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CLIMATE AND HORTICULTURE IN INDIA

A. R. SUBRAMANIAM, A. V. R. KESAVA RAO and K. BHASKARA RAO, Waltair

ABSTRACT : India, a land of many climates, has a great potential to grow an array of horticultural crops. It is well-known that climate has influence on horticultural crops, hence this study. Selected fruit and vegetable crops alone are discussed in the present paper since adequate information on ornamental crops is not available.

Data on monthly values of climatic elements are collected from the publications of India Meteorological Department, for all the available stations in the country. Waterbalance elements and indices are computed following Thornthwaite (1955). A general study is made on fruits that are grown in different parts of the country in relation to the agroclimatic zones along with water need. Frost prone fruit growing areas are identified. Distribution of fruits, with hours of bright sunshine and index of moisture adequacy are comparatively discussed and it is found that mango is grown in areas with moisture adequacy 60–80per cent , papaya in 40–70 per cent and Grapes in 60 per cent Climate and phenology for Mango, Grapes and Cashew among fruits and potato in vegetables is presented at representative stations in different parts of the country Information on cropweather calendar of important vegetables grown in South India is given. Average flowering dates of mango, and water balance and soil moisture status of the various crops are discussed.

Introduction

India being a vast sub-continent with wide range of climatic conditions has a great potential to grow an array of horticultural crops. The cultivation of fruits dates back to ancient times. However, until recent past commercial cultivation of fruits remained in its infancy. The development of fruit growing on commercial lines has taken place only during the past quatrer century. There is great potential to develop fruit and vegetable crops in the vast lands lying without any cultivation, with some improved management practices. Temperature, moisture, light intensity, length of the day, frost, strong winds, floods and droughts etc., influence plant growth, hence the quality and quantity of yield. The depth of the soil and the nature of the sub-soil are more important than the texture of the surface soil for crop growing. Different fruit, vegetable and flower crops need different depths of soil depending on their root development capacities. Since climate greatly influences growth and development of horticultural crops in India, the study of the climate in relation to horticultural crops is important, and hence the present study.

Horticulture includes growing fruits, vegetables and ornamentals. Flowers are

symbolic of beauty, love and tranquility, and have aesthetic value and are grown in all parts of India. However, data on their growth and distribution on all-India basis is not adequately available, hence only fruits and vegetables are discussed in the present study.

India is a land of many climates and varities of soils. The lofty Himalayas run along its entire length in the north. To the south of this are the alluvial plains watered by the Ganga and Yamuna. In the further south, there lies the plateau of peninsular India skirted by narrow coastal strips, the Arabian sea to the west, the Bay of Bengal to the east and the Indian ocean to the south. The great Indian desert lies in the northwestern part.

Climate and Horicultural Crops

Fruits like apple, pear, peach and strawberry, and vegetables like cabbage, cauliflower, carrot etc., can grow only on sites having sufficiently low temperature. Fruits like mango, banana and jack fruit require a long growing season and high temperature without any forest or snow fall. Grapes also require dry and warm weather during flowering and fruiting. Papya fruit attains an excellent flavour under the dry and hot conditions (Pareek, 1977). Tender crops like bean, cucumber, egg-plant, melon, tomato etc., cannot tolerate frost.

The amount of rainfall and its distribution in a given area is very important in deciding the kind of fruit or vegetable which can be grown suecessfully there. Some depend almost entirely on rainfall and can be raised without any special irrigation facilities, as in the west coast and Assam. Generally heavy rainfall is unfavourable to fruits grown in the plains, as it leads to water logging and also affects adversely the blossoms and fruits.

Hot winds and cyclones may cause damage to the fruit trees and crops. Strong dust storms become the limiting factor for growing fruits in some areas as they cause breakage of limbs of fruit trees and shedding of flowers and fruits. It is also known that occurrence of hail is a limiting factor for fruit growing.

In northern India frost causes damage to the newly opened blossoms of fruit trees, to young growths and newly set plants. Frost usually occurs during the early winter or spring. Various types of injuries such as black heat, crotch injury, crown or collar injury, splitting of the bark and killing back of shoots and young branches have been reported.

Fruit trees or plants may be protected from frost by selecting frost tolerant varieties constructing wind breaks and by planting tender fruit plants on the innerside of the orachard, so that they may receive protection from frost, it is also made by heating by smoke, covering the trees by some covering material and by use of shelters.

