ = 4.0± 1.4			

*Values derived from unrounded √frequency

**D = dominant; SD = subdominant; C = common; R = rare; VR = very rare

APPENDIX 30. Total isolates, frequency, square root of frequency, occurrence, distribution intensity index and dominance function of various fungal taxa from Salicornia europaea under sea salts treatment.

Taxa	Total isolates	Frequency (f)	√frequency	Occurrence	Distribution intensity index (DII)*	Dominance function**	Total isolates	Frequency (f)	√frequency	Occurrence	Distribution intensity index (DII)*	Dominance function**	Total isolates	Frequency (f)	√frequency	Occurrence	Distribution intensity index (DII)*	Dominance Function**	Total isolates	Frequency (f)	√frequency	Occurrence	Distribution intensity index (DII)*	Dominance Function**
	..... Temporal I						..... Temporal II						..... Temporal III						..... Temporal IV					
Acremonium furcatum													1	0.8	0.9	25	22.5	VR						
Alternaria alternata	14	11.6	3.4	75	255.0	D							77	64.0	8.0	100	800.0	D	82	90.3	9.5	100.0	950.0	D
A. chlamydospora	8	6.8	2.6	50	130.0	SD	4	13.7	3.7	100	370	SD	37	31.4	5.6	100	560.0	SD	34	37.2	6.1	100.0	610.0	SD
A. petrosilini													8	6.8	2.6	50	130.0	C	5	5.8	2.4	33.3	79.0	R
A. phragmospora	7	5.8	2.4	25	60.0	SD																		
Ascochyta chenopodii	9	7.3	2.7	75	202.5	SD																		
Aureobasidium pullulans	2	1.7	1.3	25	32.5	R	17	56.3	7.5	100	750	D												
Cladosporium herbarum	2	1.7	1.3	50	65.0	R																		
Dendryphiella arenaria	6	4.8	2.2	50	130.0	SD							2	1.7	1.3	25	32.5	VR						
Epicoccum purpurascens													1	0.8	0.9	25	22.5	VR						
Fusarium tricinctum	4	3.2	1.8	50	9.0	C	1	3.2	1.8	100	180	R	3	2.6	1.6	25	40.0	R						
Monodictys pelagica	10	8.4	2.9	50	145.0	D																		
Mucor hiemalis													2	1.7	1.3	25	32.5	VR						
Stemphylium botryosum	14	11.6	3.4	75	225.0	D	2	7.3	2.7	100	270	R	4	3.4	1.8	25	45.0	R						
sterile dark mycelia	3	2.6	1.6	25	40.0	R							9	7.3	2.7	25	67.5	C						
sterile white mycelia	1	0.8	0.9	25	22.5	VR							3	2.6	1.6	25	40.0	R	13	14.4	3.8	3.3	126.6	R
Trichocladium achrasporum	2	1.7	1.3	25	32.5	R																		
Number of starts	120						30						120						90					
	$\bar{x}_1, s_1$ = 6.3±3.2						$\bar{x}_1, s_1$ = 6.0±9.2						$\bar{x}_1, s_1$ = 13.4±32.4						$\bar{x}_1, s_1$ = 33.5±34.5					
	$\bar{x}_2, s_2$ = 4.4±1.3						$\bar{x}_2, s_2$ = 2.3±1.5						$\bar{x}_2, s_2$ = 7.0±16.5						$\bar{x}_2, s_2$ = 17.3±14.9					
	$\bar{x}_3, s_3$ = 2.2±1.0						$\bar{x}_3, s_3$ = 1.5±0.7						$\bar{x}_3, s_3$ = 3.7± 0.7						$\bar{x}_3, s_3$ = 9.0± 5.7					

*Values derived from unrounded $\sqrt{\text{frequency}}$

**D = dominant; SD = subdominant; C = common; R = rare; VR = very rare

APPENDIX 31. Total isolates, frequency, square root of frequency, occurrence, distribution intensity index and dominance function of various fungal taxa from Salicornia europaea under irrigation.

Taxa	Total isolates	Frequency (f)	√frequency	Occurrence	Distribution intensity index (DII)*	Dominance Function**
	..... Temporal I					
Acremonium furcatum	4	2.6	1.6	40	64	R
Alternaria alternata	32	21.2	4.6	100	460	D
A. petrosilini						
A. phragmospora	23	15.2	3.9	80	312	SD
A. raphani						
Ascochyta chenopodii	10	6.8	2.6	80	208	C
Aureobasidium pullulans	3	2.0	1.4	20	28	R
Cladosporium herbarum	2	1.4	1.2	40	56	R
Fusarium tricinctum	2	1.4	1.2	20	24	R
Phoma glomerata	1	0.64	0.8	20	16	R
Stemphylium botryosum	39	26.0	5.1	80	408	D
sterile dark mycelia						
Trichoderma koningii						
Number of starts	150					
		$\bar{x}_1, s_1$ = 12.9±12.5				
		$\bar{x}_2, s_2$ = 6.4± 9.2				
		$\bar{x}_3, s_3$ = 3.7± 3.8				

Taxa	Total isolates	Frequency (f)	√frequency	Occurrence	Distribution intensity index (DII)*	Dominance function**
	..... Temporal II					
Alternaria alternata	11	37.2	6.1	100	610	D
A. petrosilini	3	10.2	3.2	100	320	R
A. phragmospora	3	10.2	3.2	100	320	R
Fusarium tricinctum	1	3.2	1.8	100	180	VR
Phoma glomerata	8	27.0	5.2	100	520	SD
Stemphylium botryosum	3	10.2	3.2	100	320	R
Number of starts	30					
	$\bar{x}_1, s_1$ = 4.8±4.1					
	$\bar{x}_2, s_2$ = 3.6±2.8					
	$\bar{x}_3, s_3$ = 2.5±1.2					

Taxa	Total isolates	Frequency (f)	√frequency	Occurrence	Distribution intensity index (DII)*	Dominance function**
	..... Temporal III					
Alternaria alternata	48	79.2	8.9	100	890	D
A. petrosilini	9	15.2	3.9	50	195	SD
Fusarium tricinctum	11	18.5	4.3	100	430	SD
Phoma glomerata	4	6.8	2.6	50	130	VR
Stemphylium botryosum	10	16.8	4.1	50	205	SD
Trichoderma koningii	1	1.7	1.3	50	65	VR
Number of starts	60					
	$\bar{x}_1, s_1$ = 13.8±19.0					
	$\bar{x}_2, s_2$ = 7.0± 1.0					
	$\bar{x}_3, s_3$ = 2.5± 2.1					

Taxa	Total isolates	Frequency (f)	√frequency	Occurrence	Distribution intensity index (DII)*	Dominance function**
	..... Temporal IV					
Alternaria alternata	99	82.8	9.1	100	910.0	D
Ascochyta chenopodii	49	40.9	6.4	100	640.0	SD
Fusarium tricinctum	7	5.8	2.4	100	240.0	C
Phoma glomerata	5	4.0	2.0	50	100.0	R
Stemphylium botryosum	3	2.7	1.6	25	40.0	R
Trichoderma koningii	1	0.8	0.9	25	22.5	VR
Number of starts	120					
	$\bar{x}_1, s_1$ = 32.6±44.3					
	$\bar{x}_2, s_2$ = 16.0±24.8					
	$\bar{x}_3, s_3$ = 5.0± 1.4					

*Values derived from unrounded √frequency

**D = Dominant; SD = subdominant; C = common; R = rare; VR = very rare

APPENDIX 32. Minimum and maximum ranges of air temperature with their means and standard deviations over indicated times.

Dates 1983	Minimum ranges of air temperature °C	Maximum ranges of air temperature °C
27/5 to 6/6	3.0-(8.3±3.5)-14.5	15.0-(19.8±4.5)-26.0
7/6 to 13/6	9.0-(12.5±3.6)-17.5	15.5-(24.3±5.6)-32.5
14/6 to 23/6	11.0-(13.6±2.4)-18.5	21.0-(24.3±2.2)-27.5
24/6 to 3/7	4.5-(14.9±4.7)-21.5	14.5-(21.7±5.6)-32.0
4/7 to 15/7	11.0-(15.8±3.0)-21.5	23.0-(28.1±2.8)-31.5
16/7 to 23/7	12.0-(16.3±2.9)-20.5	24.0-(31.0±2.1)-35.0
24/7 to 6/8	12.5-(16.0±2.9)-20.5	26.5-(29.3±3.5)-37.0
7/8 to 17/8	10.0-(13.6±3.0)-19.5	23.0-(27.5±2.5)-30.5
18/8 to 26/8	8.0-(15.4±2.7)-18.0	23.5-(29.2±4.0)-30.5
27/8 to 6/9	5.0-(10.9±4.7)-19.0	15.0-(22.8±6.7)-35.0
7/9 to 17/9	0.5-(5.8±2.6)- 8.0	8.5-(14.4±3.1)-18.0
1/10 to 9/10	-1.5-(3.5±1.9)- 6.0	9.0-(10.6±2.8)-17.0

APPENDIX 33. Air, soil-surface and below-ground (10 cm) temperatures (^{o}C) over 1983 collecting dates.

Date 1983	Air	Soil surface	Below ground
6/6	20.6	21.5	18.8
13/6	20.3	21.0	19.0
23/6	24.5	25.0	21.5
3/7	23.5	24.5	20.0
15/7	25.0	26.0	22.5
23/7	29.0	31.0	26.0
6/8	24.5	26.0	21.5
17/8	25.0	26.0	23.0
26/8	28.0	29.0	25.0
6/9	23.0	23.5	20.0
17/9	11.0	13.0	10.5
9/10	8.0	8.8	7.6

APPENDIX 34. Analysis of variance of air, soil-surface and below-ground temperatures for 1983 collecting dates.

Source	SS	DF	MS	F	P
Temperature	69.095	2	34.548	80.158	<0.001
Time	1197.681	11	108.880	252.622	<0.001
Error	9.492	22	0.431		

APPENDIX 35. Mean soil moisture [% water/soil dry weight (gm/gm)] for various treatments of Salicornia europaea plots over the collecting dates.

