INTRODUCTION

India has a coastline exceeding 5,000 kilometres in length and a number of important deltas. Among the littoral and estuarine vegetation types, the mangroves present a double interest - economic and scientific. Their study was undertaken at the French Institute, Pondichery, in 1971.

Studies on vegetation usually include two major aspects, namely, the flora and the plant communities. Our knowledge of the Indian coastal plant communities to date is mainly based on systematics. No comprehensive ecological account of the coastal terrestrial communities has yet been published. In other countries certain attempts have been made on the classification of coastal communities. Hemming (1961) has described the vegetation of the Northern Eritrean coast, primarily on a geomorphological basis with pedological sub-divisions. Vesey-Fitzgerald (1955-1957) has described the vegetation of the Red Sea Coast to the north and south of Jedda in Saudi Arabia in a range of plant communities each associated with important variations of soil and drainage pattern.

The vegetation and flora of the Indian coastline have not been discussed in their proper perspective although frequent references on the occurrence of sea-shore plants find place in several floras and papers, since the time of the publication of the Flora of British India. The coastal region which comprises diverse ecosystems presents very interesting aspects for ecological, physiological, taxonomical and phytogeographical studies.

In recent years pressure on the coastal zone for recreational purposes has increased dramatically. Reacting to this pressure, conservationists, ecologists and watermen have effectively communicated to legislators the importance of these natural areas to the economic and ecological balance in the coastal zone.

The coastal flora is well known from a long time. The more eminent botanists of the nineteenth century who devoted their interest to the flora of the Gangetic delta are Roxburgh (1814), Clarke (1896), Prain (1903); Griffith (1836, 1851) and a forester Heinig also contributed to the complex problem of the biology of the mangroves and their seedlings. But it was only in 1905, that Blatter published his studies on the halophytic vegetation of the Bombay region.

The few ecological investigations on coastal plant communities are from the coasts of Trinnavelly (Fyson, 1919), Dwarka (Borgesen, 1929), Bombay (Satyanarayana, 1958), Konkan (Jain, 1962), Kanyakumari Dist. (Lawrence, 1960). Recently attention has also been given to ecological studies of Saurashtra coast (Rao *et al.*, 1967, 1968, 1971, 1974) and neighbouring islands (Rao *et al.*,1964, 1966).

In India, Bharucha (1942) for the first time initiated studies in the ecology of mangroves and along with Navalkar (1950) carried out detailed investigations on the influence of pH, Osmotic pressure, Salinity and other soil factors on *Avicennia alba* Blume, the dominant species of the Bombay coasts.

In recent years, Venkateswarulu (1944), Rao (1959), Raju (1968), Rao *et al.* (1972, 1974), have contributed much to our knowledge on the coastal flora of Andhra region.

With a view to contribute to our knowledge of the Coastal Vegetation of India in general and of Gujarat State in particular, the author undertook the preparation of the Floristic and Vegetational Studies of Gujarat coast. There are a few scattered papers on the Vegetation and Flora of different regions of Gujarat published in various journals. P. S. Toor (1958) studied the coastline of Gujarat for the first time but his work is too sketchy and incomplete. However, there is not a single work which can be looked upon as a representative coastal flora of this region of Gujarat State i.e. from Khambat to Umargam.

The present thesis mainly deals with an account of the flora and vegetation of the coastal areas of Gujarat, covering a major part from Khambat to Umargam.

We do not claim that our work is without any deficiency. We are totally aware of its shortcomings. But we do wish that the present work will prove helpful to other botanists in the field.

GEOGRAPHY OF THE GUJARAT COAST

The State of Gujarat is situated on the west coast of India, between 20° 1' and 24° 7' north latitudes and 68° 4' and 74° 4' east longitudes. Its boundaries are defined by Arabian Sea on the west, the State of Rajasthan on the north east, Madhya Pradesh on the east and Maharashtra on the south-east and south. On the north western fringe it has a common frontier with Pakistan.

An important feature of the State is its long coastline, probably the longest as compared to any other Indian State, that has an economy and social organization of the people.

The recent discovery and exploitation of petroleum in the coastal areas of the State have greatly added to the resources of the State.

The whole of the Gujarat coast from the head of the Gulf of Khambat to Valsad is irregular in its outline broken by the estuaries of the Mahi, the Narmada, the Kim and the Tapi and remarkably featureless with a slope perceptible only in the flow of the rivers.

The coast of Gujarat, with exception of south Saurashtra, is generally characterized by tidal flats and saline wastes. The Gulf of Khambat coast is very irregular in its outline, projecting deeply inland and has thus offered sites for the estuarine ports of Gujarat during pre-navigation days. The Gulf is enclosed on all sides by marshy coasts and dotted with bars and islands locally called "bets". Such "bets" occur in the mouth of the rivers Sabarmati, Mahi, Narmada and Tapi.

The entire coast is straddled by tidal flats which widens to as much as 10 Km and occasionally have a width of 16 Km along a creek. The tidal flat is submerged under water at the time of high tide or very poorly drained even if it is above the high-water level. These saline marshes locally called "Kharlands" are unsuitable for cultivation in their present state.

Valsad is the largest port of south Gujarat. Being almost on the sea-shore, it handles about 100,000 tons of Cargo every year. The importance of Surat and Billimora as ports is much less as compared to Valsad and they handle only about 15,000 tons of Cargo each.

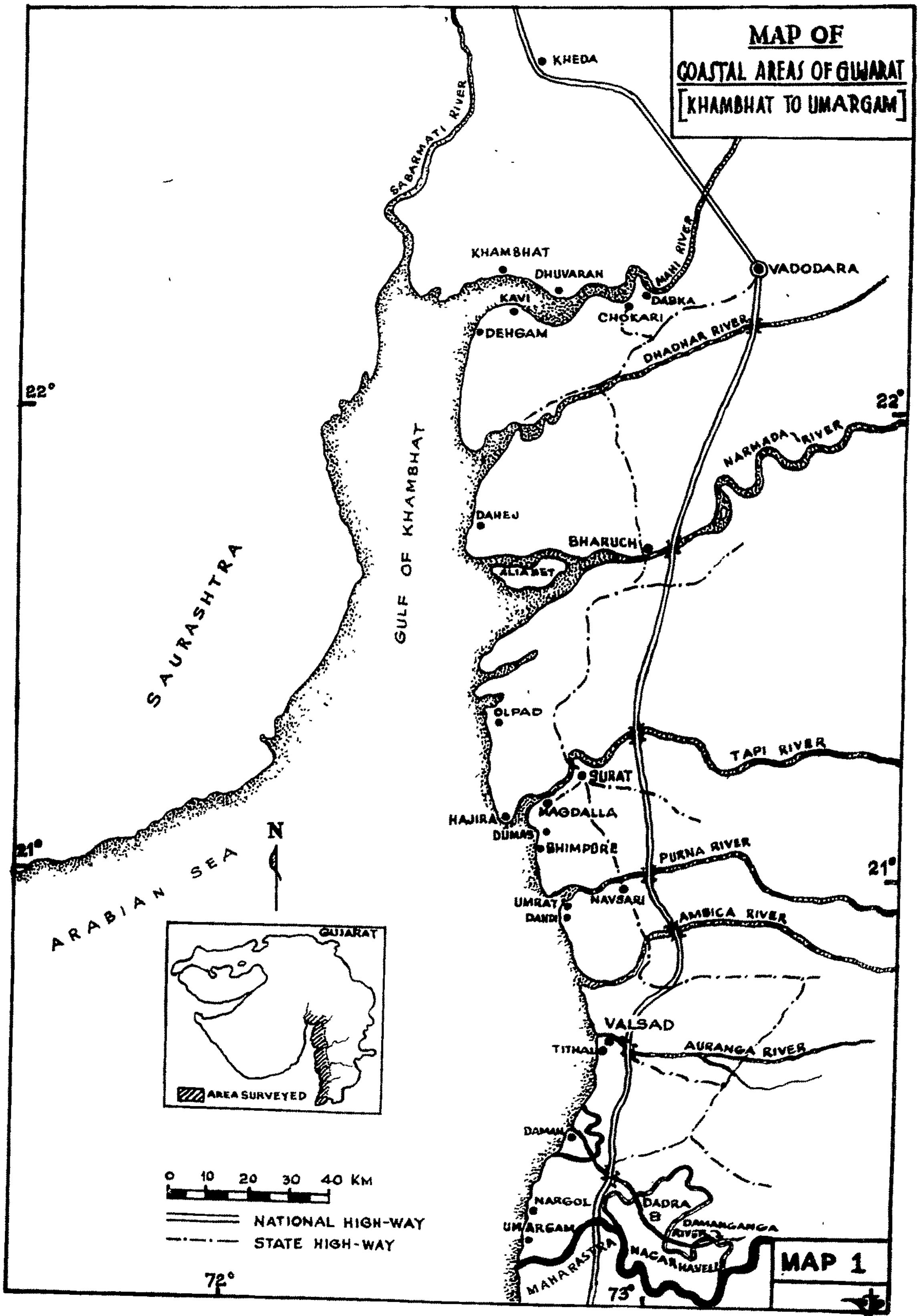
In its development, the coastal area of south Gujarat has certain advantages over the coasts of Saurashtra, Kutch or even north Gujarat. Because of higher rainfall and availability of fresh water, there is a fair possibility of reclamation of coastal saline wastes. The development of beach resorts is more likely in this part because of less vigorous weather conditions during summer. Being close to important centres of population, the coast has developed some holiday camps like Dumas and Hajira near Surat and Umrat about 15 Km west of Navsari.

Poor soil, bad drainage and marginal agricultural productivity with hardly any industrial development explain the low population density in the coastal areas.

The region with its extensive flatland holds out a promise for the future, provided the Kharlands are reclaimed, irrigation facilities are made available, drainage is improved and an efficient network of thorough fares laid.

DESCRIPTION OF THE AREA

Coastal Gujarat approximately occupies one-third of the Peninsular India, along the west coast. Gujarat coast from Khambat to Umargam runs into about 600 Kilometres. The area surveyed in the present work lies between



MAP OF
COASTAL AREAS OF GUJARAT
[KHAMBHAT TO UMARGAM]
KHEDA
SABARMATI RIVER
MAHI RIVER
VADODARA
KHAMBHAT
DHUVARAN
KAVI
DABKA
CHOKARI
DEHGAM
DHADHAR RIVER
22°
NARMADA RIVER
GULF OF KHAMBHAT
SAURASHTRA
DAHEJ
BHARUCH
ALIA BET
OLPAD
TAPI RIVER
SURAT
HAJIRA
MAGDALLA
DUMAS
BHIMPORE
PURNA RIVER
21°
N
ARABIAN SEA
UMRAT
NAVSARI
DANDI
AMBICA RIVER
GUJARAT
AREA SURVEYED
VALSAD
TITHAL
AURANGA RIVER
DAMAN
0 10 20 30 40 KM
NARGOL
DADRA
&
UMARGAM
DAMANGANGA RIVER
NATIONAL HIGH-WAY
STATE HIGH-WAY
MAHARASTRA
NAGAR HAVELI
72°
73°
MAP 1

20° 17' N and 22° 17' N latitudes and almost on 72° 30' E longitude.

The areas surveyed form a part of the Kheda District, Vadodara District, Bharuch District, Surat District and Valsad District.

