INTRODUCTION
Coastal sand dunes, result from the stabilization of transported sediment by vegetation. Krumbein and Slack (1956) divide the beach zone into two viz., the foreshore where there is transport by water currents, by waves and occasionally by wind; and the backshore where there is transport primarily by wind with breaking waves having only a minor influence. The two requisites for dune formation are adequate supply of sand and sufficient wind. Stabilization of the mobile sand by vegetation is the second phase in the process.

Coastal sand dunes are found in many parts of the world in arid, semi-arid and temperate climates, though on semi-tropical and tropical coasts luxuriant vegetation, low wind velocities and damp soil make them less frequent (Packham and Willis, 1997). Most coastal dunes are essentially phytogenic, evolving with a partial cover of vegetation which both helps to fix the ground and modifies its surface properties with respect to air flow. At a later stage in their development and seldom permanently dunes often become inactive or fixed, held by the roots of the plants covering them. The great arid deserts of the world are generally devoid of permanent vegetation and their dunes are active or live constantly changing under wind currents and fed from blowouts.

Barbour et al., (1985) and Chapman (1976) have extensively reviewed the abiotic component of coastal sand dunes. According to them high temperature, wind speed, light intensity and potential evapo-transpiration are of considerable significance. The sand is coarse with low level of inorganic content. In most
PLATE-1

VEGETATION COVER OF COASTAL SAND DUNE OF GOA (SITE: VARCA).
dunes, the primary source of water is rain, but once it has percolated through the dune to the underlying water table it is unavailable to the dune ridge plants. Three main strategies have evolved in response to this problem. (1) Dune annuals undergo their vegetative cycle in autumn and spring or other wet seasons and survive the dry periods as seeds. Perennials either (2) produce a deep rooting system and are thus able to draw water from a vertical zone or (3) produce an extensive shallow shower exploiting root system. Water availability is enhanced by diurnal temperature change, which leads to dew formation, the dune acting as large water condensers.

Coastal dune systems are dynamic natural features of vital economic and ecological importance. They function as flexible barriers to storm, tides and waves (Woodhouse, 1982). Fore dunes protect areas behind them from wave damage and salt water intrusion during storms and also are a source of sand for the beach during periods of erosion. Vegetated fore dunes restrict wind, sand and salt spray intrusion into hind dune areas. The protective action of the fore dunes allow the development of a more complex plant community on the hind dunes. Land ward dune parallel to fore dunes serve as a second line of defense against water and wind erosion.

Vegetation plays an important role in the formation and stabilization of coastal sand dunes. Pioneer plants trap and hold wind blown sand in the frontal dune and help to create condition, which encourage the establishment and growth
of other plant communities such as woodland, scrub heath and forest. The above
ground parts of the dune plants act as obstruction, increase surface roughness and
cause reduction in the surface speed of sand carrying wind. The reduction in wind
movement results in the deposition of sand around the plants. Thus dune
vegetation helps in keeping the coastal land free from erosion and also prevents
internal desertification.

Pioneer plants make up the initial dune vegetation. They are found on the
dune nearest to the sea where their survival depends on their ability to establish,
grow and reproduce in order to colonize newly formed dunes.

Mycorrhiza, are critical components of the root soil interface. These fungi
are present quite consistently on the root surfaces or in the tissues or cells of the
roots of many species so that dual organs of consistent morphological and
histological patterns are formed. They conform to a number of common kinds the
world over, and in them the fungus and the host co-exist in a physiologically,
ecologically and reproductively active state for long periods, a state called
mutualistic symbiosis. Table-1 summarizes the characteristics of the common
kinds of mycorrhizae. These symbiotic associations that participate in the uptake
of phosphorus are involved in pioneer colonization of nutrient deficient sites
(Harley, 1970). The arbuscular mycorrhizal symbiosis is a wide- spread
phenomenon which occurs in 80% of the plant species including Angiosperms,
Gymnosperms and Pteridophytes showing a little host specificity (Azon, 1994;
Baylis, 1975). It is now well known that these organisms are ubiquitous in distribution. Grasslands, muckfarms, rainforests, sand dunes and arid regions support variable levels of arbuscular mycorrhizae. Disturbed habitats may support relatively few natural infections by mycorrhizae (Hayman, 1982).

**Table 1: Characteristics of important kinds of mycorrhizas in their mature state (Harley, 1989).**

<table>
<thead>
<tr>
<th>Character</th>
<th>Kinds of mycorrhiza</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Arbuscular</td>
</tr>
<tr>
<td><strong>Fungi</strong></td>
<td></td>
</tr>
<tr>
<td>Septate</td>
<td>-</td>
</tr>
<tr>
<td>Aseptate</td>
<td>+</td>
</tr>
<tr>
<td>Hyphae enter cells</td>
<td>+</td>
</tr>
<tr>
<td>Fungal sheath</td>
<td>-</td>
</tr>
<tr>
<td>present</td>
<td></td>
</tr>
<tr>
<td>Hartig net formed</td>
<td>-</td>
</tr>
<tr>
<td>Hyphal coils in cells</td>
<td>+</td>
</tr>
<tr>
<td>Haustoria</td>
<td></td>
</tr>
<tr>
<td>Dichotomous</td>
<td>+</td>
</tr>
<tr>
<td>Not dichotomous</td>
<td>-</td>
</tr>
<tr>
<td>Vesicles in cells/tissues</td>
<td>+ or -</td>
</tr>
<tr>
<td><strong>Host Taxon</strong></td>
<td>Bryo,</td>
</tr>
<tr>
<td>Pterido,</td>
<td>Angio</td>
</tr>
<tr>
<td>Gymno,</td>
<td>(Pterido)</td>
</tr>
<tr>
<td>Angio</td>
<td></td>
</tr>
</tbody>
</table>