High temperatures during the growing and rest periods cause some injuries. Sunburn and sunscald are the usual injuries associated with high temperature. Excestive heat during the growing season often results in the burning of leaves and fruit. Protection from high temperature is made by covering with a wrapping material, shading, constructing windbreaks, irrigating at regular intervals and by whitewashing the truuk.

Data and Methodology

Data on monthly values of maximum temperature, minimum temperature, rainfall, number of rainy days, relative humidity, vapour pressure, cloud amount, and wind speed are collected from the publications of India Meteorological Department, for all the avilable stations in India. To understand the water requirements of fruit and vegetable crops and to assess the potentiality of a region for the development of horticulture water balances and the Index of moisture adequacy are computed following Thornthwaite (1955), and compared with the distribution of important crops like mango, banana, apple, grapes etc., in India. To inquire the impact of climate on various crops, a correlative study of climatic and

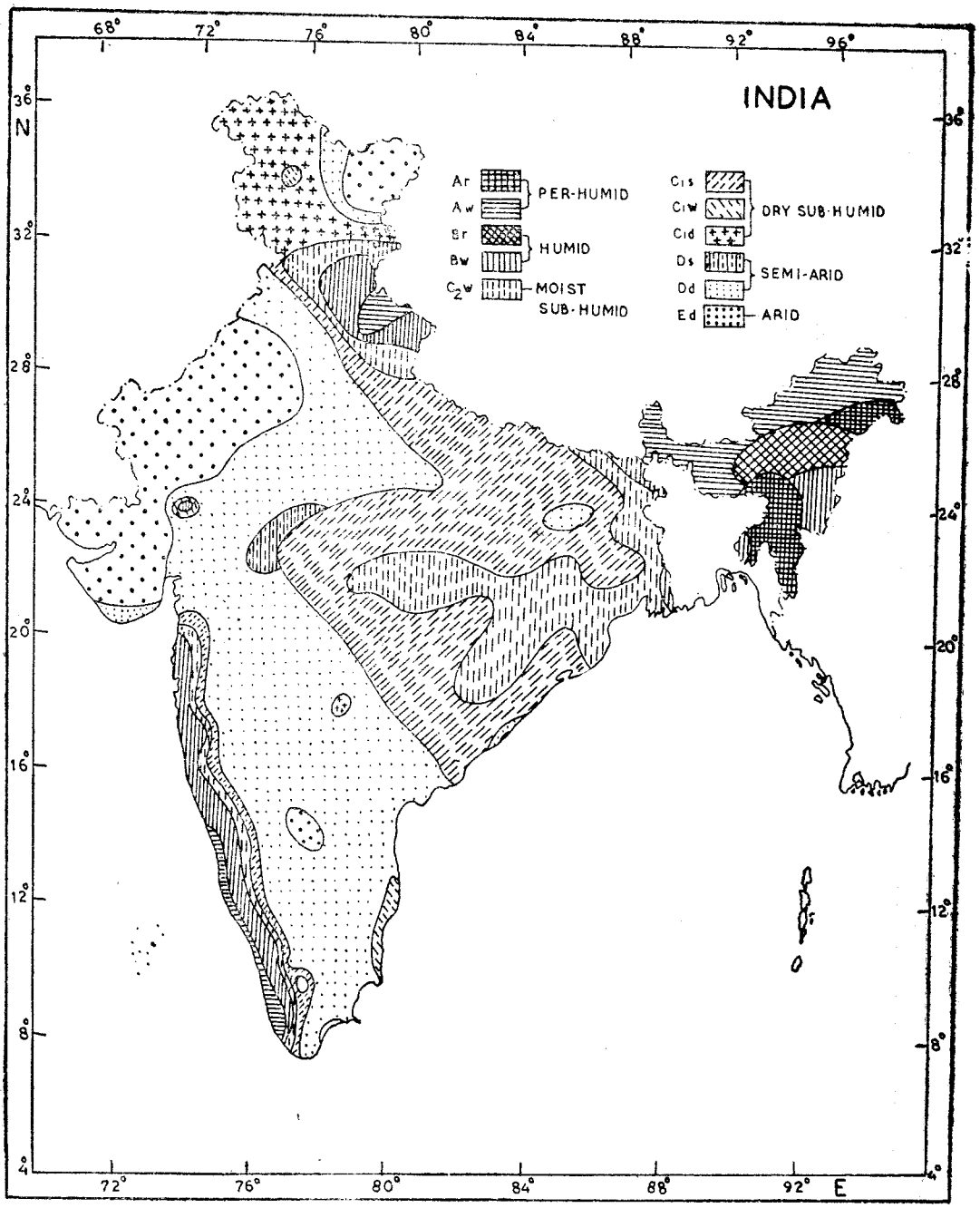


FIG.1 AGROCLIMATIC ZONES.

