ECOLOGY OF SAND DUNE VEGETATION IN RELATION TO BEACH STABILITY AT MIRAMAR, GOA

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ABSTRACT

About 67 species of plants under 62 genera belonging to 33 natural orders occur in the sand dunes. Observations made at 3 points revealed that the Light House point and Caranzalem beach have a luxuriant dune flora, while Gasper Dias proper is poor in vegetation. Psammophytes help in maintaining the beach stability of Miramar. The rainfall, temperature, wind speed, moisture and humus content of the dunes are responsible for the growth of plants. Erosion provides an adverse effect on the flora and is prevalent in certain parts of the Caranzalem beach. The vegetation in sand dunes is mostly psammophytic and *Ipomea pescaprae* is the most dominant species. The other species present are *Spinifix squarossus* and *Cyperus arenarius* followed by many more.

INTRODUCTION

Miramar is a small beach, about 4.5 km in length and lies between lat. 15°28'N and long. 73°48'E. It extends from the south of Mandovi estuary at Campal to the base of Cabo Raj Hill. It faces the Aguada Bay, which is flanked by rocky cliffs of Cabo Raj and Aguada Hills. Mandovi estuary joins this bay from the north-eastern side (Fig. 1).

The beach vegetation of Miramar has been studied in representative sectors from three observation points on the beach, at Light House, Gasper Dias and Caranzalem. The investigations were carried out with reference to sand dune vegetation and beach stability.

CLIMATOLOGY

Miramar beach of Goa is situated amidst the Ghat region of west coast of India. The important climatological factors of the regions are shown in Fig. 2 and discussed below (Anon, 1966).

Rainfall : This is a region of heavy rainfall. The average annual rainfall is 2611.7 mm, spread over 99.6 rainy days. December to March is a dry period. The rainy season during 1972, started from the last week of May. During the first week of June the rainfall was about 785 mm. In July, it increased to 900 mm. However, from August to October, it ranged from 425 to 120 mm. Thereafter, it decreased considerably (Fig. 2).

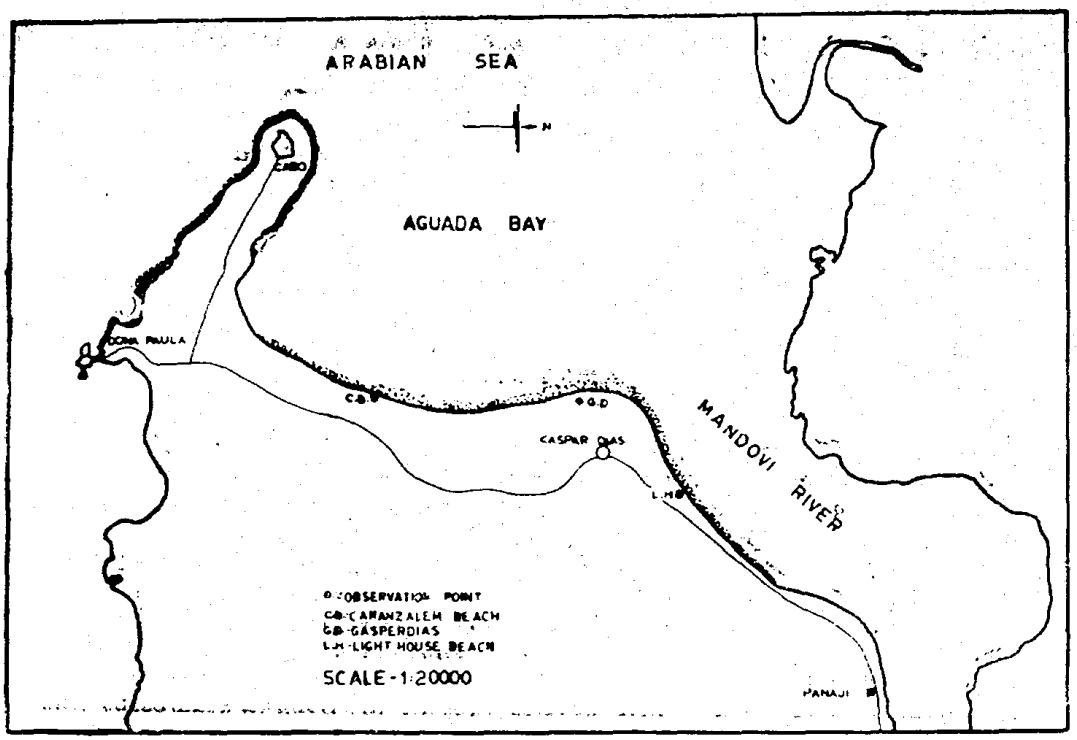

Fig. 1. Miramar beach showing the location of observation points.