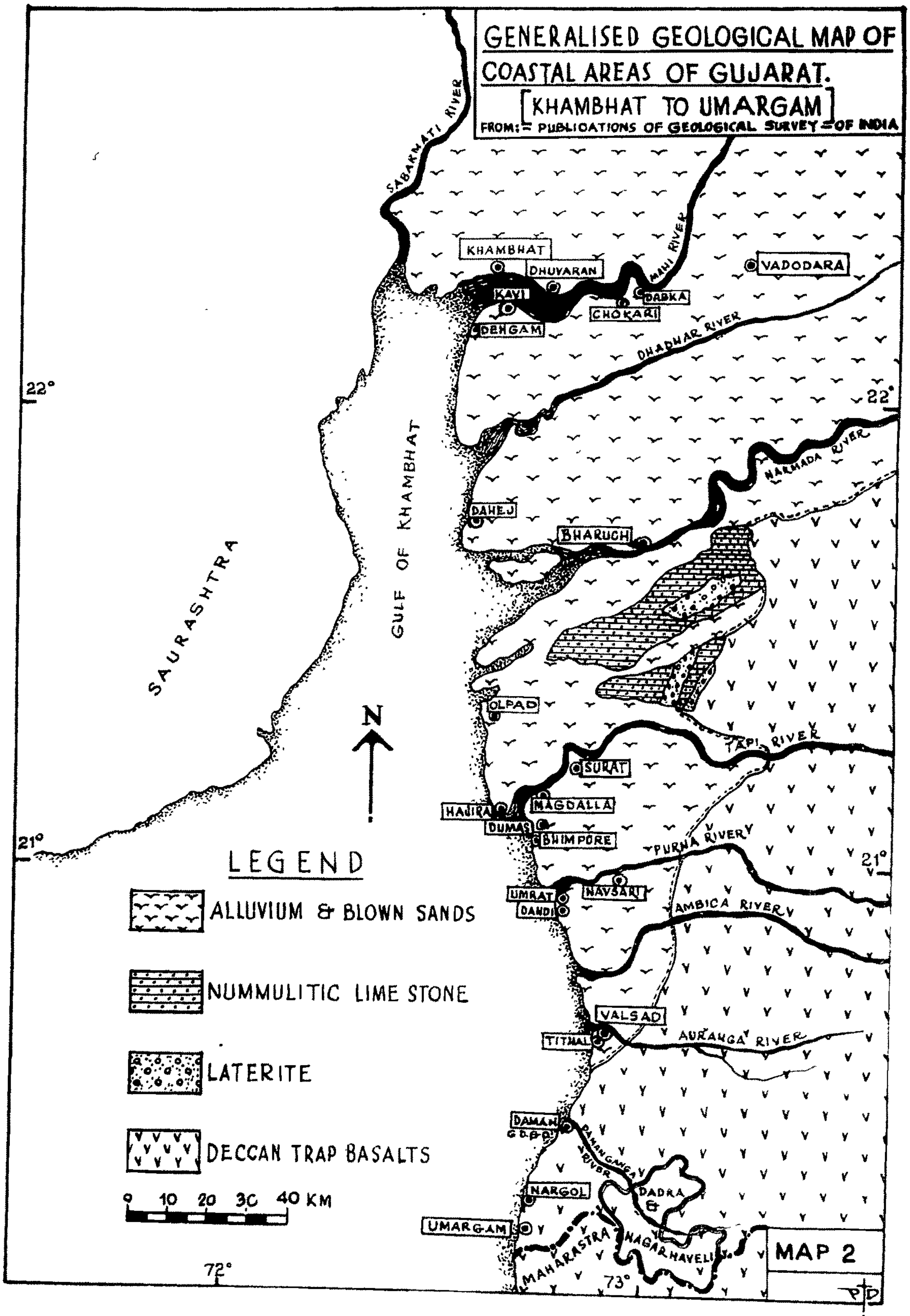
The shore relief about 5 Km interior from the coast has been surveyed with particular reference to Khambat, Chokari, Kavi, Dhuvaran (Mahi estuary), Dahej, Olpad, Dumas, Hajira, Magdalla, Bhimpore, Umrat, Dandi, Tithal, Mehdungri, Daman, Nargol, Umargam and their adjoining regions for botanical collections and ecological observations (Map 1).

The area is approachable by railway from Vadodara to Bharuch, Surat, Navsari, Valsad as well as by regularly running State Transport buses from Vadodara but the coastal areas from Bharuch, Surat, Navsari and Valsad are approachable by State Transport buses only.

Interior parts of the coastal area are not approachable during monsoon as buses are suspended in these areas because of 'Kaccha' roads.

GEOLOGY

Geologically, the study area comprises deposits of


GENERALISED GEOLOGICAL MAP OF COASTAL AREAS OF GUJARAT.
[KHAMBHAT TO UMARGAM]
FROM:- PUBLICATIONS OF GEOLOGICAL SURVEY OF INDIA
SABARMATI RIVER
KHAMBHAT
DHUVARAN
MAHI RIVER
VADODARA
KAVI
DABKA
CHOKARI
DEHGAM
DHADHAR RIVER
22°
GULF OF KHAMBHAT
SAURASHTRA
NARMADA RIVER
DAHEJ
BHARUCH
OLPAD
N
TAPI RIVER
SURAT
HAJIRA
MAGDALLA
DUMAS
BHIMPORE
21°
PURNA RIVER
UMRAT
NAVSARI
DANDI
AMBICA RIVER
VALSAD
TITHAL
AURANGA RIVER
DAMAN
DAMANGANGA RIVER
NARGOL
DADRA &
UMARGAM
MAHARASTRA
NAGAR HAVELI
73°
72°
MAP 2
LEGEND
ALLUVIUM & BLOWN SANDS
NUMMULITIC LIME STONE
LATERITE
DECCAN TRAP BASALTS
0 10 20 30 40 KM

Tertiary and Quaternary age. These sediments lie over the very ancient peninsular massif of Archaean rocks in the norther part; whereas the deposits in the southern part are underlain by the Deccan trap basalts of Eocene-cretaceous age. The coastal alluvium forms a belt along the west coast in Bharuch, Surat and Valsad districts, in south Gujarat. Some portion of the alluvium deposited along the coast is contributed by the deltaic sediments brought in by the rivers like Narmada, Tapi and Mahi.

The coastal deposits in some areas like Khambat comprise brine saturated salt deposits.

The generalised stratigraphy of the study area is as follows :

Time Stratigraphic Unit	Lithology
Recent and subrecent	Alluvium and Blown sands
Pleistocene	Conglomerate
Miocene	Ferruginous sandstone
Eocene	Nummulitic limestone
Paleocene	Laterite
Cretaceous	Deccan Trap basalts

The above stratigraphic units are described below, beginning with oldest :

Deccan Trap : These basalts cover a considerable portion of the interior parts of Surat, Navsari and Valsad. The rocks are exposed in the beds of rivers Tapi, Purna, Ambika and Daman-Ganga. They are found nearer the coast at Daman, Nargol and Umargam. In east of Valsad District they have high ridges and deep valleys trending in north-south direction. Towards west, they lose elevation and merge into alluvium. The lava flows are of "Pahoehoe", "Aa" and intermediate types having massive as well as vesicular varieties. Joining and spheroidal weathering are common features with them. Several dykes of dolerite have cut across the traps.

Important rock types of Deccan Trap are basalt and agglomerate. All these rocks are of volcanic origin.

Laterites : The laterites are found in the vicinity of Deccan Trap basalts. They are situated in Bharuch and Surat districts. These rocks are red brown in colour and have vesicular structure.

Nummulitic limestone : These rocks are found in the Bharuch and Surat districts. They are yellow to yellow brown limestones which are highly fossiliferous. The fossils are mainly foraminifers. The rocks are flaggy in nature and are used as building stones.

Ferruginous sandstone : These rocks are also found in Bharuch and Surat. districts. They are red brown in colour due to presence of iron oxides.

Conglomerates : These sedimentary rocks are found in Bharuch and Surat districts. They are grey in colour. They contain pebbles of agate and other silica minerals. The agate is used as semi-precious stone.

Alluvium and blown sands : Most of the Kheda district is covered with alluvium which has got an immense thickness comprising sand, clays and calcareous kankar. The alluvial soil is covered with brown sand forming sand sheets, dunes and mounds. The older alluvium which constitutes sand, silt, clay and kankar has been deposited and weathered during the whole length of Quaternary period. This is covered by younger alluvium and different types of soil in the Vadodara district. The overlying alluvium at the top is called older alluvium because of its antiquity. This is highly weathered forming lime kankar, calc-crusts etc. at Bharuch, Dahej, along the coast and at places, there are a few blown sand pockets also.

The level of ground water in the coastal strip known as "bara" is near the surface but it is mostly brackish. The younger alluvium is mostly confined to the proximity to streams and is very fertile. Blown sandunes are abundant in the coastal zone whereas the fluviomarine mud and other deposits abound the tidal flats and estuarines.

For the most part, the soil-cover is alluvial, and formed out of the material deposited by rivers and their tributaries. Atmospheric weathering and action of strong winds have to a certain extent affected the alluvial deposits with residual weathering products and wind borne material. As a result the existing soil cover is a mixed one formed of either black soils or else pale brown loam and sand.

SOIL

The soil is a heterogencous, polydisperse system of solid, liquid and gaseous components in various proportions.

Saline soils occur along sea coast because of tidal action or the presence of saline ground water.

Salt may influence soils in many ways.

Saline soils include soils containing soluble salts in quantities sufficient to interfere with the growth of most crop plants but not containing enough exchangeable sodium to alter soil characteristics appreciably.

Saline is used in connection with soils for which the conductivity of the saturation extract is more than 4 mmhos/cm at 25°C and the exchangeable sodium percentage is less than 15. Ordinarily the pH is less than 8.5. When adequate drainage is established, the excessive soluble salts may be removed by leaching and they again become normal soils.

Saline soils are often recognized by the presence of white crusts of salts on the surface. Soil salinity may occur in soils having distinctly developed profile characteristics or in undifferentiated soil material such as alluvium.

The chemical characteristics of soils classed as saline are mainly determined by the kinds and amounts of salts present. The amount of soluble salts present controls the osmotic pressure of the soil solution. Soluble and exchangeable potassium are ordinarily minor constituents but occasionally they may be major constituents. The chief anions are chloride, sulfate and sometimes nitrate. Small amounts of bicarbonate may occur, but soluble carbonates are almost invariably absent. In addition to the readily soluble salts, saline soils may contain salts of low solubility, such as calcium sulfate (gypsum) and carbonates of calcium and magnesium.

Owing to the presence of excess salts and the absence of significant amounts of exchangeable sodium, saline soils generally are flocculated, and as a consequence, the permeability is equal to or higher than that of similar non-saline soils.

Soil is also not suitable for crop cultivation due to high salinity. It may be only possible to irrigate soil with fresh water continuously for cultivation purpose.

The salinity of the maritime salt marsh soil (a saline soil) is dependent upon a number of factors. These were first fully enunciated by Morss (1927) and are as follows :

a) Height of the preceding tide : This determines whether the marsh has been flooded or not, it is also the most recent determinant of the soil water table.

b) Rainfall : This will be responsible for downward leaching of salt in the upper layers of the soil.

c) The height of the marsh in relation to sea level : Lower marshes are flooded more frequently than upper marshes, but in the former, the continual influx of the sea will maintain a more or less steady saline content, whilst in the case of higher marshes the long periods of continuous (non-tidal) exposure, especially in summer will result in evaporation and an increased salt concentration.

d) Proximity to creeks : Where the drainage is good the soil water drains away readily and there will not be such a great increase in salt concentration during periods of continuous (non-tidal) exposure.

e) Nature of the soil : A marsh built of a fine silty mud is likely to retain more salt than one having a high proportion of sand.

f) The presence or absence of vegetation : The presence of plants brings about a continual rise in the soil water and they also reduce the rate of evaporation from the soil surface. Bare soils always attain a higher salt concentration in summer than vegetation-covered marsh.

g) Inclination of the ground : The greater the slope, the more rapidly the salt water drains off.

h) Distance of marsh from the sea in relation to inflow of fresh water.

i) Depth of soil water table : The nearer this is to the surface, the more constant will be the soil salinity.

In the case of inland saline soils factors (b), (d), (e), (f), (g) and (i) will be operative, while the following additional factors have to be considered :

j) Depth of sub-surface salt deposits : the greater the depth, the less saline will be the surface layers.

k) Inflow of streams into the area : The streams may bring salt with them or they may dilute the salt water already in the basin.

1) Temperature climate : This exerts a much more profound effect in places where the ground is not regularly submerged.

There is a correlation between the vegetation zones on a maritime marsh and variations in salinity.

Salinity is one of the important factors operating in salt marshes, though it probably operates as either the sodium or the chloride ion. It is, however, itself affected by the tidal factor (which can be regarded as the master factor), rainfall, type of vegetation and soil. Thus salinity tends to be higher in loams than in sands.

The variations in the salinity levels were observed from patch to patch in the saline ecozone. The electrical conductivity of the soil sample was measured to get an idea of the range of variation in the salinity gradient. The electrical conductivity measurements lead to the conclusion that salinity level (Table I) fluctuates to a considerable extent. It was found that the lowest values were recorded in rainy season due to leaching and flushing of salts while the summer values were quite high. In winter although the level of salinity was quite high in some patches (Table II).

Soil samples were collected from different habitats along the coast line and analysed in the laboratory for their physical properties such as mechanical composition,

Table II. Seasonal variations in salinity gradient of the soil samples in different saline areas.