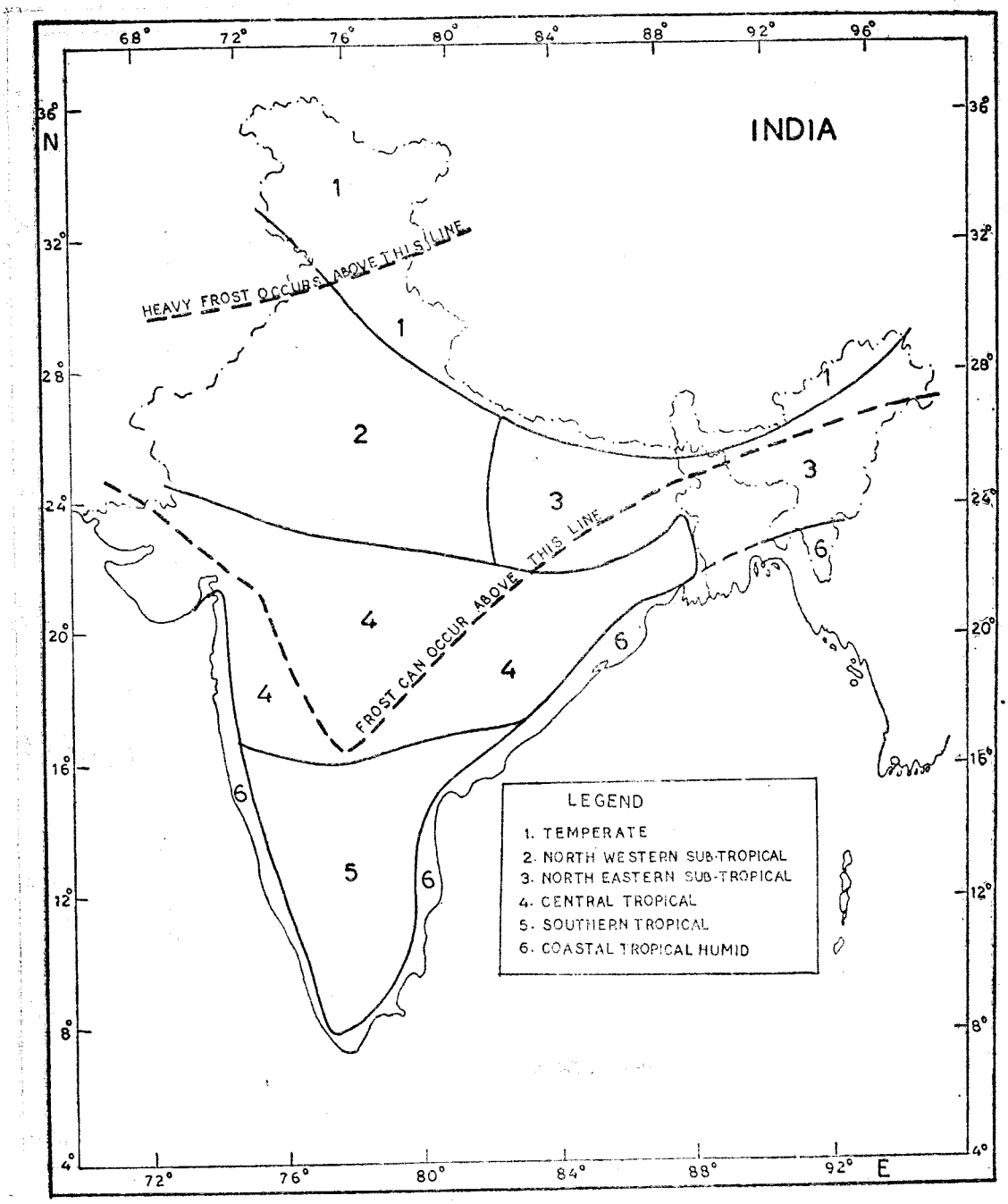


FIG. 2 FRUIT GROWING REGIONS.

