Abstract Mangroves are climax formation of hydrohalophytes inhabiting estuarine or marine salt marsches in the tropics and subtropics. As a terrestrial plant community inhabiting tidally inundated estuarine or marine sediments, mangroves show considerable adaptation to salinity, waterlogging and nutrient stress. Thirty-one species of mangrove and mangrove associates and 23 species of transported flora, belonging to 25 families at four physiographic stages of succession of the mangrove plant community at the terminal part of the Ganges river estuary in India were examined for arbuscular mycorrhizal (AM) root association. Dominant members of the mangrove plant community were all AM, mostly with ‘Paris’ type structures. Many of the known non-mycotrophic plant families, except the Cyperaceae, also showed AM association, with intracellular hyphae and vesicles as the most discernible endophyte structures. Intensity of AM colonization varied both with the species and situations of their occurrence, being more intense and also more extensive in less saline dry ridge mangroves than in more saline formative and developed swamp mangroves. Introduced exotic trees on the ridges and embankments were infected by AM, but less than the declining mangroves in the same location. Seven species of AM fungi in common with those of the upstream mesophytic plants were isolated from root-free rhizosphere soils of the mangroves, three of which predominated in root association. These species, individually and as mixtures, infected roots of salinity tolerant herbs and trees in both locational silt and upstream alluvial soil with obvious improvements in their biomass yield and phosphorus nutrition. AM infective potential of root-free rhizosphere soils of the dominant members of the mangrove community were negatively related to salinity level of the sediment soil of the successional stages. The evidences of AM association of mangroves and other salt marsh plants obtained here and those reported elsewhere are discussed.

Keywords Mangroves · (V) A mycorrhiza · Ecology · Salt marsh plants · Estuary

Introduction

Mangroves, the climax formation of hydrohalophytes belonging to several plant families, inhabit tropical and sub-tropical estuarine or marine salt marshes. Mangrove forests are considered as open ‘interface’ ecosystems connecting upland terrestrial and coastal estuarine ecosystems (Lugo and Snedaker 1974). Contributors to the geo-aquatic food chain, mangrove forests are important for biomass production and coastline protection. In the context of our studies on microbiological aspects of ecosystemic adaptation of mangroves to salinity, inundation and nutrient stress, we have examined arbuscular mycorrhizal (AM) relations of four eco-successional stages of the mangrove plant community at the terminal part of the Ganges river estuary in India. We have previously reported the occurrence of AM in four species of pioneer salt marsh plants (Sengupta and Chaudhuri 1990), heterotrophic dinitrogen fixation in mangrove root association (Sengupta and Chaudhuri 1991), and the presence of seemingly mycorrhizal, dark septate mycelial endophytes in mangrove roots (Sengupta and Chaudhuri 1994), from the same location. The recognition that dominant plants of each biome – large, easily defined terrestrial plant community units (Odum 1971) – engage in mutualistic root associations with soil fungi to form mycorrhiza (Read 1993), prompted us to see whether the tropical hydrohalophytic mangrove biome inhabiting estuarine, semi-aquatic, saline sediments belongs to the above generalization.

Materials and methods

Study location and sample collection

The terminal part of the deltaic drainage basin of the river Ganges in India, known as ‘Sundarban’ (21°30′ – 22°30′N, 88°10′ – 89°51′E)
is the home of the Indian sub-group of “Old World mangroves” (Chapman 1975). Based on physiographic characters and floristic development, the mangrove forest of Sundarban is divided into four distinct eco-successional stages: (I) formative mangrove swamps, (II) developed mangrove swamps, (III) declining ridge mangroves, and (IV) declined mangroves on embankment-protected highlands where crop agriculture and forestry with salinity tolerant plant species have been introduced (Sengupta and Chaudhuri 1991).