During the rainy season, the humidity becomes 76%, while in postmonsoon period it decreases to 73%. In the pre-monsoon period, it goes down further. The total rainfall and its distribution during the year has an important bearing on the sand dune vegetation.

Temperature : Because of the heavy rainfall, the temperature comes down as shown in Fig. 2. It remains almost uniform till October. From December to February there is a decrease in temperature. Normally the range in temperature is from 21°C to 32°C. The highest temperature from this part of Goa was 37.2°C in 1943 and lowest was 12.2°C in 1946 (Fig. 2).

Wind : The average wind speed during January to May varies from 11 to 14 km/h. However, during monsoon season the average wind direction is south-westerly with a velocity of 23 km/h. From October to December when north-east wind starts, the speed remains about 9.5 to 10 km/h (Fig. 2).

PARTICLE SIZE OF THE DUNE SAND

The average diameter of particle size was measured according to the method suggested by Krumbein and Pettijohn (1938) and the results are given in Table I. The range in the values is from 0.110 to 0.290 mm. The Caranzalem dune sand remains almost unchanged during

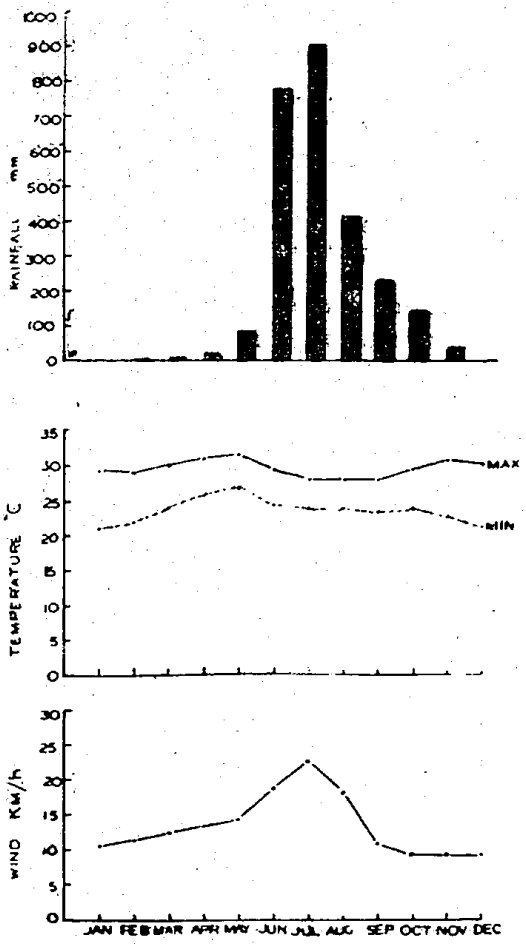

Fig. 2. Variations in the rainfall, temperature and wind during 1968 to 1973 along Goa Coast.

the months February to May (premonsoon) and October to January (postmonsoon). However, the sand deposited during the monsoon months (June to September) was finer. The Miramar Light House and Gasper Dias regions have coarser sand throughout the year.

TABLE I

Average size of sand grains (in mm)

Beach	Pre-monspon	Monsoon	Post-monsoon
Miramar Light House	0.250	0.230	0.220
Gasper Dias	0.190	0.200	0.290
Caranzalem	0.180	0.110	0.180

Just before the onset of monsoon the sedimentation of sand at the Light House and at Gasper Dias is high, because the strong wind brings in sand which gets accumulated at the dune. This helps in the initial accumulation which acts as embryonic dunes and also leads to the destruction of some vegetation at the drift line as seen at Caranzalem beach.

WATER TABLE AND MOISTURE REQUIREMENT

The water content of the sand dune in the backshore was negligible. The free water table at the foreshore regions at all the observations points, was mostly deeper than 100 cm. This part of the beach is affected by the tidal influence as has been indicated from the profile studies at different points (Dwivedi *et al*, 1973). The rainwater generally percolates through the dunes and accumulates over the subsurface deposits. According to Willis *et al.* (1959) this water forms a dome shaped structure several metres below. During the monsoon season, the plants get water primarily from the rainfall and during the dry spells, from the moisture present in the sand. Several studies on

dune communities have shown that the soil moisture is found upto a depth of about 60 cm below the dune surface and then tends to fall off to more constant levels (Salisbury, 1952; Ranwell, 1959). The light rainfall is absorbed and held near the surface by the presence of organic matter as observed by Olson-Seffer (1909).