Dates (1983)	Control	Sodium nitrate	Sea salt	Irrigation
6/6	55.4	62.5	59.1	60.3
13/6	60.8	56.4	68.8	70.1
23/6	57.6	57.2	59.0	63.7
3/7	50.8	49.1	48.5	65.1
15/7	41.5	38.9	33.1	48.2
23/7	38.1	40.1	32.6	42.9
6/8	29.6	42.6	31.3	47.1
17/8	38.3	39.2	38.6	50.0
26/8	40.5	42.3	40.7	51.9
6/9	36.9	43.7	33.3	53.8
17/9	41.8	41.4	32.6	54.8
9/10	40.6	49.3	40.1	56.9

APPENDIX 36. Analysis of variance of soil moisture for various treatments of Salicornia europaea plots over the collecting dates.

Source	SS	DF	MS	F	P
Treatments	268.206	3	89.402	30.701	<0.001
Time	391.947	11	35.632	12.236	<0.001
Error	96.097	33	2.912		

APPENDIX 37. Soil conductivity (mmhos/cm) for Salicornia europaea plots under various treatments over the 1983 collections.

Dates	Control	Sodium nitrate	Sea salts	Irrigation
6/6	26	24	23	26
13/6	41	48	50	40
23/6	38	42	46	30
3/7	40	40	42	27
15/7	73	57	68	50
23/7	78	60	77	54
6/8	43	45	55	50
17/8	45	48	68	42
26/8	50	52	60	36
6/9	58	49	55	38
17/9	71	62	66	60
9/10	72	67	71	58

APPENDIX 38. Analysis of variance of soil conductivity for *Salicornia europaea* plots under various treatments over the collecting dates.

Source	SS	DF	MS	F	P
Treatments	1302.729	3	434.243	13.602	<0.001
Time	7593.563	11	690.324	21.623	<0.001
Error	1053.521	33	31.925		

APPENDIX 39. Mean ($\bar{X}$) and standard deviation (s) (n=20) of root and shoot lengths of Salicornia europaea under various treatments.

Date		Control		Sodium nitrate		Sea salts		Irrigation	
		Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root
6/6	$\bar{X}$ =	1.10	1.37	1.03	1.39	1.14	1.33	1.02	1.13
	s =	0.254	0.142	0.271	0.251	0.207	0.211	0.271	0.44
13/6	$\bar{X}$ =	1.96	2.97	1.54	2.55	1.68	2.45	1.04	3.00
	s =	0.189	0.337	0.469	0.949	0.326	0.977	0.279	0.463
23/6	$\bar{X}$ =	1.94	5.17	2.69	6.10	2.28	5.80	1.13	5.00
	s =	0.453	0.408	0.441	0.589	0.449	0.856	0.380	1.699
3/7	$\bar{X}$ =	2.69	7.55	3.35	10.86	2.97	9.49	2.65	9.10
	s =	0.942	0.692	0.463	1.045	0.25	0.63	0.42	1.02
15/7	$\bar{X}$ =	4.60	14.30	4.31	20.60	5.10	14.40	2.95	10.00
	s =	0.645	1.34	0.477	1.60	0.39	3.03	0.29	0.94
23/7	$\bar{X}$ =	4.63	15.50	4.86	23.70	5.00	16.40	3.05	14.70
	s =	0.34	3.51	0.435	1.25	1.95	3.31	0.59	0.95
6/8	$\bar{X}$ =	4.60	17.70	5.60	25.50	5.10	17.90	3.07	14.80
	s =	1.27	4.03	1.64	0.85	1.17	3.54	0.81	1.40
17/8	$\bar{X}$ =	5.37	20.10	5.70	25.70	5.30	18.50	3.10	14.90
	s =	0.48	1.18	0.42	0.82	0.62	1.16	0.24	0.66
26/8	$\bar{X}$ =	5.40	20.01	5.70	25.90	5.40	19.30	3.10	15.00
	s =	0.47	1.41	0.52	1.10	0.60	1.30	0.20	0.44
6/9	$\bar{X}$ =	5.42	20.12	5.71	26.00	5.47	19.62	3.17	15.02
	s =	0.31	1.32	0.52	0.91	0.67	0.98	0.40	0.78
17/9	$\bar{X}$ =	5.53	20.17	5.89	26.40	5.54	20.10	3.11	15.10
	s =	0.49	1.32	0.41	0.93	0.61	1.16	0.41	0.86
9/10	$\bar{X}$ =	5.42	21.00	5.87	27.40	5.74	20.30	3.34	15.28
	s =	0.64	1.68	0.48	1.04	0.50	1.54	0.37	0.95

APPENDIX 40. Analysis of variance for root lengths of *Salicornia europaea* under various treatments over the collecting dates.

Source	SS	DF	MS	F	P
Treatments	24.513	3	8.171	36.478	<0.001
Time	98.346	11	8.941	39.915	<0.001
Error	7.390	33	0.224		

APPENDIX 41. Analysis of variance for shoot lengths of *Salicornia europaea* under various treatments over the collecting dates.

Source	SS	DF	MS	F	P
Treatments	342.150	3	114.050	24.132	<0.001
Time	2474.095	11	224.918	47.592	<0.001
Error	155.943	33	4.726		

APPENDIX 42. Mean water content [% water/plant dry weight (gm/gm)] for the roots and shoots of Salicornia europaea under various treatments for the 1983 collections.

Date	Control		Sodium nitrate		Sea salts		Irrigation	
	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot
6/6	71.0	93.0	70.2	92.5	70.8	93.2	71.1	93.0
13/6	75.0	91.3	76.9	91.6	77.2	91.7	76.9	91.4
23/6	78.8	90.5	81.1	91.7	77.4	91.3	83.3	90.9
3/7	56.9	88.8	62.7	91.1	66.2	90.2	67.2	89.7
15/7	53.0	89.3	55.2	89.6	62.4	88.2	53.4	86.8
23/7	62.5	85.8	55.6	89.4	61.5	88.4	55.6	86.3
6/8	50.9	81.9	56.3	87.3	57.2	85.0	56.2	83.8
17/8	42.7	78.7	41.2	84.5	44.2	82.7	43.4	79.8
26/8	47.3	78.2	52.1	81.4	51.0	79.5	54.6	61.3
6/9	55.2	72.4	56.5	79.1	50.0	76.6	56.5	51.9
17/9	35.0	40.6	50.0	62.3	38.3	55.3	35.0	36.2
9/10	18.0	22.5	16.8	39.8	34.6	22.6	19.9	24.7

APPENDIX 43. Analysis of variance of percentage root and shoot water content of Salicornia europaea under various treatments over time.

ROOT WATER CONTENT:

Source	SS	DF	MS	F	P
Treatments	84.914	3	28.305	1.710	0.183
Time	11531.281	11	1048.298	63.314	<0.001
Error	546.388	33	16.557		

SHOOT WATER CONTENT:

Source	SS	DF	MS	F	P
Treatments	496.934	3	165.645	5.850	0.002
Time	17861.119	11	1623.738	57.348	<0.001
Error	934.346	33	28.314		

APPENDIX 44. Concentrations (mg/gm dw) of cations and anions in shoots and roots of *Salicornia europaea* under control conditions.

	Shoots						Roots					
	Na^+	K^+	Ca^{++}	Mg^{++}	Cl^-	$SO_4^=$	Na^+	K^+	Ca^{++}	Mg^{++}	Cl^-	$SO_4^=$
6/6	21.4	3.0	3.3	4.0	16.0	11.0	10.2	2.0	2.5	1.0	6.0	5.0
13/6	33.6	11.0	4.5	7.0	28.1	20.0	11.9	4.2	2.8	1.4	9.3	7.8
23/6	37.2	13.2	6.0	9.1	35.0	18.2	13.5	12.0	2.1	1.2	14.0	7.2
3/7	42.1	8.7	7.5	11.0	53.2	38.0	18.0	14.2	3.2	2.0	16.1	14.0
15/7	87.4	8.2	8.5	5.7	93.0	28.1	31.4	15.2	2.3	1.2	57.0	11.3
23/7	64.0	12.0	7.2	5.5	44.6	24.2	20.7	11.1	3.4	1.0	23.0	10.5
6/8	55.0	8.7	6.7	13.0	46.5	24.6	16.0	5.0	3.0	1.9	20.1	10.0
17/8	61.1	12.3	5.0	6.4	36.8	23.0	14.2	5.4	3.3	1.1	14.5	8.8
26/8	53.2	13.0	2.0	8.0	36.0	20.4	15.0	3.5	1.8	1.3	16.2	9.4
6/9	50.4	13.0	1.2	6.2	29.0	18.0	14.6	3.0	1.5	1.5	11.4	10.5
17/9	42.3	11.2	2.0	4.0	37.2	15.0	17.3	2.1	1.8	1.0	15.2	10.2
9/10	45.1	8.4	1.0	2.2	28.1	9.6	20.0	2.8	1.5	1.2	18.7	7.7

APPENDIX 45. Concentrations (mg/gm dw) of cations and anions in shoots and roots of Salicornia europaea under sodium nitrate treatment.

Date	Shoots						Roots					
	Na^+	K^+	Ca^{++}	Mg^{++}	Cl^-	$SO_4^=$	Na^+	K^+	Ca^{++}	Mg^{++}	Cl^-	$SO_4^=$
6/6	20.2	3.6	2.2	3.0	19.0	15.0	8.5	2.9	1.8	1.3	6.0	6.3
13/6	54.0	7.5	5.0	6.0	41.2	23.0	14.0	5.0	2.2	2.8	11.0	8.1
23/6	75.3	9.5	7.2	14.9	86.0	10.0	48.1	7.8	3.0	2.5	45.0	12.8
3/7	91.0	8.8	3.3	3.9	63.5	36.0	20.0	10.2	2.0	1.8	30.5	15.8
15/7	96.0	9.0	7.2	7.0	61.2	37.0	22.4	9.8	3.2	2.0	33.0	11.0
23/7	112.5	8.9	5.3	8.4	48.6	35.5	18.2	7.6	2.5	2.4	25.1	10.2
6/8	87.2	8.5	4.7	8.6	38.2	37.0	16.7	7.1	2.8	2.0	20.0	8.5
17/8	66.3	11.0	5.0	6.0	42.0	32.1	14.5	5.5	3.0	3.2	24.4	7.8
26/8	63.0	10.0	3.5	11.0	48.1	30.0	11.0	4.0	2.5	2.1	21.0	7.5
6/9	58.1	12.0	3.0	7.3	40.4	28.2	17.8	4.1	2.2	1.7	18.6	8.0
17/9	64.2	10.1	2.0	3.8	33.0	21.0	21.5	3.2	1.4	1.5	16.0	7.1
9/10	68.4	7.4	2.0	2.8	18.6	11.2	24.2	3.8	2.2	1.5	20.3	6.0

APPENDIX 46. Concentrations (mg/gm dw) of cations and anions in shoots and roots of Salicornia europaea under sea salt treatment.