Location	EC : Millimhos/Cm (Season)		
	Rainy	Winter	Summer
Khambhat	7.12	11.75	15.52
Chokari	2.30	4.63	8.46
Kavi	3.94	7.13	9.87
Dhuvaran	1.64	3.46	5.64
Dahej	4.92	8.66	11.28
Dumas	2.07	5.71	9.32
Hajira	5.06	8.61	11.39
Tithal	2.55	4.32	8.39

organic matter content, Bicarbonates, Moisture holding capacity etc. and chemical properties such as Electrical Conductivity, pH, Total soluble salts, chloride, calcium carbonate, permeability etc. to study the vegetation in relation to soils, following the methods of Jackson (1967).

A reference to Table I will show that the texture of soils, which have been analysed for mechanical composition, is sand to loamy sand.

pH values of all the soils from this ecosystem exhibit moderate alkalinity.

Organic matter contents depending on the intensity and nature of the vegetation range between 0.02 and 0.14 per cent in the sandy strand habitat. Values of total soluble salts and sodium chloride contents point to the effect of salt spray but not to direct inundation with sea water.

The calcium carbonate content of the soils of this habitat is high.

The above data shows that there is not appreciable difference in the characteristics of sand under different plant communities of this habitat.

The soil from the inland sandy plain is different from the sand of the beach habitat. It is light brown with blackish tinge in colour. The surface soil is loamy sand. Soils at the surface and upto 30 cm depth were absolutely dry but after that they were found to be a little moist.

Soils from the salt pans are sandy loam, loam or silt loam with mild alkalinity. Their organic matter contents are much higher than the soils from the strand habitat. Dissolved solids and sodium chloride contents are very high as the result of direct influence of sea-water. All the soils are highly calcareous. (Table III).

The surface soils of the estuarine banks are moderately alkaline, calcareous, moderately fine textured, clay loam to clay with the highest organic matter content in the entire estuarine ecosystem (Table IV). They are practically unripe soils with extremely loose consistency and are supersaturated with saline water. Slightly upland from the estuarine shore but within the estuarine influence, the shallow wet land is characterised by extremely saline unripe soils of clay loam to clay texture with very low organic matter content. These areas are under the inclements of physical hazards of wind and tidal action and are almost devoid of vegetation.

Edaphic characters fluctuate with increasing distance from the estuarine shore and there is a change in the vegetation pattern in the form of a graded seral covering.

Table III. Analysis of Soil Samples collected within Salt Pans (0 - 20 cm. depth).

Soil Colour	Mechanical Composition			Soil texture	pH	Organic Matter %	TSS %	$CaCO_3$ %	CO_3 %	HCO_3%	Ec Milli mhos/cm
	Clay %	Silt %	Sand %								
Grey	28.2	62.7	9.1	Silty clay loam	7.7	1.86	0.99	14.0	0.0024	0.02	15.52
Greyish	33.5	50.5	16.1	Silty clay loam	8.1	1.90	1.62	17.5	0.0024	0.01	25.38
Blackish	21.8	39.8	38.2	Silty loam	8.3	0.80	0.72	15.0	0.0048	0.04	11.28
Blackish	23.5	38.3	39.3	Silty loam	8.1	1.50	0.99	11.0	0.0048	0.03	15.51

Table IV. Analysis of the soil samples collected within Estuarine zone of the Mahi River.

Soil Colour	Mechanical Composition			Soil Texture	pH	Organic Matter %	TSS %	$CaCO_3$ %	CO_3 %	HCO_3 %	Ec Milli mhos/cm
	Clay %	Silt %	Sand %								
Brown (granular)	28.0	42.0	30.0	Silty clay loam	7.8	0.79	0.54	17.5	0.0024	0.044	8.46
Brown (light granular)	18.4	77.2	4.4	silty	7.9	0.41	0.63	11.0	-	0.021	9.87
Dark brown	27.8	67.6	4.6	Silty clay loam	8.2	0.38	0.31	9.0	0.0024	0.026	4.70
Dark brown	19.7	45.4	34.9	Silty loam	8.1	0.53	0.36	17.0	0.0024	0.029	5.64

Tufts of *Suaeda's* alternate with extensive occurrence of whitish salt pans devoid of any vegetation, except for the occurrence of patches of *Aeluropus lagopoides*.

The paucity of vegetation is in confirmity with the increased salinity due to excess of total soluble salts and comparative aridity.

There is a significant increase in the number of plant species in the intertidal zone, probably due to the prevalence of less severe hazards of salinity and loamy substratum.

CLIMATE

Climate is markedly periodic and is characterised by a comparatively brief monsoon (July - September) followed by winter (November - February) gradually leading to dry summer (March - June). Temperature, Relative Humidity and Rainfall are the three most important climatic factors which have a considerable influence on the vegetation.

Climatic factors of overwhelming dominance in determining the vegetation of coastal areas are, the moderating influence of the ocean, the strong and prevailing winds coming from the Gulf of Khambhat and a continual moisture excess.

The temperature, relative humidity and rainfall in respect of four stations : Chokari (Baroda), Surat, Valsad and Daman are represented in the tables and graphs.

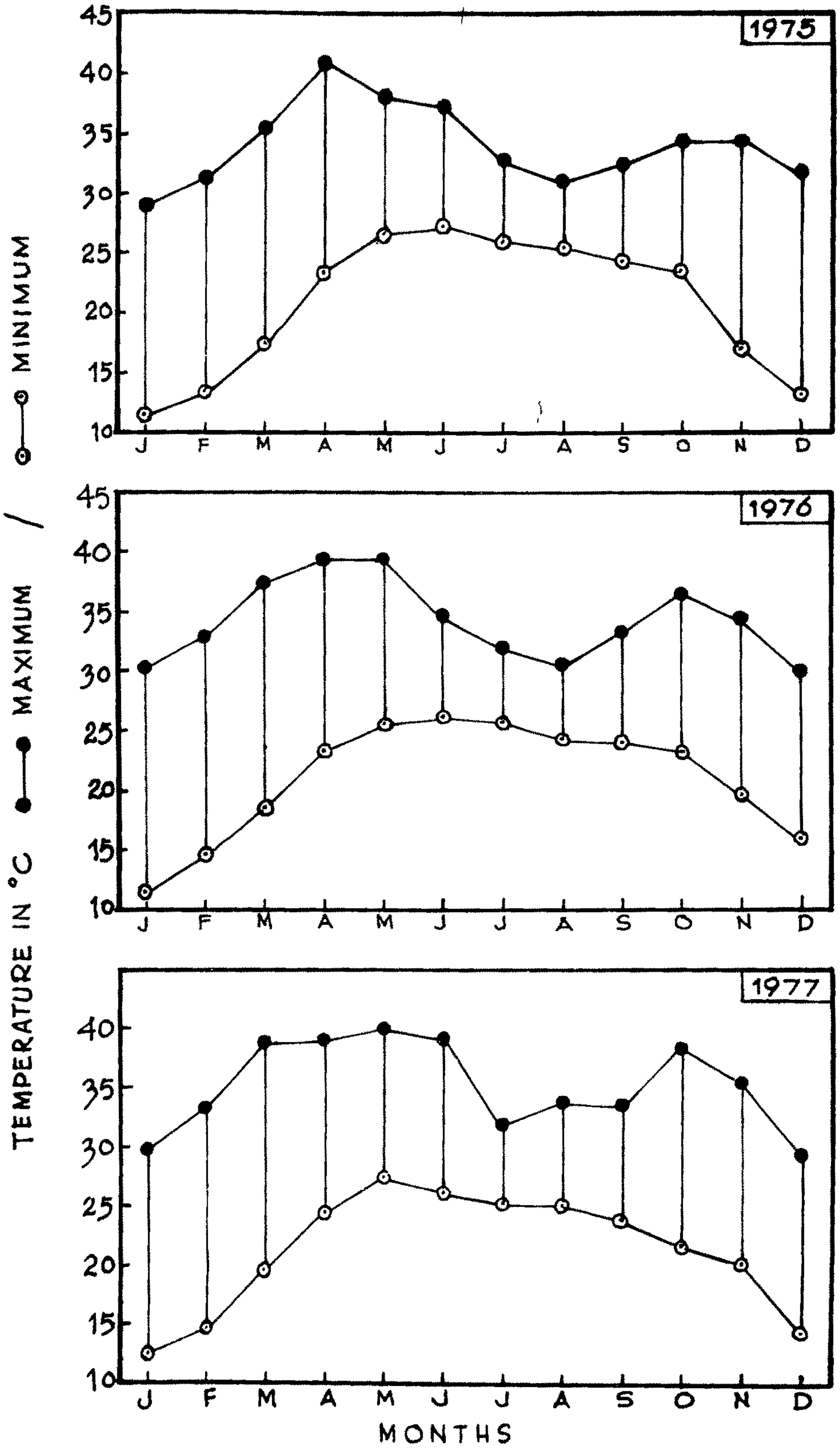
To sum up, the climate is harsh and imposes many limitations on the plant communities perched along the sandy areas. Its effect in, inshore water logged areas under the influence of the tides however, is not very much significant.

Temperature conditions : The maximum temperature in the year occurs in May when temperatures as high as 45°C are recorded in some parts of the state. A large part of the state, in this month, lies between 35° and 42.5°C isotherms. The temperatures are lowest along the coastal areas showing obviously the maritime influences which modify considerably the summer distribution of temperature. The sea breezes penetrate 30 to 40 Km inland lowering not only the temperature but also its range.

The maximum temperature in January does not exceed 30°C. The isotherms are east-west and the temperature increases steadily as one moves southwards. The only part of the state experiencing temperatures higher than 30°C in January is the Narmada-Tapi doab. The low altitude of the area, the penetration of sea breezes along the river valleys, and a considerable growth of vegetation have

Table V. Temperature (Monthly Mean) At CHOKARI.

Month	1975		1976		1977		1975-1977	
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
	°C	°C	°C	°C	°C	°C	°C	°C
January	29.20	11.40	30.21	11.511	29.61	12.51	29.6	11.8
February	31.30	13.30	32.90	14.60	33.20	14.90	32.4	14.2
March	35.61	17.41	37.61	18.51	38.91	19.61	37.3	18.5
April	40.91	23.61	39.13	23.22	39.03	24.52	39.6	23.7
May	38.11	26.81	39.21	25.63	40.01	27.53	39.1	26.6
June	37.41	27.21	34.51	26.11	39.20	26.23	37.0	26.5
July	32.91	26.13	31.92	25.71	31.83	25.22	32.2	25.6
August	31.10	25.30	30.51	24.42	33.84	25.11	31.8	24.9
September	32.40	24.51	33.40	24.13	33.63	24.00	33.1	24.2
October	34.31	23.61	36.53	23.30	38.32	21.91	36.3	22.9
November	34.22	16.91	34.44	19.91	35.51	20.40	34.7	19.0
December	31.65	13.30	29.90	15.90	29.51	14.51	30.3	14.5