Soil and root samples of mangrove and associated plants were collected during Spring (February–April) from the four physiographic stages of mangrove succession over a 10-km² area of the riverine delta. Five representative samples of soil or root for any location, or a plant species from a location, were collected and combined for analysis. As far as practicable, soil and root samples were collected from single stands of the different plant species within a designated physiographic stage. Herbaceous plants and young tree seedlings were removed from mud flats along with a ball of soil adhering to the roots with the help of a core sampler. Roots still attached with the plants were freed of soil, washed and sampled for mycorrhizal analysis. For older trees, juvenile nutritious roots were located by digging, taken out with adhering soil and sampled similarly. Root-adhered soil was air dried, bulked for a plant species from a stage and also irrespective of the plant species for a stage, sieved and then used for analysis of AM fungal spores and infective inoculum density.

Analytical methods

Standard methods of soil analysis (Jackson 1967; Dewis and Freitas 1984) were used to analyze the common physical and chemical properties of root-associated soil samples taken from the surface layer of the estuarine sediment (1–15 cm). AM root infection intensity was assessed by the slide micrometric method (Kormanik and McGraw 1984) from roots cleared and stained according to Philips and Hayman (1970), with some modification (Sengupta and Chaudhuri 1990). Three hundred 1 cm root segments taken from composite root samples were examined for each plant species from a location. The presence of any of the endophytic elements – hyphae, coils, vesicles and arbuscules – was taken as evidence of mycorrhization and used for estimating root infection intensity. Designation of the arbuscular endophytic association as either ‘Arum’ type or ‘Paris’ type was made according to the description given by Smith and Smith (1997). The wet sieving and decantation method of Gerdemann and Nicolson (1963) and density gradient centrifugation (Watrus 1984) were used to isolate spores of AM fungi from root-associated soil. Most probable number (MPN) of infective AM propagules was determined by the standard 10-fold serial dilution end-point technique (Powell 1980), taking Cajanus cajan (L.) Millsp. as the test plant. Riverine silt soil from the location was used as diluent. Root-based AM inoculum was prepared with surface-sterilized spores of the different AM fungus species isolates (Watrus 1984), singly or in mixtures, taking maize as the host plant, in sterile sand:soil (1:1) mixture in plastic containers. A growth response study of selected herbs and trees with AM inoculation was carried out in a greenhouse during the Spring – Summer season (March–June) with 5 and 12 kg soil in soil planters, for 75 and 100 days, respectively. Fresh, air-dried root-based inoculum in 5–8 mm pieces at the rate of 3 g per kg soil was used for soil inoculation. Heat-killed maize root in equivalent amount was added to the control set. The AM fungi were identified from spore morphology by reference to type descriptions of the species (Schenck and Perez 1990). The AM fungal species isolates are maintained in the author’s (S.C.) laboratory for future reference.

Results

Soil analysis data (Table 1) revealed that besides soil salinity, poor availability of major plant nutrients – particularly nitrogen and phosphorus – was a strong stress factor for the plant community of the ecosystem. Except for stage I formative swamp, all other stages had moderate organic matter contents, as is typical of tropical alluvial soil under plant cover. Concentration of total and NO₃ nitrogen, which was lowest in the formative swamps, increased with the stages of physiographic succession of the plant community. Concentrations of exchangeable NH₄ were also very low, particularly in the swampy mangrove sediments. Concentrations of available P in soil sediments of the successional stages were low to moderate, being lowest in the stage IV embankment-protected agricultural land. Concentrations of total phosphorus were relatively high, having an inverse relationship with the stages of succession compared to that of available phosphorus.

Fifty-four plant species from the four successional stages, excluding agricultural crops at stage IV, were examined for the presence of root endophytic fungi. Of these, 31 were mangrove and mangrove-associates and 23 were non-litoral, non-mangrove species, introduced by man or transported by the river to the ecosystem. All the 31 mangrove and associated species belonging to 18 plant families showed the presence of root endophytes, structurally similar to those of AM caused by the Glomalean fungi (Table 2). The non-litoral species, belonging to 13 families, including some commonly reported non-mycotrophic plant families (e.g., Amaranthaceae), but excluding those belonging to the Cyperaceae, also showed the presence of AM endophytes in their roots in their respective physiographic situations. Endophytic colonization of most of the plant species structurally resembled ‘Paris’ type AM (Smith and Smith 1997),