	Shoots						Roots					
	Na^+	K^+	Ca^{++}	Mg^{++}	Cl^-	$SO_4^=$	Na^+	K^+	Ca^{++}	Mg^{++}	Cl^-	$SO_4^=$
6/6	23.5	5.0	4.2	3.0	17.5	13.0	8.0	3.1	2.2	1.5	7.0	5.7
13/6	49.0	7.1	5.5	8.0	30.0	27.0	16.0	4.2	3.0	2.6	12.0	17.0
23/6	65.3	8.0	7.0	16.8	57.8	17.5	42.2	7.0	4.1	4.8	31.0	25.0
3/7	85.0	7.5	7.2	12.0	41.2	30.0	25.8	7.8	4.0	3.5	26.3	18.0
15/7	75.8	9.2	8.0	10.2	41.8	35.0	24.1	10.0	4.5	2.6	26.0	22.0
23/7	72.3	8.6	6.0	8.3	39.2	34.0	26.0	9.3	3.8	2.1	29.0	20.0
6/8	69.7	10.0	7.1	10.0	35.4	36.0	38.1	18.0	3.5	4.4	30.7	16.0
17/8	64.0	11.2	5.3	9.5	36.0	33.0	31.5	7.4	3.1	2.0	34.2	20.0
26/8	59.0	12.0	3.0	6.2	33.0	25.8	25.5	5.6	5.2	1.7	27.0	14.0
6/9	55.4	11.0	2.1	2.0	37.2	21.0	22.0	4.0	3.5	1.5	24.1	11.0
17/9	48.2	12.0	1.2	6.4	22.6	17.0	25.0	7.6	2.0	2.0	20.0	15.0
9/10	52.0	9.0	1.0	4.1	30.0	12.0	20.3	4.0	2.1	3.0	22.0	10.0

APPENDIX 47. Concentrations (mg/gm dw) of cations and anions in shoots and roots of Salicornia europaea under irrigation.

	Shoots						Roots					
	Na^+	K^+	Ca^{++}	Mg^{++}	Cl^-	$SO_4^=$	Na^+	K^+	Ca^{++}	Mg^{++}	Cl^-	$SO_4^=$
6/6	22.3	4.2	3.5	4.0	17.0	12.0	9.5	2.5	1.8	1.2	7.5	5.0
13/6	27.0	5.0	6.0	3.1	21.2	21.0	19.0	3.0	2.0	1.3	18.0	8.3
23/6	34.5	7.0	4.2	15.0	41.4	27.0	30.1	8.4	1.5	1.0	45.0	5.2
3/7	44.8	8.7	8.6	18.0	45.0	15.0	25.0	10.2	5.4	4.0	31.3	5.0
15/7	46.0	9.1	8.1	14.4	33.3	19.0	20.8	7.0	3.2	3.8	22.0	4.0
23/7	55.0	9.3	7.0	7.4	21.0	24.0	12.0	7.2	2.0	1.9	12.5	3.8
6/8	46.3	10.0	6.5	7.5	34.0	20.0	15.5	7.5	1.8	2.0	18.2	4.0
17/8	54.7	9.0	3.4	6.8	38.2	19.0	18.0	6.0	1.2	1.5	20.1	3.5
26/8	44.0	5.0	2.3	11.0	41.0	10.0	12.0	8.1	1.0	2.0	24.0	2.5
6/9	48.2	4.5	2.0	2.8	25.0	18.0	10.8	3.5	4.0	1.0	12.6	4.0
17/9	29.0	9.0	1.3	6.4	44.0	7.0	17.0	4.0	4.5	1.2	28.0	2.5
9/10	24.0	3.0	1.1	3.1	26.0	7.0	18.0	2.0	2.5	1.0	19.0	2.0

APPENDIX 48. Analysis of variance of cation and anion concentrations in roots of Salicornia europaea over treatments and time.

Ion	Source	SS	DF	MS	F	P
Na^+	treatments	534.587	3	178.196	4.805	0.007
	time	1529.320	11	139.029	3.749	0.001
	error	1223.853	33	37.086		
K^+	treatments	18.335	3	6.112	1.012	0.401
	time	386.152	11	35.105	5.813	<0.001
	error	199.280	33	6.039		
Ca^{++}	treatments	7.851	3	2.617	2.698	0.060
	time	9.109	11	0.828	0.854	
	error	32.004	33	0.970		
Mg^{++}	treatments	10.628	3	3.543	6.046	0.002
	time	10.937	11	0.994	1.696	0.118
	error	19.352	33	0.586		
Cl^-	treatments	197.558	3	65.853	1.037	0.389
	time	2710.472	11	246.407	3.881	0.001
	error	2095.282	33	63.493		
$SO_4^=$	treatments	799.900	3	266.633	35.732	<0.001
	time	295.655	11	26.878	3.602	0.002
	error	246.255	33	7.462		

APPENDIX 49. Analysis of variance of cation and anion concentrations in shoots of Salicornia europaea over treatments and time.

Ion	Source	SS	DF	MS	F	P
Na^+	treatments	6676.896	3	2225.632	21.919	<0.001
	time	10437.229	11	948.839	9.344	<0.001
	error	3350.854	33	101.541		
K^+	treatments	75.217	3	25.072	6.911	0.001
	time	146.682	11	13.335	3.676	0.002
	error	119.730	33	3.628		
Ca^{++}	treatments	2.152	3	0.717	0.665	
	time	221.609	11	20.146	18.671	<0.001
	error	35.595	33	1.079		
Mg^{++}	treatments	32.067	3	10.689	1.365	0.269
	time	480.421	11	43.675	5.578	<0.001
	error	258.390	33	7.830		
Cl^-	treatments	1145.684	3	381.895	2.965	0.045
	time	5956.796	11	541.527	4.204	<0.001
	error	4250.469	33	128.802		
$SO_4^=$	treatments	1056.147	3	352.049	18.257	<0.001
	time	2136.167	11	194.197	10.071	<0.001
	error	636.335	33	19.283		

APPENDIX 50. Regression of fungal isolates, diversity and salt levels on Salicornia europaea under various treatments over the temporal groups (n = number of collecting dates).

Control		Temporal I (n=5)	Temporals II-IV (n=6)
Total fungal isolates on total salts	r =	-0.93	-0.97
	a =	38.4	103.7
	b =	-0.06	-0.34
Shoot fungal isolates on shoot salts	r =	-0.91	-0.99
	a =	21.1	91.1
	b =	-.05	-0.38
Root fungal isolates on root salts	r =	-0.86	-0.83
	a =	16.95	38.4
	b =	-0.09	-0.41
Total shoot fungal isolates on divalent/monovalent ratio	r =	0.18	-0.97
	a =	11.1	40.8
	b =	4.4	-60.7
Total root fungal isolates on divalent/monovalent ratio	r =	0.56	-0.55
	a =	7.1	30.6
	b =	12.8	-29.3
Fungal diversity on total salts (roots + shoots)	r =	-0.63	-0.76
	a =	1.0	1.05
	b =	-0.002	-0.003
Fungal diversity on divalent/monovalent ratio	r =	0.79	-0.87
	a =	0.117	0.91
	b =	1.47	-1.08

..... continued

APPENDIX 50 (continued)

Sodium nitrate		Temporal I (n=5)	Temporals II-IV (n=6)
Total fungal isolates on total salts	r =	-0.1	-0.73
	a =	26.2	88.1
	b =	-0.02	-0.23
Shoot fungal isolates on shoot salts	r =	0.38	-0.86
	a =	2.3	52.2
	b =	0.04	-0.21
Root fungal isolates on root salts	r =	-0.64	-0.44
	a =	20.3	38.4
	b =	-0.18	-0.35
Total shoot fungal isolates on divalent/monovalent ratio	r =	0.28	-0.65
	a =	-2.6	36.3
	b =	47.6	-47.8
Total root fungal isolates on divalent/monovalent ratio	r =	0.34	0.27
	a =	5.8	11.3
	b =	18.3	32.2
Fungal diversity on total salts (roots + shoots)	r =	-0.48	0.14
	a =	0.8	0.47
	b =	-0.00005	0.0005
Fungal diversity on divalent/monovalent ratio	r =	0.65	0.44
	a =	0.78	0.36
	b =	0.04	0.68

..... continued

APPENDIX 50 (continued)

Sea salts		Temporal I (n=4)	Temporals II-IV (n=7)
Total fungal isolates on total salts	r =	-0.35	-0.66
	a =	35.8	62.7
	b =	-0.06	-0.1
Shoot fungal isolates on shoot salts	r =	0.17	-0.86
	a =	7.6	37.5
	b =	0.03	-0.12
Root fungal isolates on root salts	r =	-0.6	-0.26
	a =	16.8	24.3
	b =	-0.09	-0.06
Total shoot fungal isolates on divalent/monovalent ratio	r =	0.46	-0.81
	a =	-1.22	30.7
	b =	36.0	-30.3
Total root fungal isolates on divalent/monovalent ratio	r =	0.54	-0.32
	a =	1.31	29.8
	b =	15.2	-29.6
Fungal diversity on total salts (roots + shoots)	r =	0.87	0.23
	a =	0.16	0.44
	b =	0.002	0.001
Fungal diversity on divalent/monovalent ratio	r =	-0.78	0.30
	a =	1.29	0.39
	b =	-1.29	0.53

..... continued

APPENDIX 50 (continued)

Irrigation		Temporal I (n=4)	Temporals II-IV (n=7)
Total fungal isolates on total salts	r =	-0.42	-0.19
	a =	33.6	45.8
	b =	-0.043	-0.04
Shoot fungal isolates on shoot salts	r =	0.11	-0.44
	a =	13.3	28.7
	b =	0.006	-0.07
Root fungal isolates on root salts	r =	-0.83	0.11
	a =	21.3	16.3
	b =	-0.14	0.033
Total shoot fungal isolates on divalent/monovalent ratio	r =	-0.75	-0.74
	a =	21.4	29.6
	b =	-14.7	-27.3
Total root fungal isolates on divalent/monovalent ratio	r =	0.57	0.61
	a =	7.5	17.3
	b =	17.5	0.27
Fungal diversity on total salts (roots + shoots)	r =	-0.92	0.17
	a =	1.32	0.29
	b =	0.005	0.001
Fungal diversity on divalent/monovalent ratio	r =	0.86	0.70
	a =	-0.55	0.23
	b =	2.59	1.21

APPENDIX 51. Analysis of variance for the total fungal isolates on roots and shoots of Salicornia europaea under various treatments over the collecting dates.