The germination of seeds and the establishment of seedlings are dependent on the rainfall and the resultant moisture present in the dune (Biswas and Rao, 1953). Only a few species of dune plants, mostly xerophytes, e.g. *Spinifix* sp. and *Ipomea* sp., survive during the summer spell, when the temperature becomes high. The seasonal changes in the surface temperature of the dune are shown in Fig. 3. The values fluctuate between 22.5°C to 36°C.

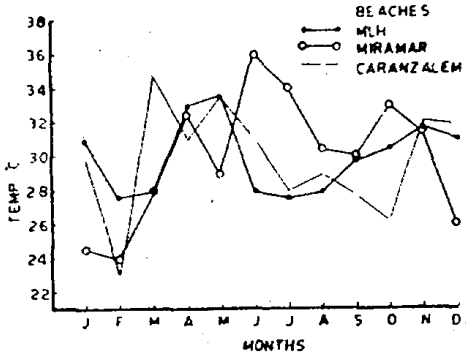

Fig. 3. Seasonal changes in the surface temperature of the dune at Miramar.

The average moisture content at the Light House point was more than that of the other two points. At Caranzalem it was the lowest (Table II). The percentage of humus content at Caranzalem was maximum, while at Gasper Dias, it was minimum (Table II).

TABLE II

Average percentage of moisture and humus

Station	Moisture content	Humus content
Light House point	5.0%	2.5%
Gaspar Dias	3.7%	1.3%
Caranzalem	2.3%	3.7%

Erosion and Accretion : It is evident from the changes in the beach profile that erosion and accretion go on simultaneously at the three points. During the premonsoon, no significant change occur. These beaches get eroded by the onset of monsoon in June. This results in sharp and continuous change in the beach profile (Dwivedi *et al.*, 1973). The changes at Gasper Dias and Light House beaches were not so pronounced as compared to Caranzalem. They follow a definite sequence, i. e., when one beach is in process of building up, the other gets eroded. At Caranzalem, the erosion is pronounced and frequently results in the destruction of coconut palms (Fig. 4 F). Recently at Caranzalem some measures to prevent the erosion have been taken up, by constructing a concrete wall.

Structure of a Typical Transect : Krumbein and Slack (1956) divided the beach into the shore, nearshore, foreshore, backshore and dune regions. The same classification has been adopted here.

Light House point : The sandy shore at this point is approximately 30 m wide. The nearshore bottom which is always submerged does not show the presence of any marine algae.

The foreshore region in this transect, which is alternately submerged and exposed during the high and low tides, is also devoid of any vegetation. The backshore portion of the sandy beach, which is nearly always exposed but occasionally gets submerged during exceptionally high waters shows the dominance of a single species, *Ipomea pes-caprae*. This species is followed by *Cyperus arenarius*, which sometimes forms an association with *Launea pinnatifida* (Fig. 4. – A, B).

The next region, i. e., dune, lies beyond the highest high tide limit and is never underwater. The moisture content of the dune at the surface is very little except during the monsoon season. However, the subsurface region where humus content is more, the quantity of moisture is larger. The temperature of the surface is also higher as compared to the other regions. A very sturdy grass *Spinifix squarossus* grows luxuriantly. It is associated with the species of *Eragrostis* (Fig. 4. C).

Beyond the spinifix community, the dune appears to be more stable, where shrubby plants like *Clerodendron inermae*, *Vitex negandu* and *Duranta plumerii* are present. Adjoining this, is a zone of *Anacardia occidentalis* and *Cocos nucifera*. Intermixed with coconut palms are seen stray plants of a branched palm, *Hyphanae indica*. Some tall trees such as *Tamarindus indica*, are also present (Table III).

2. *Gasper Dias* : The sandy shore of this point has an expanse of approximately 90 to 100 metres and is devoid of any vegetation.

The backshore zone at this point has a thick carpet growths of a creeper *I. pescaprae*, associated with patches of *S. squarossus*, *C. arenarius*, *Amaranthus spinosa*, *Boerhavia diffusa*, *Crotolaria retusa* and *Zornia diphylla*.