Legend:
- + = Present
- - = Absent
- ( ) = rare
Arbuscular mycorrhizae belonging to Zygomycetes can be identified by vesicles and arbuscules formation in roots (Abbott and Robson, 1979), dimorphic branching of extramatrical hyphae (Mosse, 1963; Nicolson, 1959) and production of large numbers of chlamydospores and azygospores in the soil. Arbuscular mycorrhiza develop when a hypha from a spore or an already infected root contacts a suitable host root (Powell, 1976). The development of AM fungi in root can be divided into four stages (Tommerup and Briggs, 1988).

a) Spore germination and hyphal growth from infective propagules of AM fungi.

b) Growth of hyphae through soil to host roots. The mycelial system surrounding the roots are dimorphic (Mosse, 1959b; Nicolson, 1967).

c) Penetration and successful initiation of infection in roots. Hyphae penetrates mechanically and enzymatically into cortical cells (Kinden and Brown, 1975). At the point of penetration, hypha may or may not form appressoria (Abbott, 1982).

d) Spread of infection and development of internal hyphal system, arbuscules, which bifurcate inside a cell and bring about nutritional transfer between two symbionts and vesicles which, develop as terminal or intercalary swellings in inter- or intra-cellular hyphae. They are responsible for storage and vegetative reproduction.
The role of AM fungi in phosphorus acquisition of plants has been well documented for more than two decades. In general, most large growth enhancement effects of root infection with mycorrhizal fungi are caused by increases in phosphorus absorption; particularly from sparingly soluble phosphorus sources (Bolan et al., 1987). When root exploration is restricted up to 80% of the plant phosphorus can be delivered by the external Am fungal hyphae to the host plant over a distance of more than 10 cm from the root surface (Li et al., 1991).

Besides this increase in spatial availability of phosphorus, effective phosphorus acquisition by the external hyphae is related to a) formation of polyphosphates in the hyphae, and thus, maintaining low internal phosphate (Pi) concentration (b) the small hyphal diameter leading to a relatively larger soil volume delivering phosphorus per unit surface area compared to the root surface (Jungk and Claassen, 1989) and a correspondingly 2-6 times higher phosphorus influx rate per unit length of hyphae (Jakobsen et al., 1992).

With respect to phosphorus nutrition, the growth response to AM infection depends on soil and plant factors which determine the phosphorus acquisition of the host plant, extent of phosphorus deficiency-induced root response and the phosphorus status of the soil. With increasing soil phosphorus, the growth enhancement effect of AM fungi declines and may either be abolished or lead to growth depressions.
When AM fungi improve phosphorus nutrition of the host plant there may be a corresponding increase in nodulation, nitrogen fixation and growth (Robson et al., 1981). There are numerous reports on the enhancement of K (Bethlenfalvay et al., 1989), Ca (Rhodes and Gerdemann, 1978a) and SO$_4$ –S (Cooper and Tinker, 1978) uptake by AM infection. It also depresses root penetration and larval development of nematode (Sikora, 1978).

Goa is one of the smallest state of India situated along the Central West Coast lying in between Latitudes $15^\circ 48' 00''$ and $14^\circ 43' 54''$ North and Longitude $74^\circ 20'13''$ to $73^\circ 40' 33''$ East (Anonymous, 1979). The Coast of Goa which extends approximately 120 Km in length has beautiful stretches of sandy shores and beaches which attract a large number of tourist from home and abroad. Demands for land, for development put increasing pressure on all land areas particularly those of relatively low agricultural values such as dunes. Many dunes have been used as residential sites – often in connection with the tourism industry. A well planned development of beaches is essential not only for sand dune vegetation but also for an ecfriendly development of tourism and other industries which will indeed be a contribution to the economy of the State.

Recent scientific results provide data which support the hypothesis that arbuscular mycorrhizal plants are effective colonizers of disturbed habitats and the lack of AM fungi exert profound influences on species composition (Tommerup and Abbott, 1981). The understanding of mycorrhizal association in sand dunes
and their distribution in soil is necessary for wise management of disturbed sand
dunes.

Arbuscular mycorrhizal fungi directly mediate interaction between plants in at-least four ways:

a) They allow trees to compete successfully with grasses and herbs for resources and they detoxify allelochemicals produced by these plants as well.

b) They may decrease competitive interactions between the plants and increase the productivity of species mixture, particularly in soil where phosphorus is limiting.

c) The hyphae that link the same and different species act as a route of material transfer among plants.

d) Arbuscular mycorrhizal fungi and other microbes affect soil formation and structural characteristics by producing humic compounds, accelerating decomposition of primary minerals and producing organic glues that bind soil particles into water stable aggregates (Rose, 1988; Varma et al., 1990).

Severing the close links between plant and soil microorganisms has contributed to degradation of many ecosystems. The re-establishment of functional ecosystems presumes knowledge of micro-elements of the system and therefore
they must be studied to understand the ecosystem changes. No effort seems to be directed to isolate and identify the native AM fungi in the sand dune soils of Goa.

The present study is taken up to determine the status of AM fungi in the sand dune vegetation of Goa. The main objectives of the present study are as follows:

1. Survey of coastal sand dune vegetation at different sites in Goa.
2. Determination of colonization of AM fungi in roots and spore density in rhizosphere of dune plants.
3. To study the diversity of the AM fungi in natural and disturbed sites of sand dunes.
4. To find AM fungal diversity in rhizosphere of each host plant species.
5. To determine the seasonal fluctuations in AM fungal colonization, spore density and diversity.
6. Preparation of pure inoculum of AM fungi in association with dune plants.
7. To assess the response of dune plants to arbuscular mycorrhization.