Treatment	Source	SS	DF	MS	F	P
Control	time	808.458	11	73.496	24.160	<0.001
	error	33.458	11	3.042		
Sodium nitrate	time	1012.458	11	92.042	15.234	<0.001
	error	66.458	11	6.042		
Sea salts	time	749.125	11	68.102	8.468	0.001
	error	88.458	11	8.042		
Irrigation	time	615.833	11	55.985	5.931	0.003
	error	103.833	11	9.439		

APPENDIX 52. Total number of fungal isolates on roots (R) and shoots (S) of *Salicornia europaea* under control conditions over the collecting dates.

Taxa	6/6		13/6		23/6		3/7		15/7		23/7		6/8		17/8		26/8		6/9		17/9		9/10	
	R	S	R	S	R	S	R	S	R	S	R	S	R	S	R	S	R	S	R	S	R	S	R	S
Acremonium furcatum F. et V. Moreau		2																			1		2	
Alternaria alternata (Fr.) Keissler	4	1	7	2	2	7	2	4	2		2	2	9	14	10	12	9	14	12	15	9	15	12	15
A. chlamydospora Mouchacca											8		3	1		1	4	3		3	9	6	4	11
A. petrosilini (Neergaard ex Simmons) M.B. Ellis											3	6	2				1							
A. phragmospora van Emden	4	1	3				3		1															
A. raphani Groves et Skolko																	4	1	6	4				
Ascochyta chenopodii Roster	1	6		3	1	3	4	1																
Aureobasidium pullulans (De Bary) Arnand				2																				
Cladosporium herbarum (Pers.) Link ex S.F. Gray				2																				
Dendryphiella arenaria Nicot									1														1	
Epicoccum purpurascens Ehrenb. ex Schlecht																		2		1				
Fusarium tricinctum (Corda) Sacc.	1												1	1	1		1	1		3	3	3		3
Gliocladium roseum Bain.	2																							
Monodictys pelagica (Johnson) E.B.G. Jones								2		1														
Mucor hiemalis Wehmer			2																					
sterile dark mycelia												1		1	6	7								
sterile white mycelia																								2
Papulaspora halima Anastasiou				2																				
Phoma glomerata (Corda) Wollen. et Hochapfel																1					1	3	6	
Stemphylium botryosum Wallr.				6	10	4		6	2	9		6												
Trichoderma koningii Oudem							2										1		1					
Total number of isolates	12	10	12	17	13	14	11	13	6	10	13	15	15	17	18	21	20	21	19	26	23	27	25	31

APPENDIX 53. Total number of fungal isolates on roots (R) and shoots (S) of *Salicornia europaea* under sodium nitrate treatment over the collecting dates.

Taxa	6/6		13/6		23/6		3/7		15/7		23/7		6/8		17/8		26/8		6/9		17/9		9/10	
	R	S	R	S	R	S	R	S	R	S	R	S	R	S	R	S	R	S	R	S	R	S	R	S
Alternaria alternata (Fr.) Keissler	3	1		1			1	2	3	6	2	3	8	10	10	12	11	11	10	13	9	10	14	15
A. chlamydospora Mouchacca							1				4	3												
A. petrosilini (Neergaard ex Simmons) M.B. Ellis									4	2	2	3												
A. phragmospora van Emden	5	1	3				5	3																
Ascochyta chenopodii Roster	2	5		2		2	2	2					4											
Aureobasidium pullulans (De Bary) Arnaud			3		1																			
Cladosporium herbarum (Pers.) Link ex S.F. Gray							2																	
Dendryphiella arenaria Nicot									2		2		3											
Fusarium moniliforme Sheldon																	2	5	5	5		3		2
F. tricinctum (Corda) Sacc.	1		4	3	2						5	2				4	6	2	10	4				
Monodictys pelagica (Johnson) E.B.G. Jones								2																
Mucor hiemalis Wehmer				3					3	4					1	1								
sterile dark mycelia			1																					
sterile white mycelia						1																	3	
Phoma glomerata (Corda) Wollen. et Hochapfel									4						9	3	3	4		3	8	10	5	11
Stemphylium botryosum Wallr.						2		3		3		1												
Trichoderma koningii Oudem																			1					
Total number of isolates	11	7	11	9	3	5	11	12	16	15	15	12	15	10	20	20	22	22	26	25	17	23	22	28

APPENDIX 54. Total number of fungal isolates on roots (R) and shoots (S) of *Salicornia europaea* under sea salts treatment over the collecting dates.

Taxa	6/6		13/6		23/6		3/7		15/7		23/7		6/8		17/8		26/8		6/9		17/9		9/10	
	R	S	R	S	R	S	R	S	R	S	R	S	R	S	R	S	R	S	R	S	R	S	R	S
Alternaria alternata (Fr.) Keissler	4	2						3	1	4	5	10	11	14	10	5	12	10	13	15	14	15	10	15
A. chlamydospora Mouchacca			3	1				1	6	1	5	2	3	3	4	7	8	5	6	3	4	8	8	5
A. petrosilini (Neergaard ex Simmons) M.B. Ellis													4	2				2		5				
A. phragmospora van Emden	4	3																						
Ascochyta chenopodii Roster	1	3					1	3	1															
Aureobasidium pullulans (De Bary) Arnand			7	10	2																			
Cladosporium herbarum (Pers.) Link ex S.F. Gray						1		1																
Dendryphiella arenaria Nicot							2	3	1		2													
Epicoccum purpurascens Ehrenb. ex Schlecht												1												
Fusarium tricinctum (Corda) Sacc.	1		1		3										1	2		1						
Monodictys pelagica (Johnson) E.B.G. Jones							2	3	2	3														
Mucor hiemalis Wehmer																2								
sterile dark mycelia										3					6	3								
sterile white mycelia						1									3								7	6
Stemphylium botryosum Wallr.				2		4		4	2	4	2	2												
Trichocladium achrasporum (Meyers et Moore) Dixon							2																	
Total number of isolates	10	8	11	13	5	6	7	18	13	15	14	15	18	19	24	19	20	18	19	23	18	23	25	26

APPENDIX 55. Total number of fungal isolates on roots (R) and shoots (S) of *Salicornia europaea* under irrigation over the collecting dates.

Taxa	6/6		13/6		23/6		3/7		15/7		23/7		6/8		17/8		26/8		6/9		17/9		9/10	
	R	S	R	S	R	S	R	S	R	S	R	S	R	S	R	S	R	S	R	S	R	S	R	S
Acremonium furcatum F. et V. Moreau		1					2	1																
Alternaria alternata (Fr.) Keissler	1	2	2		6		4	4	10	3	3	8	10	15	9	14	12	14	10	15	10	15	8	15
A. petrosilini (Neergaard ex Simmons) M.B. Ellis											2	1	4	5										
A. phragmospora van Emden	2	3	9				3	1	2	3		3												
A. raphani Groves et Skolko																	5	6	7	9	2	6	7	7
Ascochyta chenopodii Roster	3	1	1	1	1		1	2																
Aureobasidium pullulans (De Bary) Arnand				3																				
Cladosporium herbarum (Pers.) Link ex S.F. Gray					1			1																
Fusarium tricinctum (Corda) Sacc.	2										1		4		7			1	1	2	1	1		1
sterile dark mycelia															5	5							3	
Phoma glomerata (Corda) Wollen. et Hochapfel						1										4			1		3	1		
Stemphylium botryosum Wallr.				10		11		6	3	9	8	3												
Trichoderma koningii Oudem													1				1							
Total number of isolates	8	7	12	14	8	12	10	15	15	15	14	15	19	20	21	23	18	21	19	26	16	23	18	23

APPENDIX 56. Analysis of variance for the total fungal isolates on Salicornia europaea under various treatments over the collecting dates.

Source	SS	DF	MS	F	P
Treatments	68.167	3	22.722	1.316	0.285
Time	5155.667	11	468.697	27.143	<0.001
Error	569.833	33	17.268		

APPENDIX 57. Concentrations (meq. ml^{-} x 10^{-2}) of cations and anions in shoots and roots of Salicornia europaea under control conditions.

Date	Shoots						Roots					
	Na^{+}	K^{+}	Ca^{++}	Mg^{++}	Cl^{-}	$SO_4^{=}$	Na^{+}	K^{+}	Ca^{++}	Mg^{++}	Cl^{-}	$SO_4^{=}$
6/6	9.3	0.8	1.7	1.7	4.5	2.3	4.4	0.5	1.3	0.4	2.0	1.1
13/6	14.6	2.8	2.3	2.9	7.9	4.2	5.2	1.1	1.4	0.6	2.6	1.6
23/6	16.2	3.4	3.0	3.7	9.9	3.8	5.9	3.1	1.1	0.5	3.9	1.5
3/7	18.3	2.2	3.7	4.5	15.0	7.9	7.8	3.6	1.6	0.8	4.6	2.9
15/7	38.0	2.1	4.3	2.3	26.2	5.8	13.7	3.9	1.2	0.5	16.1	2.4
23/7	27.8	3.1	3.6	2.3	12.6	5.0	9.0	2.8	1.7	0.4	6.5	2.2
6/8	23.9	2.2	3.4	5.3	13.1	5.1	7.0	1.3	1.5	0.8	5.7	2.1
17/8	26.6	3.1	2.5	2.6	10.4	4.8	6.2	1.4	1.6	0.5	4.1	1.8
26/8	23.1	3.3	1.0	3.3	10.1	4.2	6.5	0.9	0.9	0.5	4.6	1.9
6/9	21.9	3.3	0.6	2.5	8.2	3.7	6.4	0.8	0.8	0.6	3.2	2.2
17/9	18.4	2.9	1.0	1.6	10.5	3.1	7.5	0.5	0.9	0.4	4.3	2.1
9/10	19.6	2.2	0.5	0.9	7.9	2.0	8.7	0.7	0.8	0.5	5.3	1.6

APPENDIX 58. Concentrations (meq. ml^{-} x 10^{-2}) of cations and anions in shoots and roots of Salicornia europaea under sodium nitrate treatment.