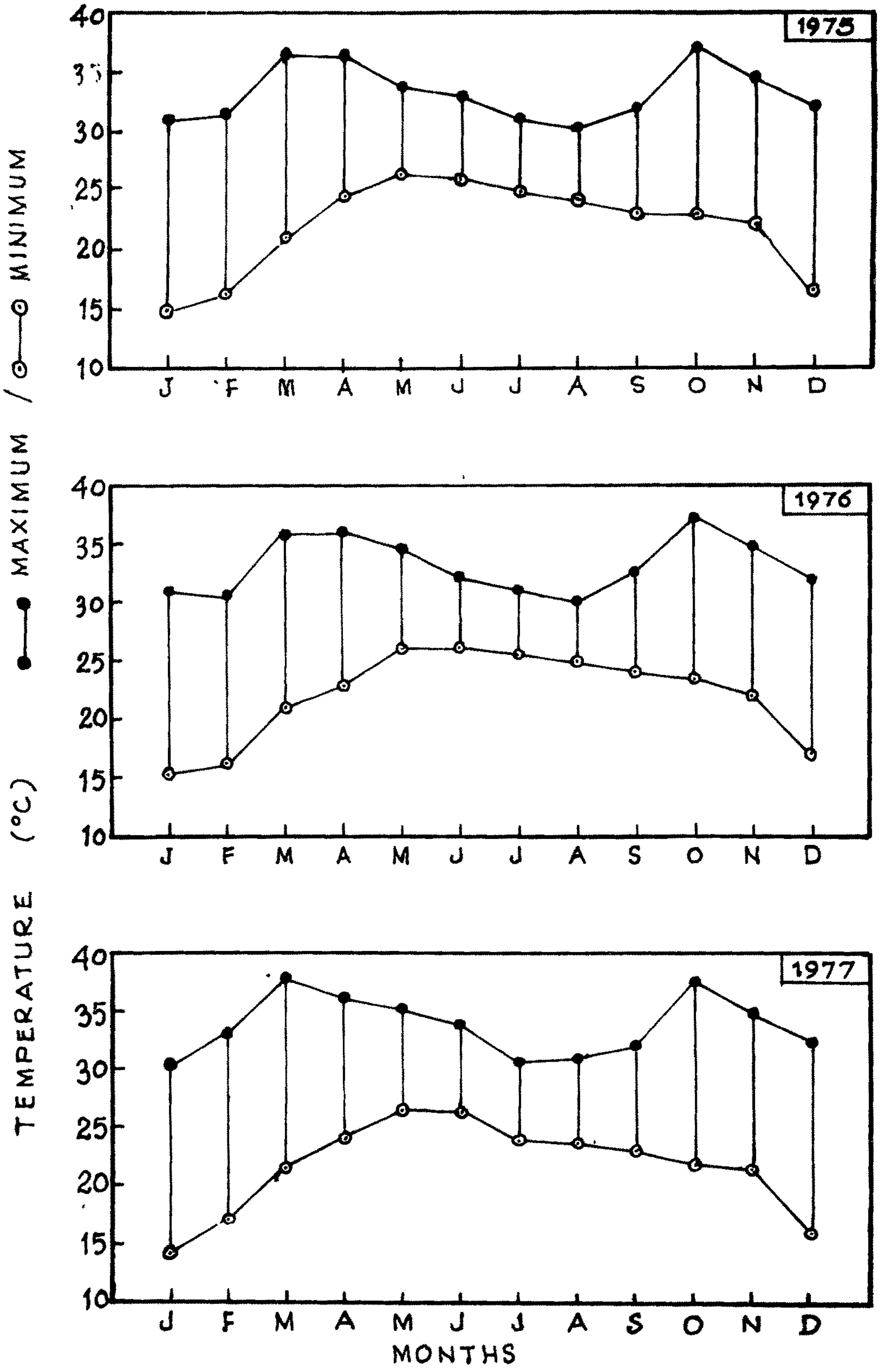


_TEMPERATURE (MONTHLY MEAN) AT 'CHOKARI'

GRAPH - 1

Table VI. Temperature (Monthly Mean) at SURAT.

Month	1975		1976		1977		1975-1977 Mean	
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
	°C	°C	°C	°C	°C	°C	°C	°C
January	30.90	14.92	31.06	15.33	30.45	14.19	30.8	14.8
February	31.92	16.88	30.65	16.10	33.08	17.07	31.9	16.6
March	36.80	21.33	36.14	21.25	38.09	21.72	37.0	21.4
April	35.92	23.98	36.21	23.64	36.04	24.52	36.0	24.0
May	34.75	26.44	34.20	26.18	35.26	26.59	34.7	26.6
June	32.95	26.03	32.29	26.04	33.96	26.50	33.0	26.1
July	31.03	25.12	31.03	25.63	30.80	24.24	30.9	24.9
August	30.59	24.32	30.27	25.01	30.92	23.86	30.5	24.3
September	31.95	23.21	32.55	24.21	32.16	22.96	32.2	23.4
October	37.45	22.90	37.54	23.57	37.51	22.29	37.5	22.9
November	34.88	22.09	34.74	22.02	35.03	21.48	34.8	21.8
December	32.14	16.50	32.13	17.16	32.38	15.99	32.2	16.5

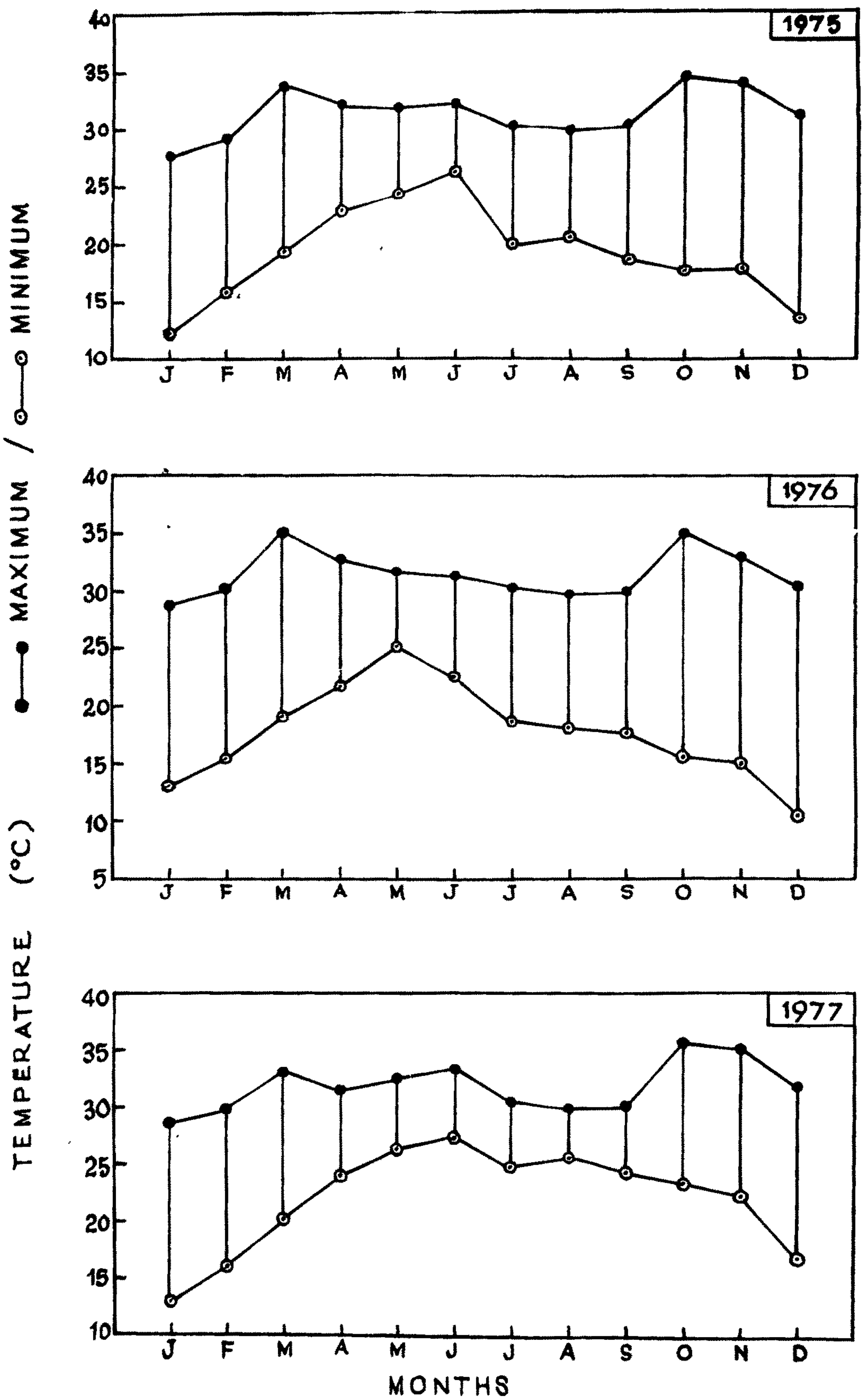


TEMPERATURE (MONTHLY MEAN) AT 'SURAT'

GRAPH - 2

Table VII. Temperature (Monthly Mean) at VALSAD.

Month	1975		1976		1977		1975–1977 Mean	
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
	°C	°C	°C	°C	°C	°C	°C	°C
January	27.89	12.30	28.90	12.90	28.60	13.06	28.4	12.7
February	29.32	15.95	29.90	15.50	29.90	16.03	29.7	15.8
March	33.90	19.30	34.61	18.95	33.30	20.30	33.9	19.5
April	32.45	22.90	32.87	21.73	31.70	24.11	32.3	22.9
May	31.95	25.04	31.82	25.21	32.82	26.40	32.1	25.5
June	32.34	26.30	31.21	22.52	33.56	27.50	32.3	25.4
July	30.20	19.93	30.45	18.76	30.60	24.99	30.4	21.2
August	29.90	20.80	29.63	18.00	30.10	25.63	29.8	21.4
September	30.30	18.89	30.04	17.77	30.93	24.45	30.1	20.4
October	34.89	17.83	34.99	15.81	35.85	23.50	35.2	19.0
November	33.90	17.90	33.06	15.23	35.37	22.43	34.1	18.5
December	31.30	13.80	30.49	10.86	32.12	16.90	31.3	13.8



TEMPERATURE (MONTHLY MEAN) AT 'VALSAD'

GRAPH - 3

prevented the temperatures from falling too low.

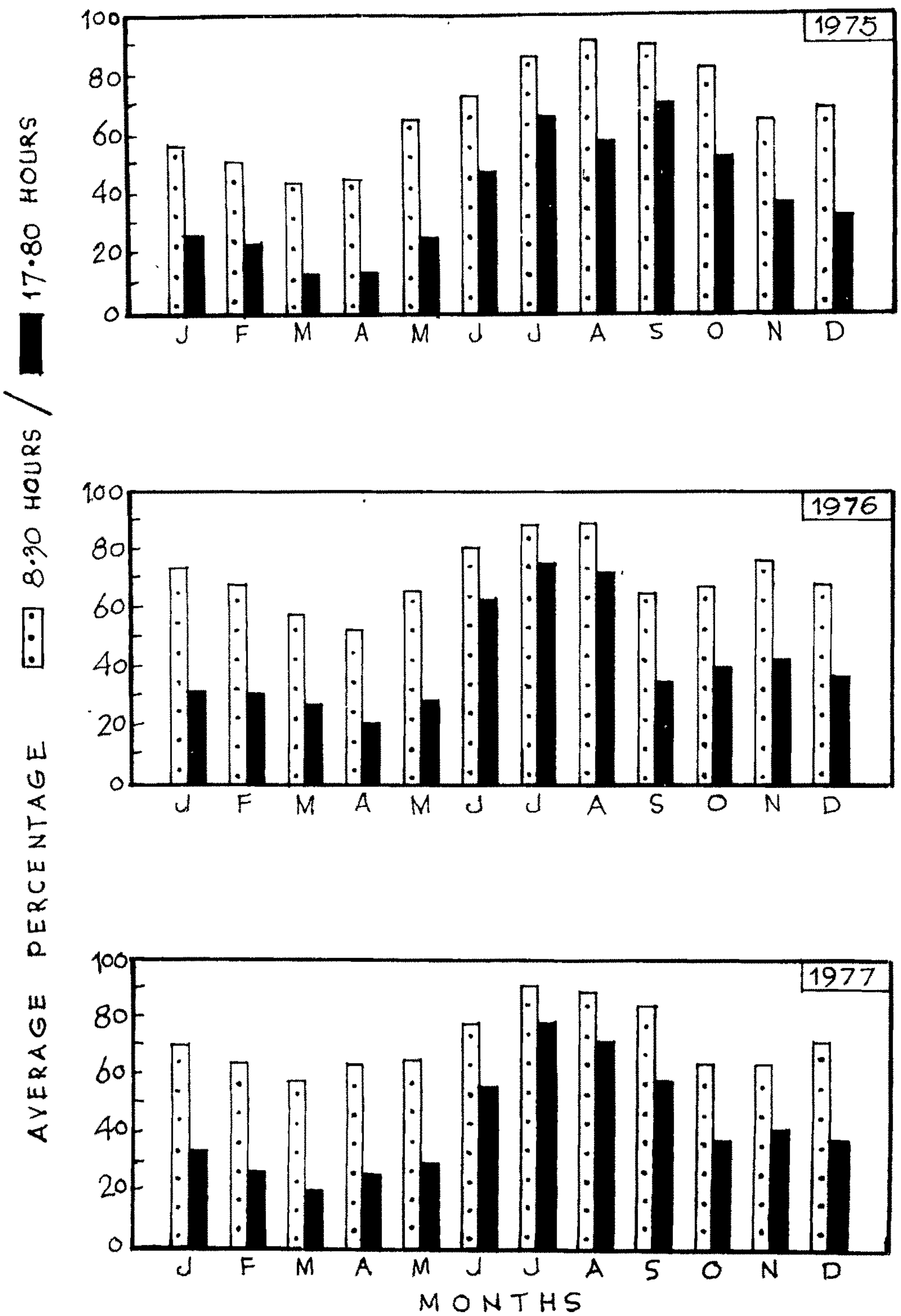
As a rule, the range of temperature in Gujarat is always higher in winter than in summer. Equally significant is the fact that the coastal areas show a lower range than places in the interior. Average monthly range of temperatures during the study period has been highest in month of April or May when it is 39° to 41°C. Though the average maximum reaches to 38° or 39°C the average minimum temperature remains 24° to 26°C (Tables V, VI, VII, XIV and Graphs 1, 2, 3; 10, 11, 12 and 13).