Beyond the backshore zone, a 3 to 4 m high and 2 to 3 m wide sand dune is present (Fig. 4. E). This is mostly covered by *I. pes-caprae*, while at the top some grasses like *Eragrostis* sp.,

TABLE III

Floral distribution in different zones of a typical transect

Zone	Dominant species	Associate species
Nearshore	Nil	Nil
Foreshore	Nil	Nil
Backshore	*Ipomea pes-caprae*	*Cyperus arenarius* *Launea pinnatifida*
Dune	*Spinifix squarossus* *Vitex negandu* *Duranta plumerii* *Cocos nucifera* *Anacardium occidentale*	*Eragrostis* sp. *Crotolaria retusa* *Clerodendron inerme* *Casurina* sp. *Jatropha gossypifolia*

Cynodon dactylon and *Dactyloctenium aegypticum* are growing. Beyond this zone is seen the presence of *V. negandu*, *D. plumerii*, *C. inermae* etc., which grow luxuriantly. This dune at some places extends as far as 1 km also, where either paddy cultivation is being done or wild plants continue to grow. The water table in this part of the transect depends on the height of the dune and varies from 2 to 3 m.

3. *Caranzalem :* The nearshore, foreshore and backshore regions are devoid of any vegetation because of constant sand movement. During the last 40 years, the sea at different points has advanced about 40 m towards the land resulting in beach erosion. A laterite wall, which was built 30 to 40 years ago, remains submerged. It however, gets exposed during the lowest low tide. To check further erosion, a new concrete wall has been constructed recently. However, the land beyond the wall, which is also sandy and mixed with humus, is being used for cultivation.

SPECIES DISTRIBUTION

To study the species distribution and diversity, plants from various parts of Miramar beach, were collected. This included the weed flora from the adjoining fields also. It was observed that there are 67 species and 62 genera belonging to 23 families of angiosperms. Gramineae, represented by 15 species seems to be dominant, followed by the Compositae –7 species, and the Papilionaceae – 5 species. Amongst the species available, the herbaceous plants were common. These mostly grow in the backshore and dune region and mainly include psammophytic plants. Shrubs and trees were not abundant.

The species distribution was also studied by quadrant method. A 4 m^2 quadrant was divided in 4 squares of 1 m^2. Of these two opposite squares at

TABLE – IV

Species distribution at the Miramar Beach

Sr. No.	Species	Light House Point		Gasper Dias		Caranzalem	
		I	II	I	II	I	II
1.	*Spinifix squarrous*	–	25	5	–	15	–
2.	*Ageratum* sp.	20	34	–	15	–	–
3.	*Boraria stricta*	60	2	9	4	–	–
4.	*Crotolaria retusa*	4	1	12	78	1	6
5.	*Launia pinnatifida*	10	5	15	–	22	5
6	*Leacus* sp.	–	1	–	–	–	–
7.	*Ipomea pes-caprae*	–	–	3	–	6	8
8.	*Helianthus* sp.	–	–	–	–	1	–
9.	*Cyperus arenarius*	–	–	–	53	–	2
10.	*Dactyloctenium aegypticum*	–	–	–	–	–	41

the corners were studied. From this method it became clear that *S. squarossus* is the most common species followed by *C retusa*, *L. pinnatifida*, *B stricta*, *I. pes caprae*, *Ageratum* sp., *Helianthus* sp., and *D. aegypticum* (Table IV.)

Some of the vascular plants like *Casurina equisettifolia*, *A. occidentalis*, *T. indica* etc., were probably introduced on this beach by outside agencies. It has generally been accepted that the dune flora contains a large element derived from the weed flora of adjoining agricultural fields. The branched palm *Hyphanae indica* was also probably introduced on this beach areas by sea drifted fruits from other areas where they are commonly found.

PROPAGATION AND AVERAGE GROWTH

The capacity of the dune plants to bind sand grains, resulting into the stability of the beach, lies in the ability to perennate and to develop extensive horizontal and vertical root and shoot systems. Propagations from the disintegrated shoots is common and important in reproduction. The elongation of shoot occurs from buried vertical stems in *S. squarossus*, *C. arenarius*, *B. diffusa* and *Boraria stricta*, which grow along the Light House and Gasper Dias beach (Fig. 4. D).