Date	Shoots						Roots					
	Na^{+}	K^{+}	Ca^{++}	Mg^{++}	Cl^{-}	$SO_4^{=}$	Na^{+}	K^{+}	Ca^{++}	Mg^{++}	Cl^{-}	$SO_4^{=}$
6/6	8.8	0.9	1.1	1.2	5.4	3.1	3.7	0.7	0.9	0.5	1.7	1.3
13/6	23.5	1.9	2.5	2.5	11.6	4.8	6.1	1.3	1.1	1.2	3.1	1.7
23/6	32.7	2.4	3.6	6.1	24.3	2.1	20.9	2.0	1.5	1.0	12.7	2.7
3/7	39.6	2.2	1.7	1.6	17.9	7.5	8.7	2.6	1.0	0.7	8.6	3.3
15/7	41.7	2.3	3.6	2.9	17.3	7.7	9.7	2.5	1.6	0.8	9.3	2.3
23/7	48.9	2.3	2.7	3.5	13.7	7.4	7.9	1.9	1.3	1.0	7.1	2.1
6/8	37.9	2.2	2.4	3.5	10.8	7.7	7.3	1.8	1.4	0.8	5.6	1.8
17/8	28.8	2.8	2.5	2.5	11.8	6.7	6.3	1.4	1.5	1.3	6.9	1.6
26/8	27.4	2.6	1.8	4.5	13.6	6.3	4.8	1.0	1.3	0.9	5.9	1.5
6/9	25.3	3.1	1.5	3.0	11.4	5.9	7.7	1.0	1.1	0.7	5.3	1.7
17/9	27.9	2.6	1.0	1.6	9.3	4.4	9.3	0.8	0.7	0.6	4.5	1.5
9/10	29.7	1.9	1.0	1.2	5.3	2.3	10.5	1.0	1.1	0.6	5.7	1.3

APPENDIX 59. Concentrations (meq. ml^{-} x 10^{-2}) of cations and anions in shoots and roots of Salicornia europaea under sea salt treatment.

Date	Shoots						Roots					
	Na^{+}	K^{+}	Ca^{++}	Mg^{++}	Cl^{-}	$SO_4^{=}$	Na^{+}	K^{+}	Ca^{++}	Mg^{++}	Cl^{-}	$SO_4^{=}$
6/6	10.2	1.3	2.1	1.2	4.9	2.7	3.5	0.8	1.1	0.6	2.0	1.2
13/6	21.3	1.8	2.8	3.3	8.5	5.6	7.0	1.1	1.5	1.1	3.4	3.5
23/6	28.4	2.1	3.5	6.9	16.3	3.6	18.3	1.8	2.1	2.0	8.7	5.2
3/7	36.9	1.9	3.6	4.9	11.6	6.2	11.2	2.0	2.0	1.4	7.4	3.7
15/7	32.9	2.4	4.0	4.2	11.8	7.3	10.5	2.6	2.3	1.1	7.3	4.6
23/7	31.4	2.2	3.0	3.4	11.1	7.1	11.3	2.4	1.9	0.8	8.2	4.2
6/8	30.3	2.6	3.6	4.1	10.0	7.5	16.6	4.6	1.8	1.8	8.7	3.3
17/8	27.8	2.9	2.7	3.9	10.2	6.9	13.7	1.9	1.6	0.8	9.6	4.2
26/8	25.7	3.1	1.5	2.5	9.3	5.4	11.1	1.4	2.6	0.7	7.6	2.9
6/9	24.1	2.8	1.0	0.8	10.4	4.4	9.6	1.0	1.8	0.6	6.8	2.3
17/9	21.0	3.1	0.6	2.6	6.4	3.5	10.9	1.9	1.0	0.8	5.6	3.1
9/10	22.6	2.3	0.5	1.7	8.4	2.5	8.8	1.0	1.1	1.2	6.2	2.1

APPENDIX 60. Concentrations (meq. ml^{-} x 10^{-2}) of cations and anions in shoots and roots of Salicornia europaea under irrigation.

Date	Shoots						Roots					
	Na^{+}	K^{+}	Ca^{++}	Mg^{++}	Cl^{-}	$SO_4^{=}$	Na^{+}	K^{+}	Ca^{++}	Mg^{++}	Cl^{-}	$SO_4^{=}$
6/6	9.7	1.1	1.8	1.7	4.8	2.5	4.1	0.6	0.9	0.5	2.1	1.0
13/6	11.7	1.3	3.0	1.3	5.9	4.3	8.3	0.8	1.0	0.5	5.1	1.7
23/6	15.0	1.8	2.1	6.2	11.8	5.5	13.1	2.2	0.7	0.4	12.7	1.1
3/7	19.5	2.2	4.3	7.4	12.7	3.1	10.9	2.6	2.7	1.7	8.8	1.0
15/7	20.0	2.3	4.1	5.9	9.4	3.9	9.0	1.8	1.6	1.6	6.2	0.8
23/7	23.9	2.4	3.5	3.1	5.9	4.9	5.2	1.8	1.0	0.8	3.5	0.8
6/8	20.0	2.6	3.3	3.1	9.6	4.1	6.7	1.9	0.9	0.8	5.1	0.8
17/8	23.8	2.3	1.7	2.8	10.8	3.9	7.8	1.5	0.6	0.6	5.7	0.7
26/8	19.1	1.3	1.2	4.5	11.6	2.1	5.2	2.1	0.5	0.8	6.8	0.5
6/9	21.0	1.2	1.0	1.2	7.1	3.6	4.7	0.9	2.0	0.4	3.6	0.8
17/9	12.6	2.3	0.7	2.6	12.4	1.4	7.4	1.0	2.3	0.5	8.1	0.5
9/10	10.4	0.8	0.6	1.3	7.3	1.4	7.8	0.5	1.3	0.4	5.4	0.4

APPENDIX 61. Total number of fungal isolates on *Atriplex patula* under sodium nitrate treatment.

Taxa	T_1 6/6	T_2 13/6	T_3 23/6	T_4 3/7	T_5 15/7	T_6 23/7	T_7 6/8	T_8 17/8	T_9 26/8	T_{10} 6/9	T_{11} 17/9	T_{12} 9/10
Alternaria alternata	6	5	2	12	11	6	3	2	7	7	10	12
A. tenuissima		2										
Fusarium moniliforme		2	6	8	9	18	14	18	25	27	26	30
F. tricinctum	6	5		8	9	3	3	2	1		7	
Mucor hiemalis	1	5					8	12	3	6	7	8
sterile dark mycelia				3								
Trichoderma koningii	2											
Total number of isolates	15	19	8	31	29	27	28	34	36	40	50	50

APPENDIX 62. Total number of fungal isolates on Atriplex patula under sea salts treatment.

Taxa	T_1 6/6	T_2 13/6	T_3 23/6	T_4 3/7	T_5 15/7	T_6 23/7	T_7 6/8	T_8 17/8	T_9 26/8	T_{10} 6/9	T_{11} 17/9	T_{12} 9/10
Alternaria alternata	8	5	3	18	11	8	9	5	25	27	27	30
A. raphani											4	
A. tenuissima		3			1		3					
Ascochyta chenopodii			2	7	6			2				2
Cladosporium herbarum	1		1									
Dendryphiella arenaria		2										1
Fusarium moniliforme		1				2	1	17		3		
F. tricinctum	3	1			1			4			6	5
Mucor hiemalis	6					17	1	2	2	1		
Phoma glomerata					1							5
Stemphylium botryosum					10							
sterile dark mycelia				1	1							
Trichoderma koningii									4	5	3	
Total number of isolates	18	12	6	26	31	27	14	30	31	36	40	43

APPENDIX 63. Total number of fungal isolates on Atriplex patula under irrigation.

Taxa	T_1 6/6	T_2 13/6	T_3 23/6	T_4 3/7	T_5 15/7	T_6 23/7	T_7 6/8	T_8 17/8	T_9 26/8	T_{10} 6/9	T_{11} 17/9	T_{12} 9/10
Alternaria alternata	6	7	8	10	28	10	18	20	17	16	20	30
A. raphani				1			7					
A. tenuissima		1										
Ascochyta chenopodii			3									
Cladosporium herbarum		1										5
Drechslera halodes											5	
Epicoccum purpurascens											1	
Fusarium tricinctum	11	3	3	9		1		5	17	21	6	1
Mucor hiemalis	2	4	7			15	5	7			10	2
Phoma glomerata												1
sterile dark mycelia			1	1								
sterile white mycelia											1	
Trichoderma koningii							2		3	2		
Total number of isolates	19	16	22	21	28	26	32	32	37	39	43	39

APPENDIX 64. Fungal species common to the nine different paired combinations of *Atriplex patula* under various treatments.

	SEA SALTS	SODIUM NITRATE	IRRIGATION
CONTROL	*Alternaria alternata* *A. raphani* *A. tenuissima* *Ascochyta chenopodii* *Fusarium moniliforme* *F. tricinctum* *Mucor hiemalis* *Phoma glomerata* *Stemphylium botryosum* sterile dark mycelia *Trichoderma koningii*	*Alternaria alternata* *A. tenuissima* *Fusarium moniliforme* *F. tricinctum* *Mucor hiemalis* sterile dark mycelia *Trichoderma koningii*	*Alternaria alternata* *A. raphani* *A. tenuissima* *Ascochyta chenopodii* *Fusarium tricinctum* *Mucor hiemalis* *Phoma glomerata* sterile dark mycelia *Trichoderma koningii*
SEA SALTS	*Alternaria alternata* *A. tenuissima* *Fusarium moniliforme* *F. tricinctum* *Mucor hiemalis* sterile dark mycelia *Trichoderma koningii*	*Alternaria alternata* *A. raphani* *A. tenuissima* *Ascochyta chenopodii* *Cladosporium herbarum* *Fusarium tricinctum* *Mucor hiemalis* *Phoma glomerata* sterile dark mycelia *Trichoderma koningii*	
SODIUM NITRATE			*Alternaria alternata* *A. tenuissima* *Fusarium tricinctum* *Mucor hiemalis* sterile dark mycelia *Trichoderma koningii*

APPENDIX 65. Number of fungal taxa in common (a), number of taxa present only on the horizontally listed conditions (b), number of taxa present only on the vertically listed conditions (c), and number of taxa not present on either of the conditions (d) in each of the nine conditions for Atriplex patula.