<u>Relative Humidity</u> : The relative humidity in all parts of the state is low, lingering in the neighbourhood of 50% between October and May. This however, does not apply to the coastal areas where the moisture content of the atmosphere is moderately high all the year round with a maximum in the summer months. In summer, the R.H. in the coastal areas is recorded as high as 75%. The relative humidity of the coastal places in the afternoons is not so low. A very high relative humidity is often associated with cloudiness and rains in the months of July and August (Tables VIII, IX, X, XIV and Graphs 4, 5, 6, 10, 11, 12 and 13).

<u>Rainfall</u> : Gujarat receives much of its rains from the south-west monsoon during the period between June and

Table VIII. Average Percentage Relative Humidity at CHOKARI.

Month	1975		1976		1977		1975–1977 Mean
	8.30 hrs.	17.30 hrs.	8.30 hrs.	17.30 hrs.	8.30 hrs.	17.30 hrs.	(8.30 hrs.)
January	57.0	27.7	74.7	32.0	71.8	34.0	67.83
February	51.8	23.0	68.8	31.2	64.6	27.3	61.7
March	44.3	13.3	58.3	27.6	58.1	19.9	53.5
April	46.3	14.6	53.3	21.7	64.5	26.5	54.7
May	65.4	26.4	65.9	28.5	66.4	30.6	65.9
June	72.9	47.8	81.4	63.1	78.4	56.0	77.5
July	85.9	65.9	89.7	75.5	91.3	78.6	88.9
August	91.4	58.3	89.2	72.3	89.7	72.2	90.1
September	90.3	69.9	65.0	35.2	84.5	59.2	79.9
October	82.5	51.9	67.5	40.2	64.7	38.4	71.5
November	65.6	37.3	76.2	43.1	64.8	42.6	68.8
December	69.6	33.1	68.2	37.1	71.9	39.4	69.9

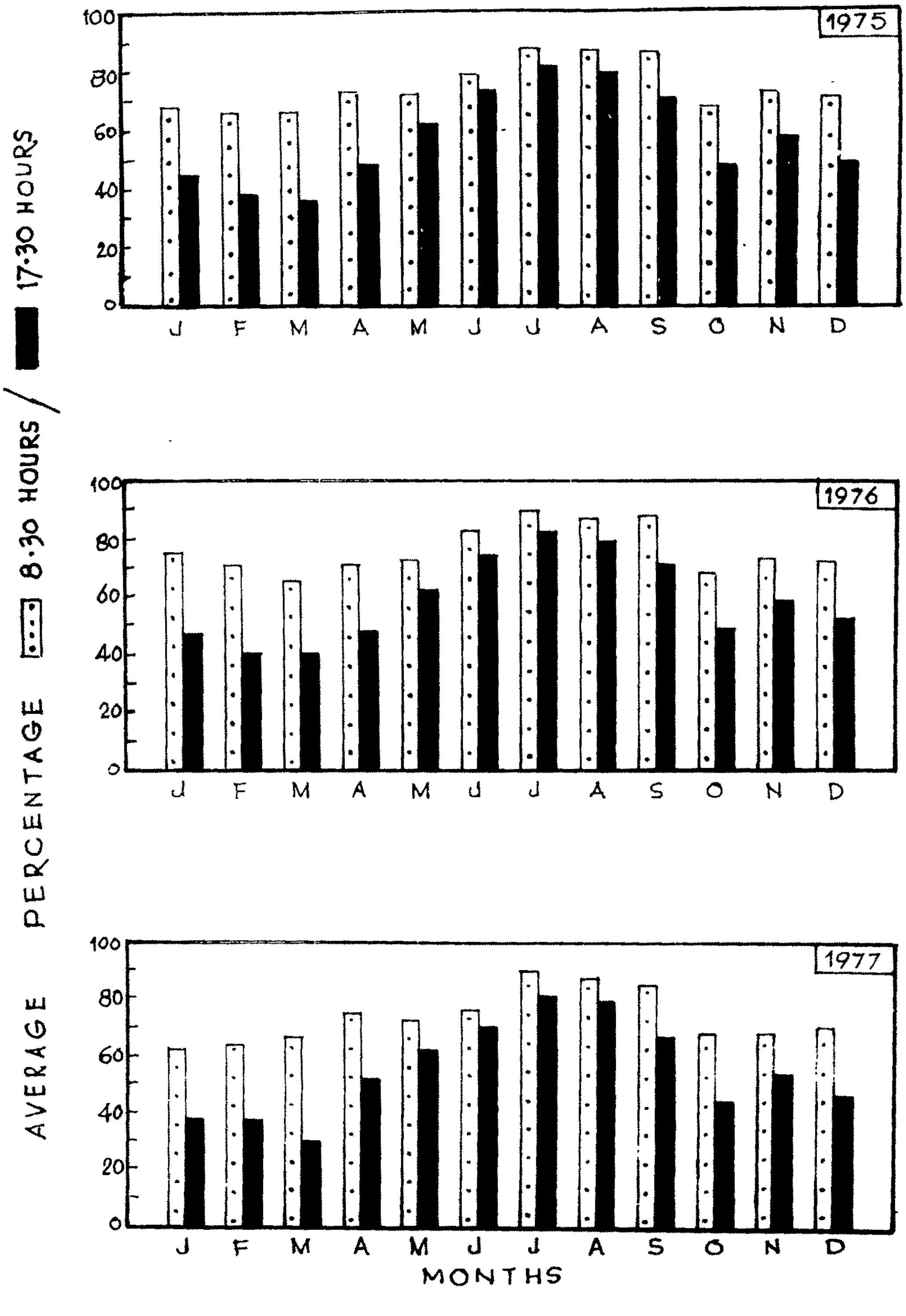


_AVERAGE PERCENTAGE RELATIVE HUMIDITY AT 'CHOKARI'

GRAPH - 4

TableIX. Average Percentage Relative Humidity at SURAT.

Month	1975		1976		1977		1975–1977 Mean
	8.30 hrs.	17.30 hrs.	8.30 hrs.	17.30 hrs.	8.30 hrs.	17.30 hrs.	(8.30 hrs.)
January	68.3	45.30	74.60	47.4	62.3	38.3	68.4
February	66.4	38.30	71.7	40.5	64.2	37.8	67.4
March	65.9	35.9	65.6	40.8	67.4	30.7	66.3
April	72.8	49.8	71.6	48.6	75.7	52.0	73.3
May	71.9	60.9	72.1	61.9	72.5	61.9	72.1
June	79.3	73.2	82.7	74.2	76.3	71.6	79.4
July	87.8	81.8	89.9	82.8	90.3	81.2	89.6
August	86.5	78.9	87.2	79.4	87.7	79.6	87.1
September	86.3	70.6	88.6	71.5	85.8	67.5	86.9
October	67.8	47.3	68.5	49.6	68.8	44.6	68.3
November	72.3	56.8	74.1	58.4	68.8	54.2	71.7
December	71.3	48.7	72.6	52.2	70.9	47.5	71.6

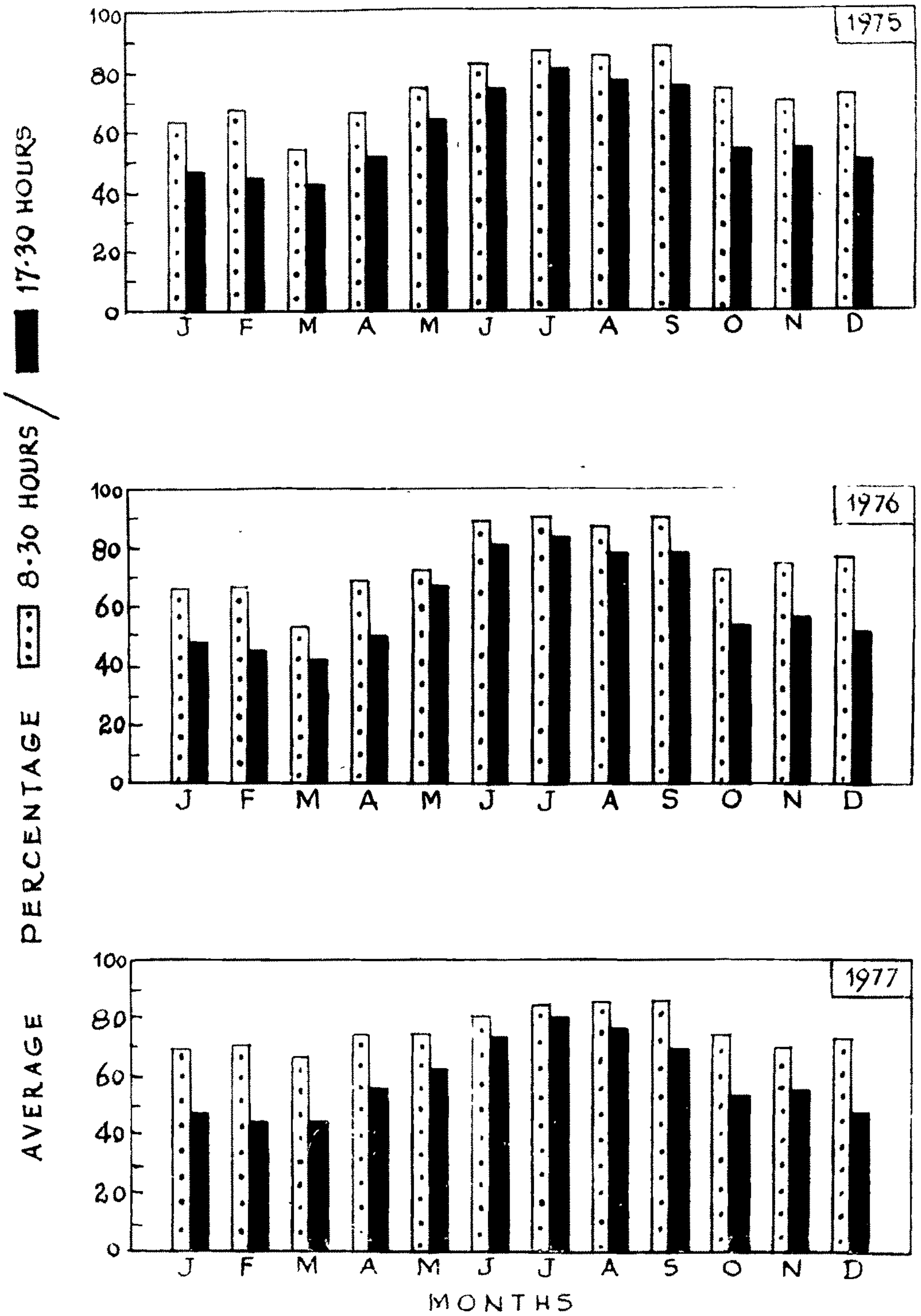


AVERAGE PERCENTAGE RELATIVE HUMIDITY, AT 'SURAT'

GRAPH - 5

Table X. Average Percentage Relative Humidity at VALSAD.