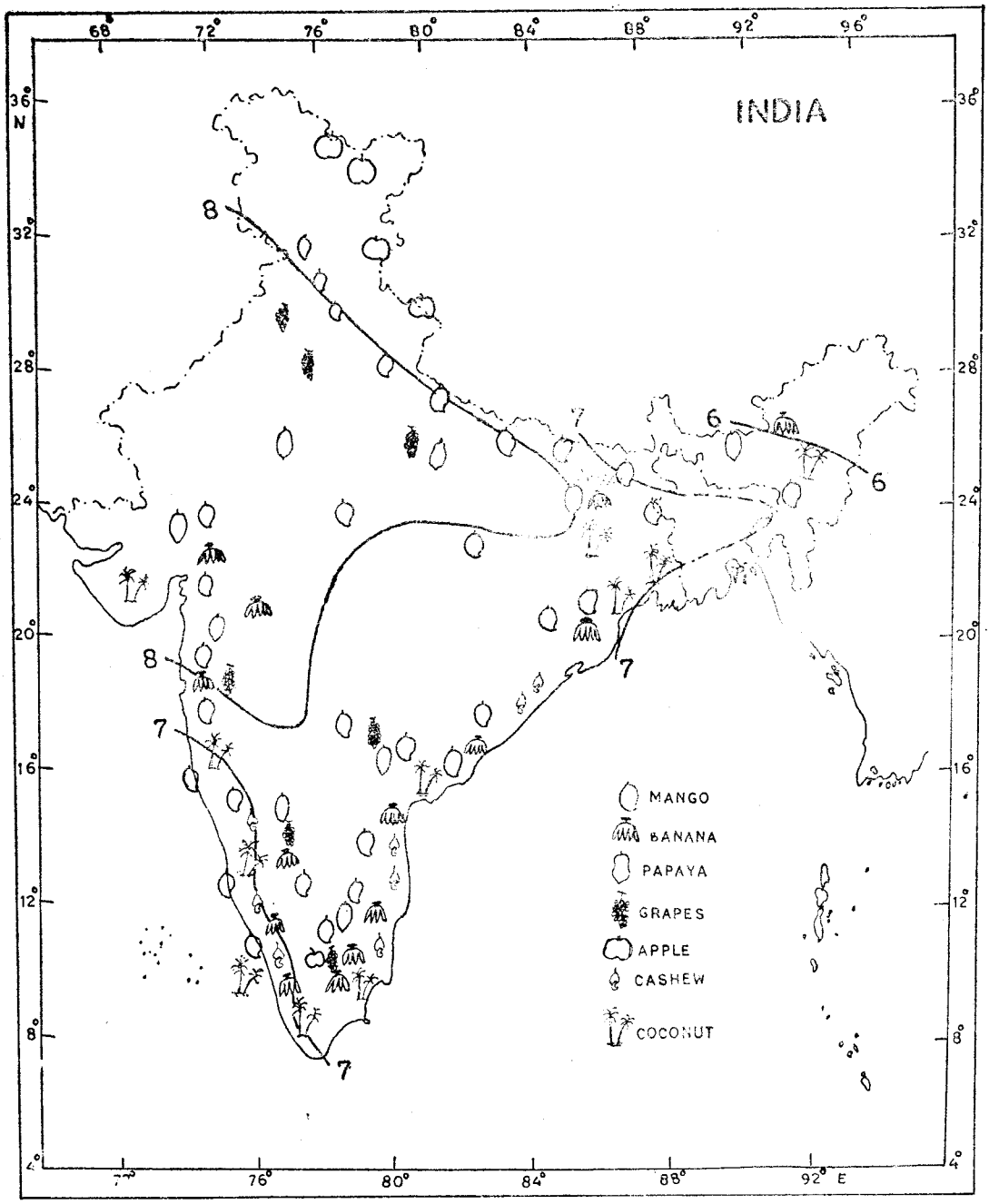


FIG. 3 FRUITS IN DIFFERENT REGIONS AND ANNUAL MEAN DAILY HOURS OF BRIGHT SUNSHINE.

crop factors is made at different phenological stages. Water balance and soil moisture status diagram are presented for the representative stations for selected (mango grapes, cashew and potato) crops. Investigation on flower and ornamental crops could not be undertaken for lack of information.