These dune plants which have a highly specialized root and shoot systems, check the erosion caused by wind. However, these species can not withstand the high wave action, particularly in the monsoon resulting in their damage. Once these areas are stabilized and a thick growth is accomplished, there is little danger of erosion.

Laing (1954) and Olson (1958) have shown that the patterns of sand deposition can be determined from the measurements of internodal lengths. Wide spacing of internodes occurs following a rapid deposition of sand during post-monsoon. The root, shoot and internodes of some dune plants were measured from the 10 samples collected of each species. The results of these measurements are as follows :-

1. *Ipomea pes-caprae :* This species has got very long branches creeping over the dune surface. The average length of the tap root varies from 5 to 8 m. The length of the creeping branches also varies in different plants depending upon the age of the plant and the conditions to which they are exposed. The average length of the shoot was 4.29 m at this beach. The shoot systems spread in all directions. At regular intervals, two rootlets develop at the node; they give mechanical strength to the creeper and help in binding the sand. The average length of the internodes was found to be 10.3 cm, while the rootlets were of 35.95 cm in length.

2. *Spinifix squarossus :* Like the other members of the dune vegetation, *S. squarossus* also shows a similar tendency of growth. The average length of the main rhizome is about 15 to 20 cm, while the lenght of rootlets at nodes is about 28.5 cm. On the other hand, shoot attains the average height of 72.1 cm. The distance between the nodes was observed to be 6.7 cm (Fig. 4 C).

3. *Launea pinnatifida* : The tap root of this species goes upto a depth of 50 cm. The shoot portion develops into many branches, which creep over the

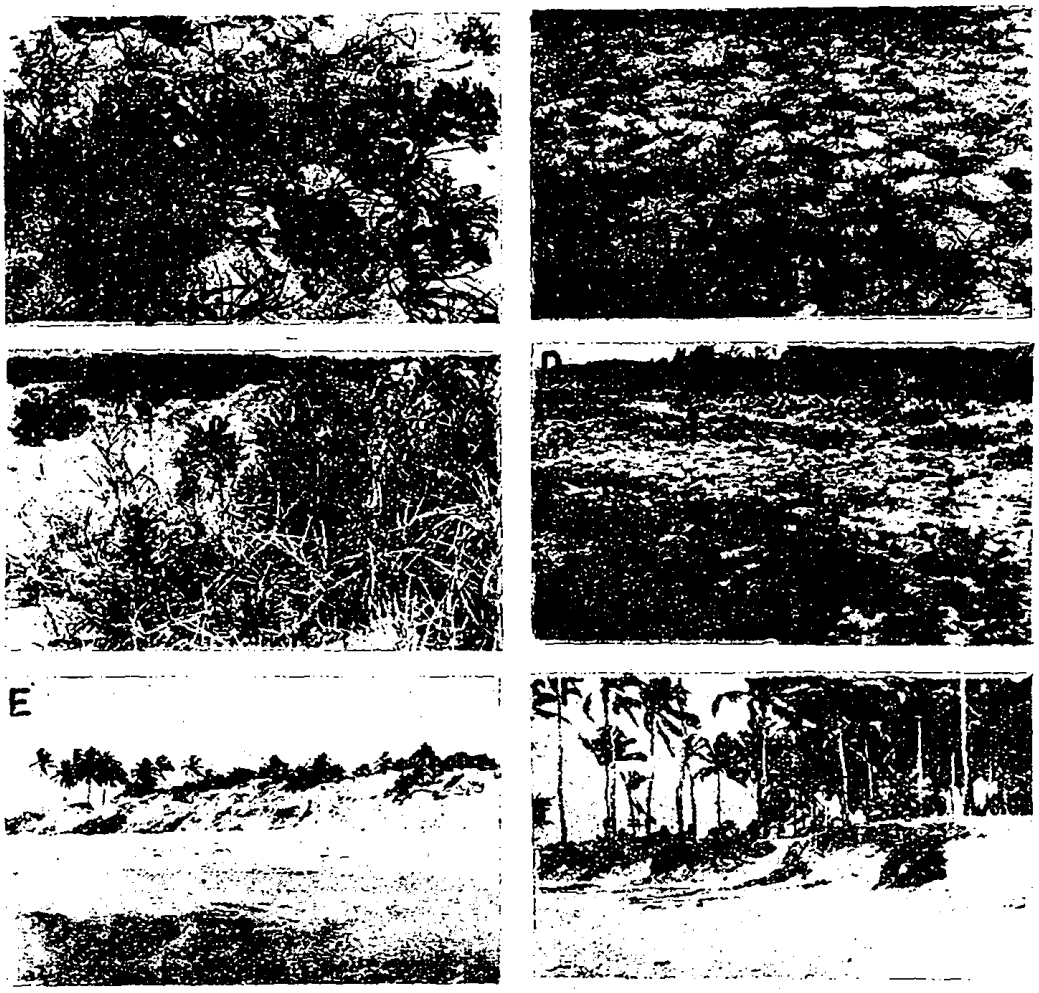

Fig. 4.