Month	1975		1976		1977		1975-1977 Mean
	8.30 hrs.	17.30 hrs.	8.30 hrs.	17.30 hrs.	8.30 hrs.	17.30 hrs.	(8.30 hrs.)
January	64.3	47.0	65.9	48.3	69.2	47.1	66.4
February	68.5	44.9	67.8	45.1	71.1	45.3	69.1
March	55.7	43.3	53.4	42.1	67.5	45.0	58.8
April	67.3	52.3	68.8	50.2	75.2	56.4	70.4
May	74.2	64.3	73.3	67.5	75.0	63.8	74.1
June	83.3	75.3	89.4	80.9	81.6	74.7	84.7
July	87.4	81.0	91.6	84.3	85.1	81.2	88.3
August	85.2	77.3	87.7	79.2	86.0	77.4	86.3
September	88.7	75.0	90.4	78.8	86.6	70.4	88.5
October	74.6	53.9	73.3	54.2	75.1	54.5	74.3
November	70.3	54.8	75.4	56.9	71.4	55.9	72.3
December	72.1	49.9	77.6	51.9	74.2	48.8	74.6

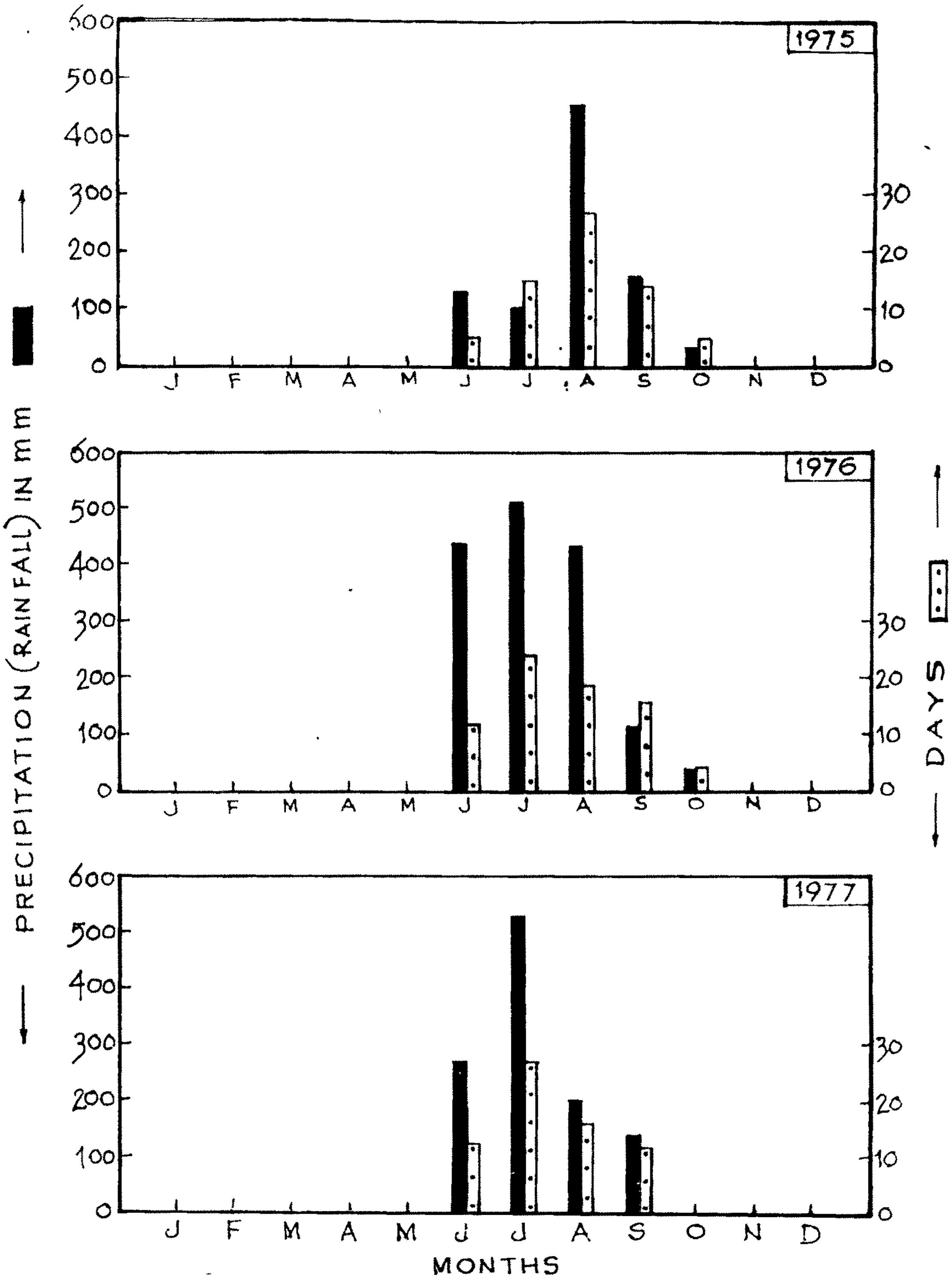


AVERAGE PERCENTAGE RELATIVE HUMIDITY AT 'VALSAD'

GRAPH - 6

Table XI. Rainfall Pattern at Chokari (1 rainy day $\geq$ 2.5 mm Rainfall).

Month	1975		1976		1977		1975–1977 Mean
	Rainfall in mm	Days	Rainfall in mm	Days	Rainfall in mm	Days	
January	0.0	-	0.0	-	0.0	-	-
February	0.0	-	0.0	-	0.0	-	-
March	0.0	-	0.0	-	0.0	-	-
April	0.0	-	0.0	-	0.0	-	-
May	1.4	1	0.0	-	0.0	-	0.46
June	131.8	5	437.7	12	271.8	12	280.43
July	103.8	15	510.0	24	530.3	27	381.36
August	456.0	27	427.8	19	202.9	16	362.23
September	159.2	14	113.2	16	139.6	12	137.33
October	38.3	5	36.2	4	0.0	-	24.83
November	1.6	-	1.8	-	0.0	-	1.13
December	0.0	-	0.0	-	0.0	-	-
Annual Rainfall	892.1	-	1526.7		1144.6		1187.80

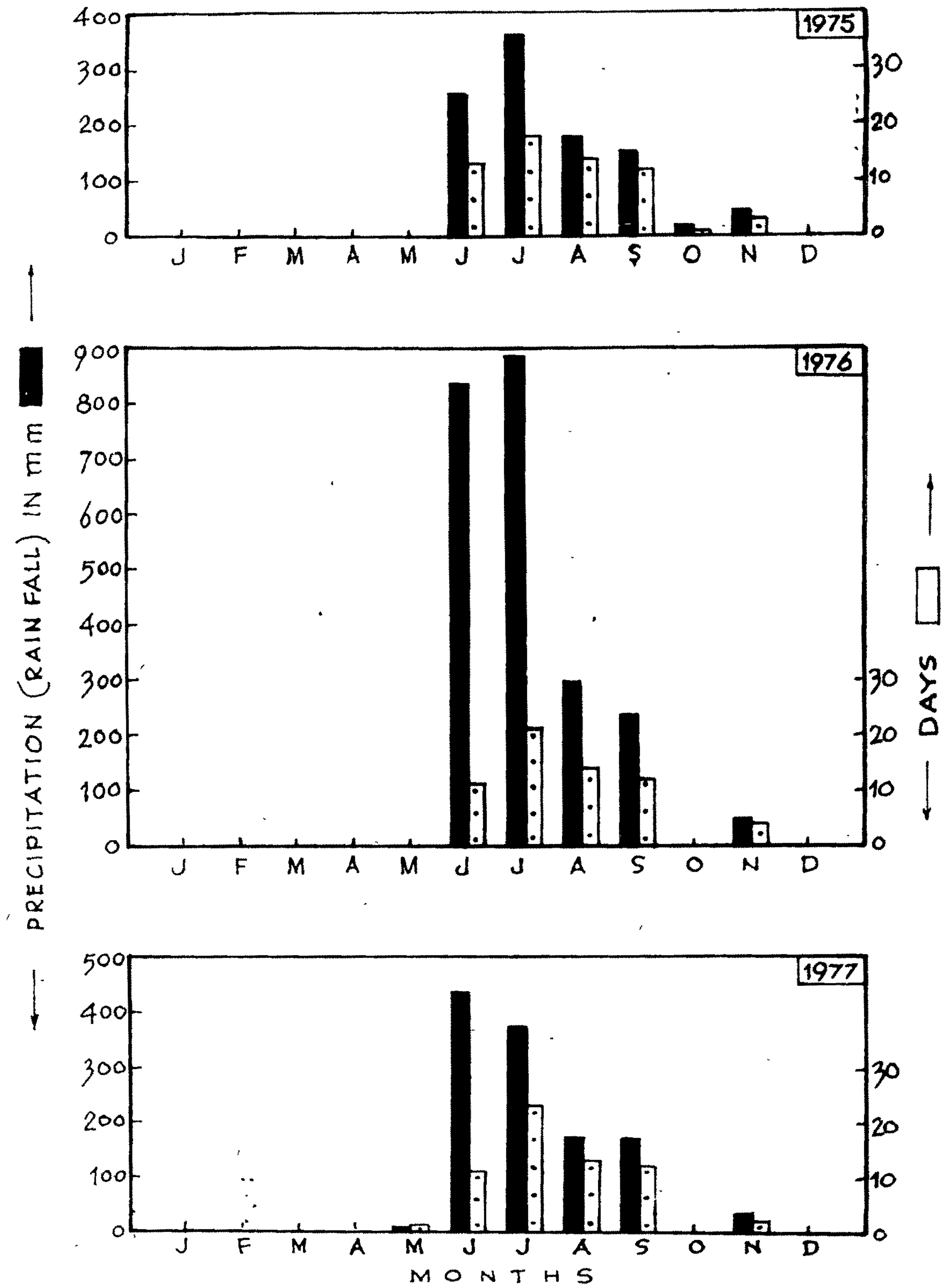


PRECIPITATION (RAIN FALL) PATTERN AT 'CHOKARI'

GRAPH - 7

Table XII. Rainfall Pattern at Surat.

Month	1975		1976		1977		1975-1977 Mean
	Rainfall in mm	Days	Rainfall in mm	Days	Rainfall in mm	Days	
January	0.0	-	0.0	-	0.0	-	-
February	0.0	-	0.0	-	0.0	-	-
March	0.0	-	0.0	-	0.0	-	-
April	0.0	-	0.0	-	0.0	-	-
May	0.0	-	0.0	-	7.4	1	2.46
June	258.7	13	836.7	11	439.8	11	511.73
July	360.2	18	884.4	21	372.8	23	539.13
August	181.3	14	293.7	14	170.7	13	215.23
September	155.4	12	235.6	12	171.2	12	187.40
October	15.7	1	0.0	-	0.0	-	5.23
November	43.0	3	[illegible]	4	31.8	2	41.03
December	0.0	-	0.0	-	0.0	-	-
Annual Rainfall	1014.3		2298.7		1193.7		1502.23

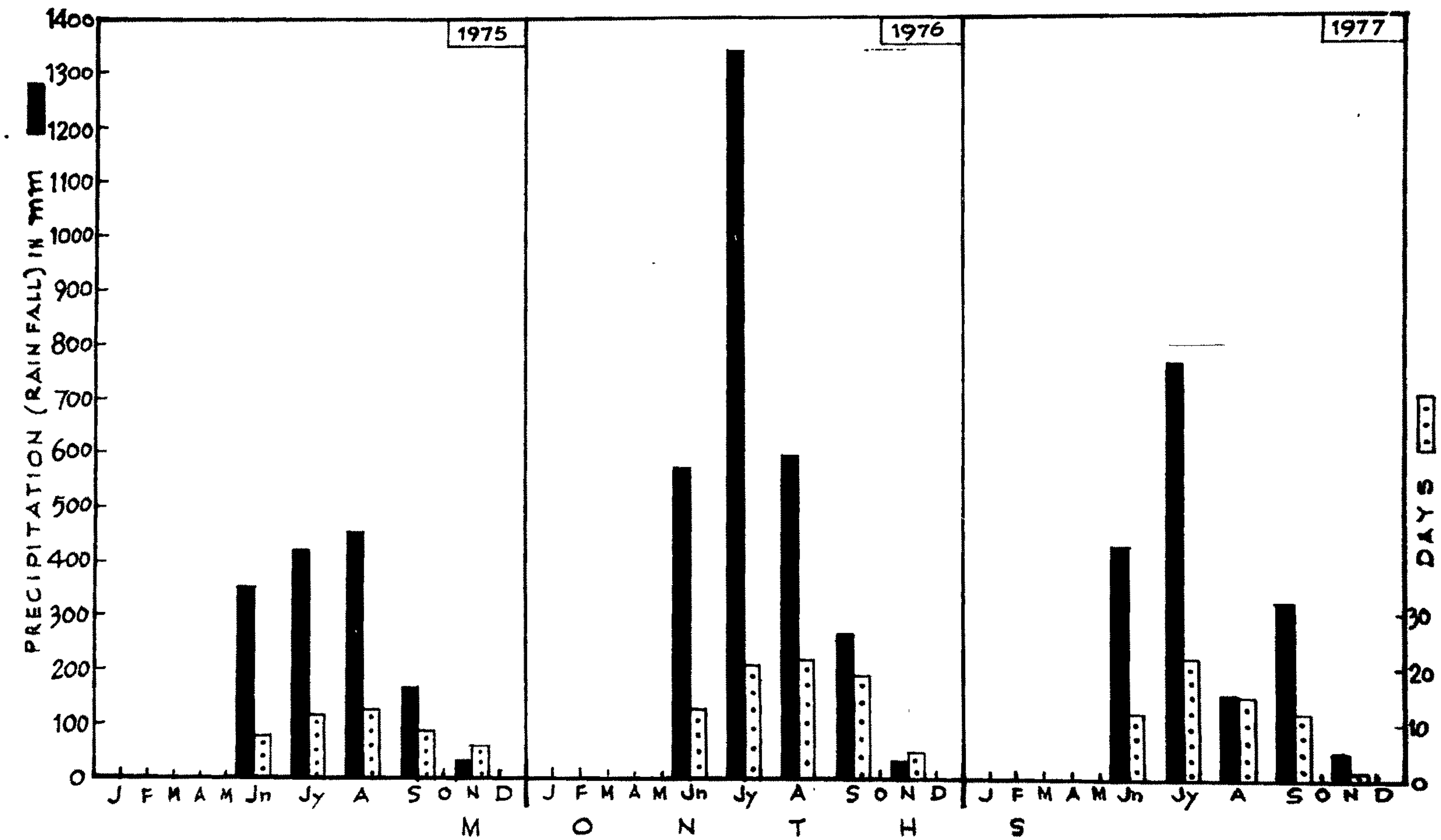


_ PRECIPITATION (RAIN FALL) PATTERN AT 'SURAT'

GRAPH - 8

Table XIII. Rainfall Pattern at Valsad.