Fruit Crops

Crop development in a region is influenced by climate and hence the agroclimatic zones of India are shown in Fig. 1 (Anon. 1978). It can be seen from the figure that a spectrum of all the five agro-climates are present, a major portion being under semiarid type of climate. Humid and perhumid types of climates are found in the northeast and on the west coast. Arid climates are dominant in the northwest in the Deccan plateau and in the eastern part of Kashmir.

India can brolady be divided into six fruit growing regions from the climatic point of view and a map showing the fruit growing regions with information on frost occurrence is shown in Fig.2 (Sham Singh et al. 1967). It can be seen from the figure that frost can occur in parts of central, and northern India.

Important fruits grown in different parts of India are shown in Fig. 3 (Ranjit Singh, 1969). Apple is an important temperate fruit and grown mostly in the temperate regions of Punjab, Uttar Pradesh, Himachal Pradesh and Kashmir. In the south it is grown in the Nilgiris to a small extent. Mango is found growing all over India. Banana is principally grown in the south, west and eastern regions. It occupies about 20 per cent of the total area under fruit crops and it is strictly a tropical fruit and does not perform well in the arid zones of central and north India as it is a moisture loving plant. Damage through high winds is not uncommon to banana. As many as sixty varities are grown in India and about a dozen have commercial importance. Banana is grown throughout the year. Under favourable conditions it flowers in the 9th to 12th month from the time of planting and takes about 3 to 4 months to mature its fruit. Grapes are grown in restricted areas without high altitude and humid climates. Papaya is found to be grown generally in the dry zones. Cashew an important nut crop is grown principally in the coastal areas of peninsular India. The coconut is a humid tropical crop and a very important drupe fruit of India. It is grown in the coastal tracts of south India and in Bihar and Assam. Coconut is densely cultivated on the west coast of Kerala and southern Karnataka (Menon and Pandalai, 1953). Other important crops that are grown in India are the pear, peach, plum, apricot, cherry (temperate fruits), almond, hazel-nut, walnut (nuts), citrus, guava, jackfruit, custard apple (tropical and subtropical fruits) etc.

Crop production is mainly dependent upon the availability of water and different crops have different water needs in different regions. Hence, it is essential to know the water need of crops in different agroclim atic zones, for better irrigation scheduling. With this view, fruit crops grown and their annual water need in different parts of India in different climatic zones are given in Table I.

The index of moisture adequacy is the ratio of actual evapotranspiration to water need expressed as a percentage and is useful measure in assessing the extent to which crop water requirements are met. Distribution of this index over India is shown in Fig. 4. A comparison of this map with the distribution of fruit crops shows that mango is grown generally in areas with moisture adequacy ranging from 60–80 per cent. Papaya is grown in the areas with moisture adequacy 40--70, per cent and grapes in the areas having 60 per cent of moisture adequacy.

A detailed study of mango, grape and cashew is discussed to understand the impact of climate on these important crops.