	SEA SALTS	SODIUM NITRATE	IRRIGATION
CONTROL	11 2 2 3	7 6 0 5	9 4 4 1
SEA SALTS	7 0 6 5	10 3 3 2	
SODIUM NITRATE	6 7 1 4		
IRRIGATION			

LEGEND

a	b
c	d

APPENDIX 66. Principal component analysis coordinates derived from the total number of fungal isolates on Atriplex patula under sodium nitrate treatment. The total number of isolates is extracted from Appendix 61 in this dissertation.

Point	Coordinates	
	Axis 1	Axis 2
1	-4.7617355	0.0476619
2	-3.9030571	-0.8605253
3	-2.9031333	-1.2569233
4	-2.4452378	2.1444765
5	-2.2115283	2.0098245
6	0.5378637	0.4404100
7	-0.1851941	-1.5820970
8	1.2496163	-2.4037386
9	2.8765104	0.1834665
10	3.6948629	-0.3371068
11	3.2253325	1.0571634
12	4.8257002	0.5573882

Origin is at x = 6.2088172 and y = -9.7012768

APPENDIX 67. Principal component analysis coordinates derived from the total number of fungal isolates on Atriplex patula under sea salts treatment. The total number of fungal isolates is extracted from Appendix 62 in this dissertation.

Point	Coordinates	
	Axis 1	Axis 2
1	-2.0122749	1.0007804
2	-2.7202321	-0.8548143
3	-3.2429039	-0.9385139
4	1.0968591	-0.7984247
5	-0.9831714	-1.6355168
6	-2.6814127	4.0265733
7	-1.6277466	-0.4052768
8	-3.4961501	-1.1065183
9	3.1872607	0.5917842
10	3.7041801	0.2701114
11	3.9986125	-0.0156579
12	4.7769793	-0.1345267

Origin is at x = -6.2088172 and y = -4.7536256

APPENDIX 68. Principal component analysis coordinates derived from the total number of fungal isolates on Atriplex patula under irrigation. The total number of fungal isolates is extracted from Appendix 63 in this dissertation.

Point	Coordinates	
	Axis 1	Axis 2
1	-3.2681873	0.1540360
2	-1.8213807	-1.8234133
3	-1.6007430	-2.1985906
4	-1.9262170	0.4942567
5	4.0934236	0.7452676
6	-0.7468623	-3.5880207
7	1.5452201	-1.3304270
8	1.2852552	-0.2082790
9	-1.2686400	3.2672784
10	-2.1023493	4.0140006
11	1.1886061	-0.4664832
12	4.6218745	0.9403744

Origin is at x = 9.3132258 and y = 1.1447507

APPENDIX 69. Total isolates, frequency, square root of frequency, occurrence, distribution intensity index and dominance function of various fungal taxa from *Atriplex patula* under sodium nitrate treatment.

Taxa	Total isolates	Frequency	√frequency	Occurrence	Distribution intensity index*	Dominance function**	Total isolates	Frequency	√frequency	Occurrence	Distribution intensity index*	Dominance function**	Total isolates	Frequency	√frequency	Occurrence	Distribution intensity index*	Dominance function**	Total isolates	Frequency	√frequency	Occurrence	Distribution intensity index*	Dominance function**	Total isolates	Frequency	√frequency	Occurrence	Distribution intensity index*	Dominance function**
	Temporal I						Temporal II						Temporal III						Temporal IV						Temporal V					
Alternaria alternata	13	14.5	3.8	100.0	380.0	D	23	38.3	6.2	100	620.0	D	6	20	4.5	100	450	R	5	8.3	2.9	100	290	R	36	30.0	5.5	100	550.0	R
A. tenuissima	2	2.2	1.5	33.3	49.7	R																								
Fusarium moniliforme	8	8.9	2.9	66.7	198.9	SD	17	28.3	5.3	100	530.0	SD	18	60	7.8	100	780	D	32	53.3	7.3	100	730	D	108	90.0	9.5	100	950.0	D
F. tricinctum	11	12.2	3.5	66.7	233.2	D	17	28.3	5.3	100	530.0	SD	3	10	3.2	100	320	R	5	8.3	2.9	100	290	R	8	6.7	2.6	50	129.1	VR
Mucor hiemalis	6	6.7	2.6	66.7	172.2	SD													20	33.3	5.8	100	580	SD	24	20.0	4.5	100	450.0	R
sterile dark mycelia							3	5.0	2.2	50	111.8	R																		
Trichoderma koningii	2	2.2	1.5	33.3	49.7	R																								
Number of starts	90						60						30						60						120					
		$\bar{x}_1, s_1$ = 7.0±3.1						$\bar{x}_1, s_1$ = 15.0±3.5						$\bar{x}_1, s_1$ = 9.0±6.9						$\bar{x}_1, s_1$ = 15.5±13.1						$\bar{x}_1, s_1$ = 44.0±44.2				
		$\bar{x}_2, s_2$ = 4.5±1.4						$\bar{x}_2, s_2$ = 12.4±0.0						$\bar{x}_2, s_2$ = 4.5±2.1						$\bar{x}_2, s_2$ = 10.0± 8.7						$\bar{x}_2, s_2$ = 22.7±14.1				
		$\bar{x}_3, s_3$ = 2.0±0.0						$\bar{x}_3, s_3$ = 3.0±0.0						$\bar{x}_3, s_3$ = 4.5±2.1						$\bar{x}_3, s_3$ = 5.0± 0.0						$\bar{x}_3, s_3$ = 22.7±14.1				

*Values derived from unrounded √frequency

**D = dominant; SD = subdominant; C = common; R = rare; VR = very rare

APPENDIX 70. Total isolates, frequency, square root of frequency, occurrence, distribution intensity index and dominance function of various fungal taxa from *Atriplex patula* under sea salts treatment.

Taxa	Temporal I						Temporal II						Temporal III						Temporal III						Temporal IV						Temporal V					
	Total isolates	Frequency	√frequency	Occurrence	Distribution intensity index*	Dominance function**	Total isolates	Frequency	√frequency	Occurrence	Distribution intensity index*	Dominance function**	Total isolates	Frequency	√frequency	Occurrence	Distribution intensity index*	Dominance function**	Total isolates	Frequency	√frequency	Occurrence	Distribution intensity index*	Dominance function**	Total isolates	Frequency	√frequency	Occurrence	Distribution intensity index*	Dominance function**	Total isolates	Frequency	√frequency	Occurrence	Distribution intensity index*	Dominance function**
Alternaria alternata	8	26.7	5.2	100	520	D	33	22.0	4.7	100	470.0	D	18	60.0	7.8	100	780	D	18	60.0	7.8	100	780	D	8	26.7	5.2	100	520	SD	109	90.8	9.5	100	950.0	D
A. raphani																															4	3.3	1.8	25	45.7	C
A. tenuissima							7	4.7	2.2	60	129.6	C																								
Ascochyta chenopodii							10	6.7	2.6	60	154.9	SD	7	23.3	4.8	100	480	C	7	23.3	4.8	100	480	C							2	1.7	1.3	25	33.3	R
Cladosporium herbarum	1	3.3	1.8	100	180	VR	1	0.7	0.8	20	16.3	VR																			1	0.8	0.9	25	22.8	R
Dendryphiella arenaria							2	1.3	1.2	20	23.1	R																			3	2.5	1.6	25	39.6	R
Fusarium moniliforme							19	12.7	3.6	60	213.6	D													2	6.7	2.6	100	260	R	11	9.2	3.0	50	150.0	SD
F. tricinctum	3	10.0	3.2	100	320	R	6	4.0	2.0	60	120.0	C																			3	2.5	1.6	50	79.1	R
Mucor hiemalis	6	20.0	4.5	100	450	D	3	2.0	1.4	40	56.6	R													17	56.7	7.5	100	750	D	5	4.2	2.1	25	52.5	C
Phoma glomerata							1	0.7	0.8	20	16.3	VR																								
sterile dark mycelia							1	0.7	0.8	20	16.3	VR	1	3.3	1.8	100	180	R	1	3.3	1.8	100	180	R												
Stemphylium botryosum							10	6.7	2.6	20	52.0	SD																								
Trichoderma koningii																															12	10.0	3.2	75	237.2	SD
Number of starts	30						150						30						30						30						120					
			$\bar{x}_1,s_1 = 4.5\pm1.4$ $\bar{x}_2,s_2 = 2.0\pm1.4$ $\bar{x}_3,s_3 = 2.0\pm1.4$						$\bar{x}_1,s_1 = 8.5\pm10.3$ $\bar{x}_2,s_2 = 4.6\pm 2.1$ $\bar{x}_3,s_3 = 2.2\pm 1.7$								$\bar{x}_1,s_1 = 8.7\pm7.8$ $\bar{x}_2,s_2 = 4.0\pm4.2$ $\bar{x}_3,s_3 = 1.0\pm0.0$								$\bar{x}_1,s_1 = 8.7\pm7.8$ $\bar{x}_2,s_2 = 4.0\pm4.2$ $\bar{x}_3,s_3 = 1.0\pm0.0$								$\bar{x}_1,s_1 = 9.0\pm6.4$ $\bar{x}_2,s_2 = 5.0\pm0.0$ $\bar{x}_3,s_3 = 2.0\pm0.0$								$\bar{x}_1,s_1 = 16.7\pm50.0$ $\bar{x}_2,s_2 = 5.2\pm 3.8$ $\bar{x}_3,s_3 = 3.0\pm 0.0$				

*Values derived from unrounded √frequency

**D = dominant; SD = subdominant; C = common; R = rare; VR = very rare

APPENDIX 71. Total isolates, frequency, square root of frequency, occurrence, distribution intensity index and dominance function of various fungal taxa from Atriplex patula under irrigation.