Month	1975		1976		1977		1975–1977 Mean
	Rainfall in mm	Days	Rainfall in mm	Days	Rainfall in mm	Days	
January	0.0	-	0.0	-	0.0	-	-
February	0.0	-	0.0	-	0.0	-	-
March	0.0	-	0.0	-	0.0	-	-
April	0.0	-	0.0	-	0.0	-	-
May	0.0	-	1.8	-	1.6	-	1.13
June	352.3	8	572.6	13	428.2	12	451.3
July	421.4	12	1334.3	21	760.0	22	838.5
August	453.6	13	595.7	22	151.0	15	400.1
September	168.3	9	268.9	9	322.7	12	253.3
October	0.0	-	0.0	-	0.0	-	-
November	37.8	6	27.9	5	045.3	1	37.0
December	0.0	-	0.0	-	0.0	-	-
Annual Rainfall	1433.4		2801.2		1708.8		1981.33

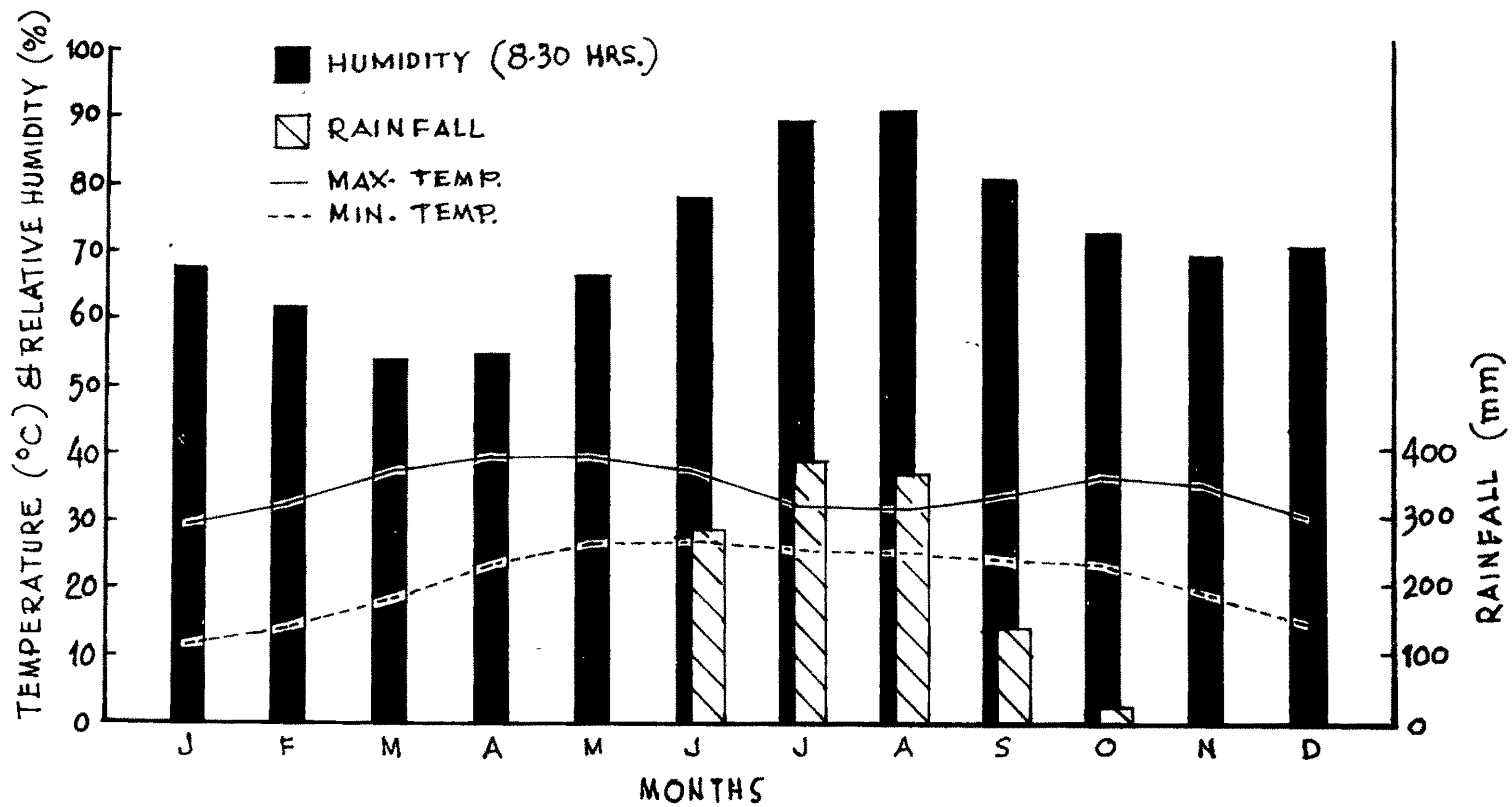


PRECIPITATION (RAIN FALL) PATTERN AT 'VALSAD'

GRAPH - 9

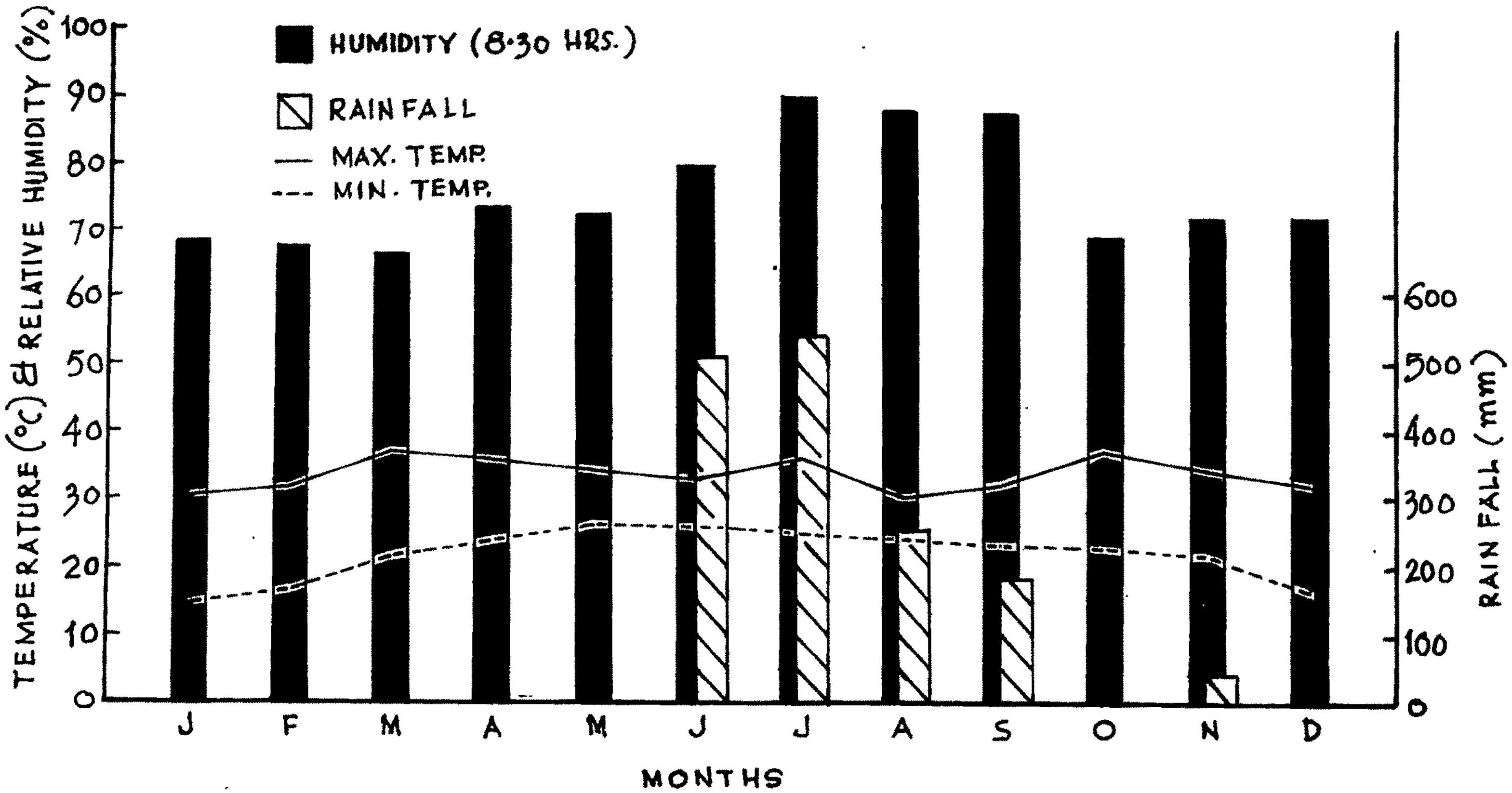
Table XIV. Temperature (Monthly Mean), Average Percentage Relative Humidity and Rainfall Pattern at DAMAN (for the year 1977). (For Daman Meteorological Data from Meteorological Centre, Ahmedabad, are available for the year 1977 only).

Month	Temperature		Relative Humidity		Rainfall	
	Maximum °C	Minimum °C	8.30 hrs.	17.30 hrs.	Rainfall in mm	Days
January	28.11	14.49	66.45	55.45	-	-
February	28.43	15.50	58.78	55.75	-	-
March	33.16	22.36	60.38	50.64	-	-
April	32.00	25.50	69.36	60.80	-	-
May	32.60	27.65	71.66	67.83	-	-
June	33.42	27.52	80.60	75.26	351.3	12
July	30.10	25.30	90.12	86.16	759.8	25
August	29.50	25.20	87.41	83.90	247.1	18
September	30.50	24.60	85.73	76.76	199.1	10
October	32.50	20.43	69.77	66.23	017.8	1
November	31.10	22.46	67.63	67.40	048.5	1
December	30.30	17.60	71.77	55.93	-	-
				Annual Rainfall	1623.6	