Table I

Fruit Crops and their Annual Water Need in Different Climatic Zones in India

Agroclimatic zone		Water need (mm)	Crops grown in area
Per humid	Ar	900–1100	Mango (Tripura and Meghalaya)
	Aw	1100-1300	Jack fruit (Pine apple, Papaya and Banana (Assam)
		700–1300	Apple (U. P.)
		1300–1700	Mango, Pine apple, Banana (Southern west coast of Karnataka and Kerala)
Humid	Br	900–1300	Banana, Mango, Mandarin (Meghalaya, Assam, Nagaland)
	Bw	700–1300	Apple, Mango, Loquat (Himachal Pradesh, U. P.)
		1100–1500	Mango, Banana, Jack fruit (Maharashtra coastal area, belt parallel to coast line of Karnataka and Kerala)
Moiat sub humid	C_2w	700–1300	Apple, Banana (Parts of Bihar West Bengal, Orissa, M. P.)
		1030–1700	Mango Banana (Parts of Bihar, West Bengal, orissa M. P.)
		900–1800	Mango Jack fruit Banana (Area parallel to the west coast of small belt)
Dry sub humid	C_1s	1300–1700	Mango, Guava, Ber, mandarin, custerd apple, Banana, litchi, Papaya(Parts of U. P., Bihar West Bengal, M. P. Maharashtra, Orissa, A. P.)
		900–1800	Mango, Papaya (Parts of Maharashtra, Karnataka, Kerala)
	$_1Cw$	900–1300	Mango, Banana (Rajasthan and Tamil
		1700–1800	Nadu)
	C_1d	500–700	Apple (Kashmir)
Semi arid	Ds	–	—
	Dd	1300–1800	Mango, Banana, Guava, Papaya, Sweet Orange, Grapes, Custerd apple, Pomegranite. (Punjab, U. P. Rajasthan, Gujarat, Maharashtra, Karnataka, A. P., Tamil Nadu)
Arid		1300–1500	Sweet Orange, Ber (Rajasthan)

Ar = Little or no water deficit, Aw—Moderate winter deficit, Br = Little or no water deficit
Bw = Moderate winter deficit, C_2w = Moderate winter deficit, C_1a = Moderate winter surplus,
C_1w = Moderate summer surplus, C_1d = Little or no water surplus, Ds = Moderate winter surplus,
Dd = Little or no water surplus.