A. An association of *I. pes-caprae* and *C. arenarius* on Miramar beach (top left)

B. *Cyperus arenarius* growth at Light House Point (top right)

C. A view of *Spinifix squarossus* on Miramar beach (middle left)

D. General view of the beach showing different zones of *I. pes-caprae*, *C. arenarius*, *S. squarossus* and at the back *Casurina* plantation (middle right)

E. A view of a sand dune at Miramar (bottom left)

F. Erosion of coconut plantation at Caranzalem beach (bottom right)

TABLE V

Average growth of root, shoot and internodes of sand dune flora

(Values in cm)

Name of plant	Root	Shoot	Internodes
Spinifix squarossus	28.50	72.1	6.7
Ipomea pes-caprae	35.95	4290.0	10.3
Launea pinnatifida	8.25	1900.0	9.85
Cyperus arenarius	3.05	32.1	4.55
Boraria stricta	29·40	29.6	3.50
Ageratum sp.	13.50	24.4	–
Crotalaria retusa	27.50	61.5	–

dune surface. At every node there is a rhizoidal growth for giving mechanical strength to the plant. The average length of these rootlets is about 8.25 cm, while the shoot is very dwarf, about 1.90 cm in height. The average length of the internodes is 9.5 cm.

Similarly, the root, shoot and the internodal distances were measured of the other species like *C. arenarius*, *B. stricta*, *Ageratum* sp. and *Crotolaria retusa* etc., and these have been shown in Table V.

EFFECT OF ENVIRONMENTAL PARAMETERS

The environment directly and indirectly controls the distribution and abundance of vegetation along the different parts of the beaches. Some of the environmental parameters have been discussed below.

1. *Tidal influence :* The intertidal region of the Miramar beach is totally devoid of any vegetation. During the monsoon, because of strong tidal waves the beach gets eroded alongwith its floral elements. During postmonsoon and premonsoon period, when the sea is usually calm, some stray marine algae like *Enteromorpha* and *Ulva* grow on the rocks submerged in this region. Because of the tides, many drifted seeds and fruits come to the shore and establish there after germination, if the conditions are favourable.

2. *Temperature* : As noted earlier, the air temperature of Miramar beach ranges from 29°C to 32°C. However, the surface temperature of the dune may sometimes increase upto 36°C. Species like *I. pes-caprae* and *S. squarossus* can withstand high temperature, while many other plants die of scorching heat on the sand dunes. Ranwell (1972) stated that the annual plants of the sandy beaches tend to pass through the hot summer as seeds and then begin to grow in cooler months. At Miramar beach also a high rate of germination was found during the monsoon months. Temperature was higher on the barren sand dunes than beneath the vegetation. Salisbury (1934) also observed similar

differences in the temperature distribution.

3. *Rainfall*: This factor has a direct influence on the germination of seeds. It was observed that most of the seeds, which are drifted on the beach, germinate during the monsoon, while in other seasons, if the conditions are favourable, they may continue to grow or may die, when the conditions are adverse.

4. *Wind:* The growth of the dune plants is profoundly influenced by the wind, which helps in the redistribution of organic and inorganic nutrients, propugules and affect the ground on which the plants grow. Seeds and fruits of the dune plants are carried away by the wind to distant places. The wind also helps in the formation of embryonic dunes. However, during the period, when strong wind blows, the sand moves rapidly in the same direction and the plants lose their hold in the dune and are swept away. They may also get buried under the sand (Chapman, 1964).

Thus the sand dune vegetation plays an important role in the stability of the beaches. Initially the vegetation may be influenced more by the various factors, however, once the dense growth is attained, the beach may be saved from erosion.

The long branched creepers in the foreshore, herbacious species in the backshore, bushy plants in the dune region and tall trees like *Casurina equisettifolia* at the end create the proper environment for beach stability.

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