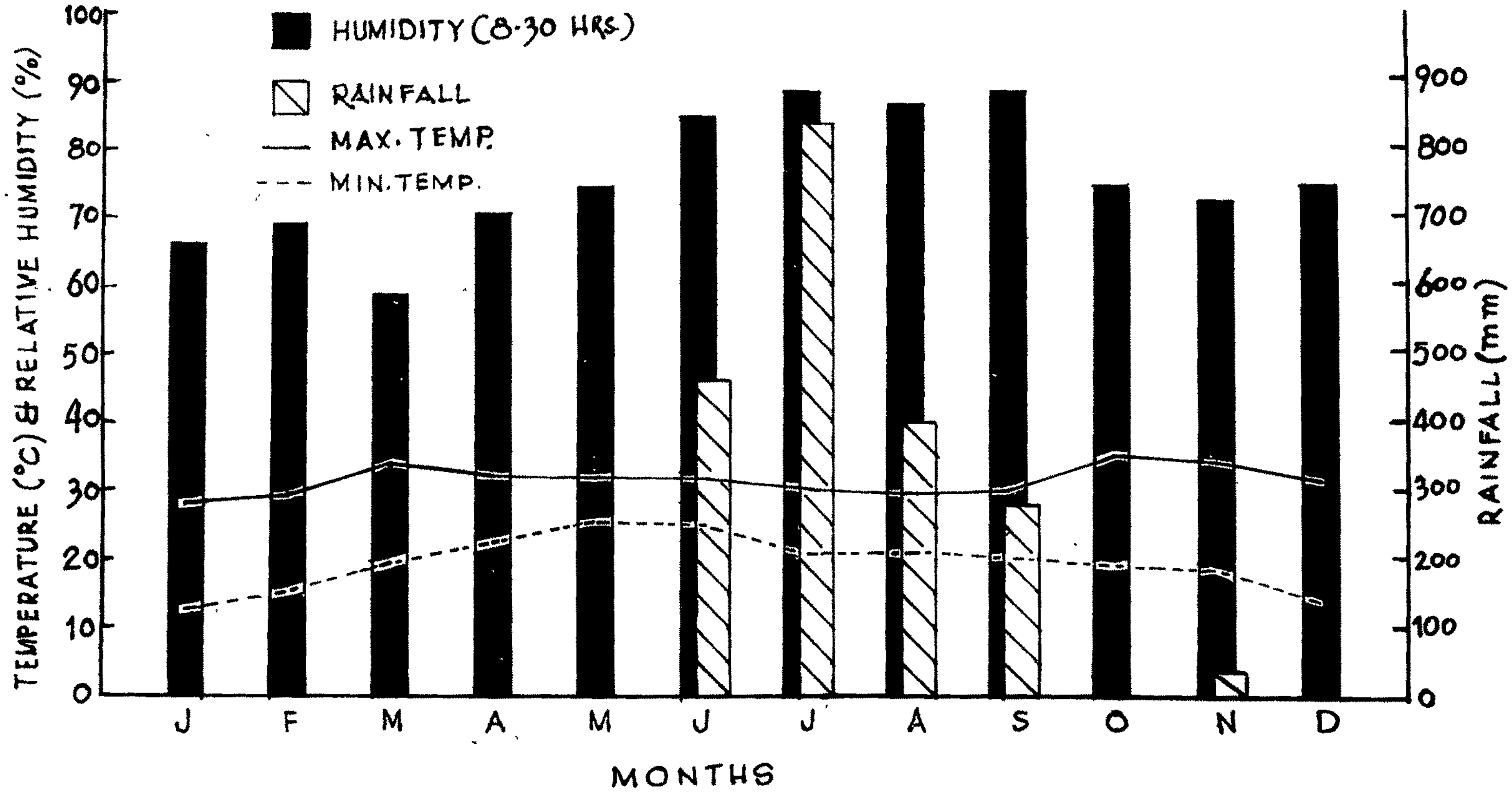
OMBROTHERMIC DIAGRAM FOR 'CHOKARI' (1975-77 MEAN)

GRAPH - 10



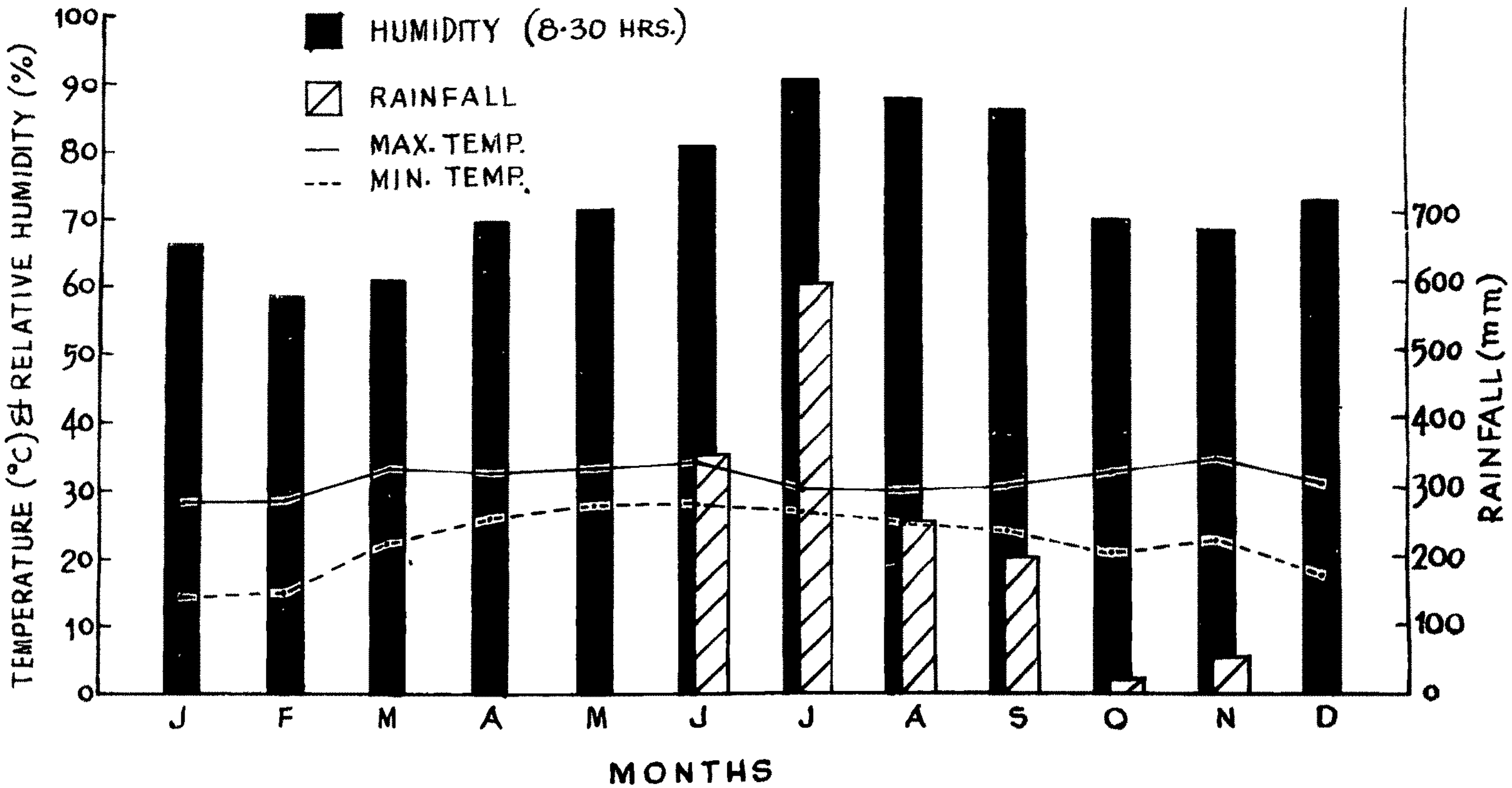
OMBROTHERMIC DIAGRAM FOR 'SURAT' (1975-77 MEAN)

GRAPH - 11



<u>OMBROTHERMIC DIAGRAM FOR 'VALSAD'</u> (1975-77 MEAN)

<u>GRAPH - 12</u>



OMBROTHERMIC DIAGRAM FOR 'DAMAN' (1977)

GRAPH - 13

September. The monsoon breaks in June, reaches its maximum intensity in July, which is the wettest month of the year and decreases towards the end of September. September is the month of marginal rainfall while October is marked by very occasional showers. November to May is a dry period, though occasional cloudiness, thunder or a little rain may occur in any month.

The amount of rainfall varies considerably from one part of the state to the other. The southernmost part of the state, part of Valsad district, receives as high as 2,000 mm of rainfall. The decrease in the amount of rainfall, to the north is rather abrupt and in less than 100 Km to the north, it dwindles to 1,040 mm at Surat. All parts of the coast face a wide stretch of sea and the onshore monsoons are equally strong everywhere (Tables XI, XII, XIII, XIV and Graphs 7, 8, 9, 10, 11, 12, 13).

PRESENT WORK

The area selected for the present work is botanically virgin and uptill now no intensive study of the area was undertaken. The work embodies the results of four years of intensive and extensive exploration of the entire area. The area displays a remarkable diversity of floristic composition. The vegetation pattern is influenced by a complex of environmental factors, including frequency and range of tides, salinity, microrelief, substrate and storms.

The habitat types included are waste places, estueries, ponds and puddles, and saline marshes along the sea-coast. The coastline bordering the Gulf of Khambhat is muddy with limited strand conditions.

The coastal vegetation of Gujarat is divisible into three sub-groups, viz., Strand, Salt marsh and Estuarine. The strand vegetation is characteristic with open, mat forming pioneer species followed by scattered herbs, shrubs and trees dispersed along the relief beyond the high tide limit of the backshore region. This is further divisible into two substrate types, namely, sand strand and rock strand. The salt marsh is chiefly composed of mangroves growing on low lying muddy shores and sandy saline areas under the influence of tides. The coastal area of the places visited was found to be sandy, muddy or mixed and nowhere rocky coast was encountered. It was observed that although tolerant of high salinity conditions, mangroves appear to reach their best development in polyhaline (estuarine) situations.

Regular excursions were planned in different seasons in all the coastal regions in order to provide the base line information on seasonal changes in the vegetation, phenology of plants and floristic composition.

To study soil features in relation to plant communities, soil samples were collected from different localities and different zones within a locality and analysed in the laboratory for physical and chemical properties such as mechanical composition, organic matter, moisture holding capacity, percentage bicarbonates, pH salinity (Ec), chloride, calcium carbonate, total soluble salts, carbonate content, permeability etc.

The field studies produced an abundance of data not apparent or easily extracted from the more generalised vegetational analysis. This fact, together with the fact that few floristic studies specific to the maritime provinces have been written, led to the preparation of this flora of the coastal areas of Gujarat.

In the thesis, arrangement of families is according to Cooke's (reprinted, 1958) Flora of the Presidency of Bombay. For the sake of convenience, the genera in a family and species with a genus are arranged alphabetically. Artificial keys based on exomorphic characters have been given for genera and species.

The nomenclature has been brought up-to-date in the light of current researches and in accordance with the rules of the "International Code of Botanical Nomenclature 1966". Most of the names are those given in Cooke's Flora, but when the name is changed, the correct name is given first. It is followed by such synonym as may explain the reasons for nomenclatural changes.

Based on personal critical observations from fresh as well as herbarium materials, a short description is given for each plant which is followed by a note on its habit, habitat, local names, economic or local uses if any, world distribution and critical notes to explain either nomenclature or remarks on the identity of plants are given wherever necessary.

In support of observations are given illustrations and photographs of plants.

METHODOLOGY

(A) Field Work : An intensive field work was carried out every week in all seasons with more frequency during rainy season, so that nothing escapes of the herbaceous ephemeral flora appearing in that season.

During collection trips, plants were collected in different developmental stages and exhaustive field notes were taken. Special care was taken to record habit, habitat, abundance, colour and fragrance of the flower etc. Specimens collected during the excursions were processed and preserved in the usual manner, following Lawrence (1951) and Santapau (1955). Cooke's Flora was the basis for a cursory identification at the end of a day's work. All the localities were covered in different seasons which resulted in obtaining information about the phenology of the plants and the seasonal changes in the vegetational and floristic composition.

During outings several black and white and coloured photographs were taken.

The constant moving from place to place, the accumulation of half dried specimens that had to be attended to, the primitive convenience of the sea-coast expenses - all these made the trips a series of strenuous undertakings compensated by a sense of achievement and the joy of discovery.

Further, sufficient material was preserved in liquid media (4% formalin) to enable subsequent laboratory studies.

(B) Laboratory Work : To confirm the field identification, innumerable specimens of almost every species represented in the thesis have been dissected and critically examined in the laboratory and by reference to Cooke's Flora of the Presidency of Bombay or the Hooker's Flora of British India. Line drawings of most of the plants were prepared. The line drawings will be of great help in the identification of the plants.

Identified herbarium specimens were compared with the authentic ones in the Blatter Herbarium, Bombay, Central National Herbarium, Howrah, and Herbarium, National Botanical Gardens, Lucknow.

After identifications were confirmed, the herbarium sheets were labelled and deposited in the Herbarium of the Department of Botany, The M. S. University of Baroda, Baroda, Gujarat, India. A few families have been split following recent monographic works.

The collected information about the plants that was entered in the field diaries was then transferred to index cards. The brief but entirely original descriptions have been made from fresh or preserved specimens. Reference to various regional floras indicated the range of distribution within the subcontinent and outside.