Taxa	Total isolates	Frequency	√frequency	Occurrence	Distribution intensity index*	Dominance function**
	Temporal I					
Alternaria alternata	16	26.7	5.2	100	520.0	D
A. raphani	1	1.7	1.3	50	64.6	R
A. tenuissima						
Ascochyta chenopodii						
Cladosporium herbarum						
Drechslera halodes						
Epicoccum purpurascens						
Fusarium tricinctum	20	33.3	5.8	100	580.0	D
Mucor hiemalis	2					C
Phoma glomerata						
sterile dark mycelia	1	1.7	1.3	50	64.6	R
sterile white mycelia						
Trichoderma koningii						
Number of starts	60					
	$\bar{x}_1,s_1$ = 8.0±2.8					
	$\bar{x}_2,s_2$ = 1.3±0.0					
	$\bar{x}_3,s_3$ = 1.3±0.0					

Taxa	Total isolates	Frequency	√frequency	Occurrence	Distribution intensity index*	Dominance function**
	Temporal II					
Alternaria alternata	25	27.8	5.3	100.0	530.0	D
A. raphani						
A. tenuissima	1	1.1	1.1	33.3	35.1	R
Ascochyta chenopodii	3	3.3	1.8	33.3	60.8	C
Cladosporium herbarum	1	1.1	1.1	33.3	35.1	R
Drechslera halodes						
Epicoccum purpurascens						
Fusarium tricinctum	7	7.8	2.8	100.0	280.0	SD
Mucor hiemalis	26	28.9	5.4	100.0	540.0	D
Phoma glomerata						
sterile dark mycelia	1	1.1	1.1	33.3	35.1	R
sterile white mycelia						
Trichoderma koningii						
Number of starts	90					
	$\bar{x}_1,s_1$ = 9.2±10.7					
	$\bar{x}_2,s_2$ = 2.6± 2.8					
	$\bar{x}_3,s_3$ = 1.5± 1.4					

Taxa	Total isolates	Frequency	√frequency	Occurrence	Distribution intensity index*	Dominance function**
	Temporal III					
Alternaria alternata	58	64.5	8.0	100.0	800.0	D
A. raphani	7	7.8	2.8	33.3	92.9	R
A. tenuissima						
Ascochyta chenopodii						
Cladosporium herbarum						
Drechslera halodes	5	5.6	2.4	33.3	78.5	R
Epicoccum purpurascens	1	1.1	1.1	33.3	35.1	VR
Fusarium tricinctum	11	12.2	3.5	66.7	233.2	C
Mucor hiemalis	22	24.5	4.9	100.0	490.0	SD
Phoma glomerata						
sterile dark mycelia						
sterile white mycelia	1	1.1	1.1	33.3	35.1	VR
Trichoderma koningii	2	2.2	1.5	33.3	49.6	R
Number of starts	90					
	$\bar{x}_1,s_1$ = 13.4±21.9					
	$\bar{x}_2,s_2$ = 6.7± 7.6					
	$\bar{x}_3,s_3$ = 4.3± 3.1					

Taxa	Total isolates	Frequency	√frequency	Occurrence	Distribution intensity index*	Dominance function**
	Temporal IV					
Alternaria alternata	33	55.0	7.4	100	740.0	D
A. raphani						
A. tenuissima						
Ascochyta chenopodii						
Cladosporium herbarum						
Drechslera halodes						
Epicoccum purpurascens						
Fusarium tricinctum	38	63.3	7.9	100	795.8	D
Mucor hiemalis						
Phoma glomerata						
sterile dark mycelia						
sterile white mycelia						
Trichoderma koningii	5	8.3	2.9	100	290.0	SD
Number of starts	60					
	$\bar{x}_1,s_1$ = 25.3±3.5					
	$\bar{x}_2,s_2$ = 5.0±0.0					
	$\bar{x}_3,s_3$ = 0.0±0.0					

Taxa	Total isolates	Frequency	√frequency	Occurrence	Distribution intensity index*	Dominance function**
	Temporal V					
Alternaria alternata	58	96.7	9.8	100	980	D
A. raphani						
A. tenuissima						
Ascochyta chenopodii						
Cladosporium herbarum	5	8.3	2.8	50	140	SD
Drechslera halodes						
Epicoccum purpurascens						
Fusarium tricinctum	1	1.7	1.3	50	65	VR
Mucor hiemalis	2	3.3	1.8	50	90	R
Phoma glomerata	1	1.7	1.3	50	65	VR
sterile dark mycelia						
sterile white mycelia						
Trichoderma koningii						
Number of starts	60					
	$\bar{x}_1,s_1$ = 13.4±37.5					
	$\bar{x}_2,s_2$ = 2.3± 2.1					
	$\bar{x}_3,s_3$ = 2.0± 0.7					

*Values derived from unrounded √frequency

**D = dominant; SD = subdominant; C = common; R = rare; VR = very rare

APPENDIX 72. Total number of fungal isolates on Suaeda depressa under sodium nitrate treatment.

Taxa	T_2 13/6	T_3 23/6	T_4 3/7	T_5 15/7	T_6 23/7	T_7 6/8	T_8 17/8	T_9 26/8	T_{10} 6/9	T_{11} 17/9	T_{12} 9/10
Alternaria alternata	3	6	3	3	3	5	2	4	9	18	27
A. dennisii		5	5	2							
Cladosporium herbarum			1								
Fusarium moniliforme			1	13	7	27	30	29	26	6	16
F. tricinctum							3	5	4	26	10
Mucor hiemalis	4						1			3	
Phoma glomerata	7		1	4							
Stemphylium botryosum		5	7	2							
sterile white mycelia			4	2							
Total number of isolates	14	16	22	26	10	32	36	38	39	53	53

APPENDIX 73. Total number of fungal isolates on Suaeda depressa under sea salts treatment.

Taxa	T_2 13/6	T_3 23/6	T_4 3/7	T_5 15/7	T_6 23/7	T_7 6/8	T_8 17/8	T_9 26/8	T_{10} 6/9	T_{11} 17/9	T_{12} 9/10
Alternaria alternata	3	3	3	3	5	15	12	27	30	30	30
A. citri				2		3					
A. dennisii					1	1	5				
A. tenuissima						6					
Ascochyta chenopodii	2		4			2	2				
Cladosporium herbarum			1								
Dendryphiella arenaria		4	4	6	2						1
Fusarium tricinctum						3		1	4	3	4
Mucor hiemalis	2					1					3
Phoma glomerata	4		6	4			5		2	1	
Stemphylium botryosum		3	8	13	1						
sterile dark mycelia		2			1	2		7	5	2	8
sterile white mycelia			3	1			5			4	4
Trichoderma koningii					1						
Total number of isolates	11	12	29	29	11	33	29	35	41	40	50

APPENDIX 74. Total number of fungal isolates on Suaeda depressa under irrigation.

Taxa	T_2 13/6	T_3 23/6	T_4 3/7	T_5 15/7	T_6 23/7	T_7 6/8	T_8 17/8	T_9 26/8	T_{10} 6/9	T_{11} 17/9	T_{12} 9/10
Alternaria alternata	4	6	5	6	8	21	17	20	29	30	26
A. citri						2					
A. dennisii			4	4	1		3				
A. raphani			2								
A. tenuissima					2			5			
Ascochyta chenopodii	2	3			4	1	1				2
Epicoccum purpurascens											1
Fusarium tricinctum	1				1	2	11	6	5	6	4
Mucor hiemalis	2					4	5	4	6	5	
Phoma glomerata	2		5	2							
Stemphylium botryosum		3	4	16	4						
sterile dark mycelia											6
Trichoderma koningii						1					1
Total number of isolates	11	12	20	28	20	31	37	35	40	41	40

APPENDIX 75. Fungal species common to the nine different paired combinations of *Suaeda depressa* under various treatments.

	SEA SALTS	SODIUM NITRATE	IRRIGATION
CONTROL	*Alternaria alternata* *A. citri* *A. dennisii* *A. tenuissima* *Ascochyta chenopodii* *Cladosporium herbarum* *Fusarium tricinctum* *Mucor hiemalis* *Phoma glomerata* *Stemphylium botryosum* sterile dark mycelia sterile white mycelia *Trichoderma koningii*	*Alternaria alternata* *A. dennisii* *Cladosporium herbarum* *Fusarium tricinctum* *Mucor hiemalis* *Phoma glomerata* *Stemphylium botryosum* sterile white mycelia	*Alternaria alternata* *A. citri* *A. dennisii* *A. tenuissima* *Ascochyta chenopodii* *Epicoccum purpurascens* *Fusarium tricinctum* *Mucor hiemalis* *Phoma glomerata* *Stemphylium botryosum* sterile dark mycelia *Trichoderma koningii*
SEA SALTS		*Alternaria alternata* *A. dennisii* *Cladosporium herbarum* *Fusarium tricinctum* *Mucor hiemalis* *Phoma glomerata* *Stemphylium botryosum* sterile white mycelia	*Alternaria alternata* *A. citri* *A. dennisii* *A. tenuissima* *Ascochyta chenopodii* *Fusarium tricinctum* *Mucor hiemalis* *Phoma glomerata* *Stemphylium botryosum* sterile dark mycelia *Trichoderma koningii*
SODIUM NITRATE			*Alternaria alternata* *A. dennisii* *Fusarium tricinctum* *Mucor hiemalis* *Phoma glomerata* *Stemphylium botryosum*

APPENDIX 76. Number of fungal taxa in common (a), number of taxa present only on the horizontally listed conditions (b), number of taxa present only on the vertically listed conditions (c), and number of taxa not present on either of the conditions (d) in each of the nine conditions for Suaeda depressa.

	SEA SALTS	SODIUM NITRATE	IRRIGATION
CONTROL	13 4 1 2	8 9 1 2	12 5 1 2
SEA SALTS		8 6 1 3	11 3 2 4
SODIUM NITRATE			6 3 7 4
IRRIGATION			

LEGEND

a	b
c	d

APPENDIX 77. Principal component analysis coordinates derived from the total number of fungal isolates on Suaeda depressa under sodium nitrate treatment. The total number of fungal isolates is extracted from Appendix 72 in this dissertation.

Point	Coordinates	
	Axis 1	Axis 2
1	-4.4490978	-2.0035622
2	-4.5665627	-1.4540914
3	-4.3891785	-2.2448185
4	-0.4321915	-2.1028249
5	-2.0453673	-1.8915276
6	4.1693281	-1.4562857
7	5.0902157	-1.4491460
8	4.7747323	-0.5740823
9	3.8226589	0.3160369
10	-2.5773287	7.2185127
11	0.6027915	5.6417890

Origin is at x = -1.6933138 and y = -1.6933138

APPENDIX 78. Principal component analysis coordinates derived from the total number of fungal isolates on Suaeda depressa under sea salts treatment. The total number of fungal isolates is extracted from Appendix 73 in this dissertation.

Point	Coordinates	
	Axis 1	Axis 2
1	-3.5377034	-1.5990986
2	-3.6231236	-0.4484269
3	-4.2538015	1.2387947
4	-4.5564833	2.7220387
5	-2.8925165	-1.1435883
6	0.3595830	-1.1703997
7	-0.8579510	-0.9306411
8	4.1869443	0.0634504
9	5.0185266	0.3681169
10	4.8825636	0.3911726
11	5.2739618	0.5085813

Origin is at x = 3.3866276 and y = -8.8898973

APPENDIX 79. Principal component analysis coordinates derived from the total number of fungal isolates on Suaeda depressa under irrigation. The total number of fungal isolates is extracted from Appendix 74 in this dissertation.

Point	Coordinates	
	Axis 1	Axis 2
1	-3.3448990	-1.8770490
2	-3.1611659	-0.7837296
3	-3.7484426	-0.1934570
4	-4.3988629	3.2847276
5	-2.6348690	-0.3660943
6	1.8050085	-0.1875331
7	1.2507112	-0.8628954
8	1.8176006	-0.5183144
9	4.4281088	0.5037968
10	4.7336506	0.5925495
11	3.2531598	0.4079989

Origin is at x = 1.6933138 and y = -8.4665689

APPENDIX 80. Total isolates, frequency, square root of frequency, occurrence, distribution intensity index and dominance function of various fungal taxa from Suaeda depressa under sodium nitrate treatment.

Taxa	Total isolates	Frequency	√frequency	Occurrence	Distribution intensity index*	Dominance function**	Total isolates	Frequency	√frequency	Occurrence	Distribution intensity index*	Dominance function**	Total isolates	Frequency	√frequency	Occurrence	Distribution intensity index*	Dominance function**	Total isolates	Frequency	√frequency	Occurrence	Distribution intensity index*	Dominance function**
	Temporal I						Temporal II						Temporal III						Temporal IV					
Alternaria alternata	12	13.3	3.7	100.0	370.0	SD	6	10.0	3.2	100	320	SD	20	16.7	4.1	100	410.0	SD	45	75.0	8.7	100	870	D
A. dennisii	10	11.1	3.3	66.6	219.8	D	2	3.3	1.8	50	90	R												
Cladosporium herbarum	1	1.1	1.1	33.3	36.6	R																		
Fusarium moniliforme	1	1.1	1.1	33.3	36.6	R	20	33.3	5.8	100	580	D	112	93.3	9.7	100	970.0	D	22	36.7	6.1	100	610	C
F. tricinctum													12	10.0	3.2	75	240.0	R	36	60.0	7.8	100	780	SD
Mucor hiemalis	4	4.4	2.1	33.3	69.9	R							1	0.8	0.9	25	22.5	VR	3	5.0	2.2	50	110	R
Phoma glomerata	8	8.9	3.0	66.6	199.8	SD	4	6.7	2.6	50	130	C												
Stemphylium botryosum	12	13.3	3.7	66.6	246.4	D	2	3.3	1.8	50	90	R												
sterile white mycelia	4	4.4	2.1	33.3	69.9	R	2	3.3	1.8	50	90	R												
Number of starts	90						60						120						60					
	$\bar{x}_1, s_1$ = 6.1±2.9						$\bar{x}_1, s_1$ = 6.0±9.8						$\bar{x}_1, s_1$ = 36.3±55.6						$\bar{x}_1, s_1$ = 26.5±11.6					
	$\bar{x}_2, s_2$ = 4.5±0.7						$\bar{x}_2, s_2$ = 3.2±2.0						$\bar{x}_2, s_2$ = 11.0± 5.7						$\bar{x}_2, s_2$ = 20.3± 9.9					
	$\bar{x}_3, s_3$ = 2.5±2.1						$\bar{x}_3, s_3$ = 2.5±1.4						$\bar{x}_3, s_3$ = 6.5± 7.8						$\bar{x}_3, s_3$ = 12.5± 0.0					

*Values derived from unrounded √frequency

**D = dominant; SD = subdominant; C = common; R = rare; VR = very rare

APPENDIX 81. Total isolates, frequency, square root of frequency, occurrence, distribution intensity index and dominance function of various fungal taxa from Suaeda depressa under sea salts treatment.

Taxa	Total isolates	Frequency	√frequency	Occurrence	Distribution intensity index*	Dominance function**	Total isolates	Frequency	√frequency	Occurrence	Distribution intensity index*	Dominance function**	Total isolates	Frequency	√frequency	Occurrence	Distribution intensity index*	Dominance function**	Total isolates	Frequency	√frequency	Occurrence	Distribution intensity index*	Dominance function**
	Temporal I						Temporal II						Temporal III						Temporal IV					
Alternaria alternata	11	12.2	3.5	100.0	350.0	D	6	10.0	3.2	100	320	C	27	45.0	6.7	100	670	D	117	98.0	9.9	100	999.0	D
A. citri							2	3.3	1.8	50	90	R	3	5.0	2.2	50	110	VR						
A. dennisii	1	1.1	1.1	33.3	36.3	VR							6	10.0	3.2	100	320	R						
A. tenuissima													6	10.0	3.2	50	160	R						
Ascochyta chenopodii	2	2.2	1.5	33.3	50.0	R	4	6.7	2.6	50	130		4	6.7	2.6	100	260	R						
Cladosporium herbarum							1	1.7	1.3	50	65	VR												
Dendryphiella arenaria	6	6.7	2.6	66.6	173.2	SD	10	16.7	4.1	100	410	SD							1	0.8	0.9	25	22.5	R
Fusarium tricinctum													3	5.0	2.2	50	110	C	12	10.0	3.2	100	320.0	SD
Mucor hiemalis	2	2.2	1.5	33.3	50.0	R							1	1.7	1.3	50	65	VR	3	2.5	1.6	25	40.0	C
Phoma glomerata	4	4.4	2.2	33.3	73.2	C	10	16.7	4.1	100	410	SD	5	8.3	2.9	50	145	C	3	2.5	1.6	50	80.0	R
Stemphylium botryosum	4	4.4	2.2	66.6	146.5	C	21	35.0	5.9	100	590	D												
sterile dark mycelia	3	3.3	1.8	66.6	119.9	R							2	3.3	1.8	50	90	R	22	18.3	4.3	100	430.0	SD
sterile white mycelia							4	6.7	2.6	100	260	R	5	8.3	2.9	50	145	C	8	6.7	2.6	50	130.0	
Trichoderma koningii	1	1.1	1.1	33.3	36.3	VR																		
Number of starts	90						60						60						120					
	$\bar{x}_1, s_1 = 3.8 \pm 3.2$						$\bar{x}_1, s_1 = 7.3 \pm 6.3$						$\bar{x}_1, s_1 = 13.9 \pm 29.1$						$\bar{x}_1, s_1 = 12.9 \pm 25.8$					
	$\bar{x}_2, s_2 = 2.9 \pm 1.7$						$\bar{x}_2, s_2 = 5.3 \pm 3.6$						$\bar{x}_2, s_2 = 6.1 \pm 3.5$						$\bar{x}_2, s_2 = 5.0 \pm 1.5$					
	$\bar{x}_3, s_3 = 2.4 \pm 1.3$						$\bar{x}_3, s_3 = 3.4 \pm 1.9$						$\bar{x}_3, s_3 = 5.1 \pm 1.3$						$\bar{x}_3, s_3 = 1.7 \pm 1.2$					

*Values derived from unrounded $\sqrt{\text{frequency}}$

**D = dominant; SD = subdominant; C = common; R = rare; VR = very rare

APPENDIX 82. Total isolates, frequency, square root of frequency, occurrence, distribution intensity index and dominance function of various fungal taxa from Suaeda depressa under irrigation.

Taxa	Total isolates	Frequency	√frequency	Occurrence	Distribution intensity index*	Dominance function**	Total isolates	Frequency	√frequency	Occurrence	Distribution intensity index*	Dominance function**	Total isolates	Frequency	√frequency	Occurrence	Distribution intensity index*	Dominance function**	Total isolates	Frequency	√frequency	Occurrence	Distribution intensity index*	Dominance function**
	Temporal I						Temporal II						Temporal III						Temporal IV					
Alternaria alternata	23	19.2	4.4	100	440.0	D	6	20.0	4.5	100	450	SD	58	64.4	8.0	100.0	800.0	D	65	72.2	8.5	100.0	850.0	D
A. citri													2	2.2	1.5	33.3	50.0	R						
A. dennisii	5	4.2	2.0	50	100.0	C	4	13.3	3.7	100	370	R	3	3.3	1.8	33.3	60.0	R						
A. raphani	2	1.7	1.3	25	32.5	R																		
A. tenuissima	2	1.7	1.3	25	32.5	R							5	5.6	2.4	33.3	80.0	R						
Ascochyta chenopodii	9	7.5	2.7	75	202.5	SD							2	2.2	1.5	66.6	100.0	R	2	2.2	1.5	33.3	50.0	R
Epicoccum purpurascens																			1	1.1	1.1	33.3	34.4	R
Fusarium tricinctum	2	1.7	1.3	50	65.0	R							19	21.1	4.6	100.0	460.0	SD	15	16.7	4.1	100.0	410.0	SD
Mucor hiemalis	2	1.7	1.3	25	32.5	R							13	14.4	3.8	100.0	380.0	C	11	12.2	3.5	66.6	233.1	SD
Phoma glomerata	7	5.8	2.4	50	120.0	C	2	6.7	2.6	100	260	R												
Stemphylium botryosum	11	9.2	3.0	75	225.0	SD	16	53.3	7.3	100	730	D												
sterile dark mycelia																			6	6.7	2.6	33.3	86.6	C
Tricoderma koningii													1	1.1	1.1	33.3	34.4	VR	1	1.1	1.1	33.3	34.4	R
Number of starts	120						30						90						90					
	$\bar{x}_1, s_1$ = 7.0±7.1 $\bar{x}_2, s_2$ = 5.0±2.6 $\bar{x}_3, s_3$ = 3.3±1.4						$\bar{x}_1, s_1$ = 7.0±7.1 $\bar{x}_2, s_2$ = 4.0±1.4 $\bar{x}_3, s_3$ = 3.0±1.4						$\bar{x}_1, s_1$ = 12.9±24.4 $\bar{x}_2, s_7$ = 6.4± 7.0 $\bar{x}_3, s_3$ = 4.3± 5.7						$\bar{x}_1, s_1$ = 17.3±37.4 $\bar{x}_2, s_2$ = 6.0± 4.5 $\bar{x}_3, s_3$ = 2.5± 2.8					

*Values derived from unrounded √frequency

**D = dominant; SD = subdominant; C = common; R = rare; VR = very rare

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