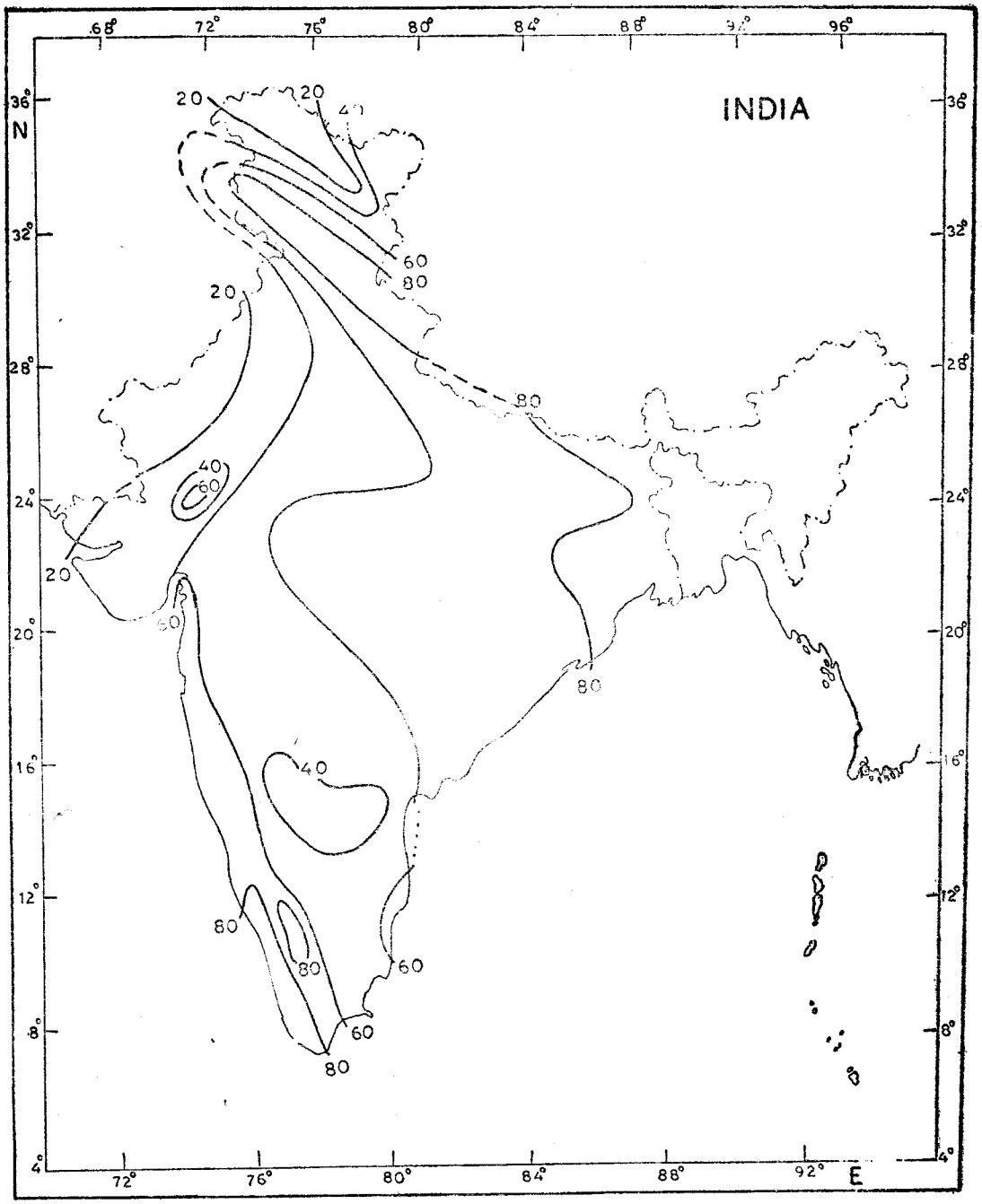


FIG. 4 INDEX OF MOISTURE ADEQUACY %

Mango

The mango *(Mangifera indica L.)* is the most important among the tropical fruits of India. Ripe mango is exceedingly refreshing to eat and is an excellent source of vitamins A and C. Mango is cultivated all over India and occupies an area of more than 6 lacs of hectares, which is more than 50 per cent of the total area under fruits.

Mango grows well in hnmid as well as dry climates found in different parts of India. However, it blossoms and fruits better in regions where there is good rainfall for four months from June to September, followed by a period of dry and rainless weather for eight months. It does not thrive well in the humid zone of West Bengal, Assam, Kerala and in the extrime south-eastern Tamil Nadu. Rain, fog or cloudy weather at the time of flowering from November to February prevents the setting of fruit and favours the development of pests and diseases. Where a mild, cool and dry season prevails duriug the normal flowering period of the mango, good yield can be expected. When young, the trees are damaged by frost. Summer temperatures ranging from 46°C to 50°C accomanied by strong winds may occasionally cause sunburn to the fruit. Hence it is necessary to plant the wind--breaks before planting the orchard, preferably Shisham trees *(Dalbergia sisso)*,Jaman (*Syzygium cuminit*), Red Sanders (*Pterocarpus santalinus*) etc. (Gangolly et al, 1957).

Mango requires a deep but well drained soil as it develops a deep and widely spread root system. The alluvial loam soils of the deltas of Ganga, Godavari, are krishna very much suitable for mango growing. The number of varieties of mango found in India is great and estimated at over thousand.

Mango can be propagated principally from seed. In order to ensure early bearing, productiveness and unformity, it is propagated vegetatively by inarching or budding, in situ in the nursery. Grafted plants are ready for trasplanting in the field after 6 to 12 months, and the beginning of the monsoon in low rainfall areas, and the end of the monsoon in heavy rainfall areas is the best time for planting. The grafted mango begins to bear fruit from the 4th or 5th year of the planting, depending on the variety. No systematic pruning is required except removal of diseased and over crowded branches. The time of flowering in different regions is greatly influenced by local weather conditions. Flowering takes place during December to January in peninsular India, and in the north, mango flowers late in January or in the beginning of the February or even as late as March in some sub-montane districts. Average dates of flowering of mango in India is given in Fig. 5 (Anon. 1957). Flowering continues in two or three distinct flushes and takes about 5 to 6 months for maturing.

To understand the effect of climate on mango at different phenological stages, the climatic data for two representative stations one in the north (Lucknow, U. P.) and the other in the south (Gannavaram, A. P), where mango is popularly grown in Fig. 6. Higher wind speeds are found at the time of flowering at Gannavaram than at Lucknow, indicating the need for construction of shelter belts. Also, the humidity is high in the south compared to the north, at the time of flowering. On the other hand, minimum temperature of about 9°C is observed at Lucknow with the danger of occurrence of frost in January, indicating need for adopting frost control measures.

The way in which water need is met or in short fall in the soil horizon at the two representative stations Lucknow and Gannvaram can be best illustrated by means of wata balance diagrms shown in Fig. 7. Although the water balance information relates to upper soil horizons to a depth of 30 cm, the significance of its contribution may be taken into account even though when considering perennial tree crops like mango, whose roots penetrate far below 130 cm level in quest of water, when surface

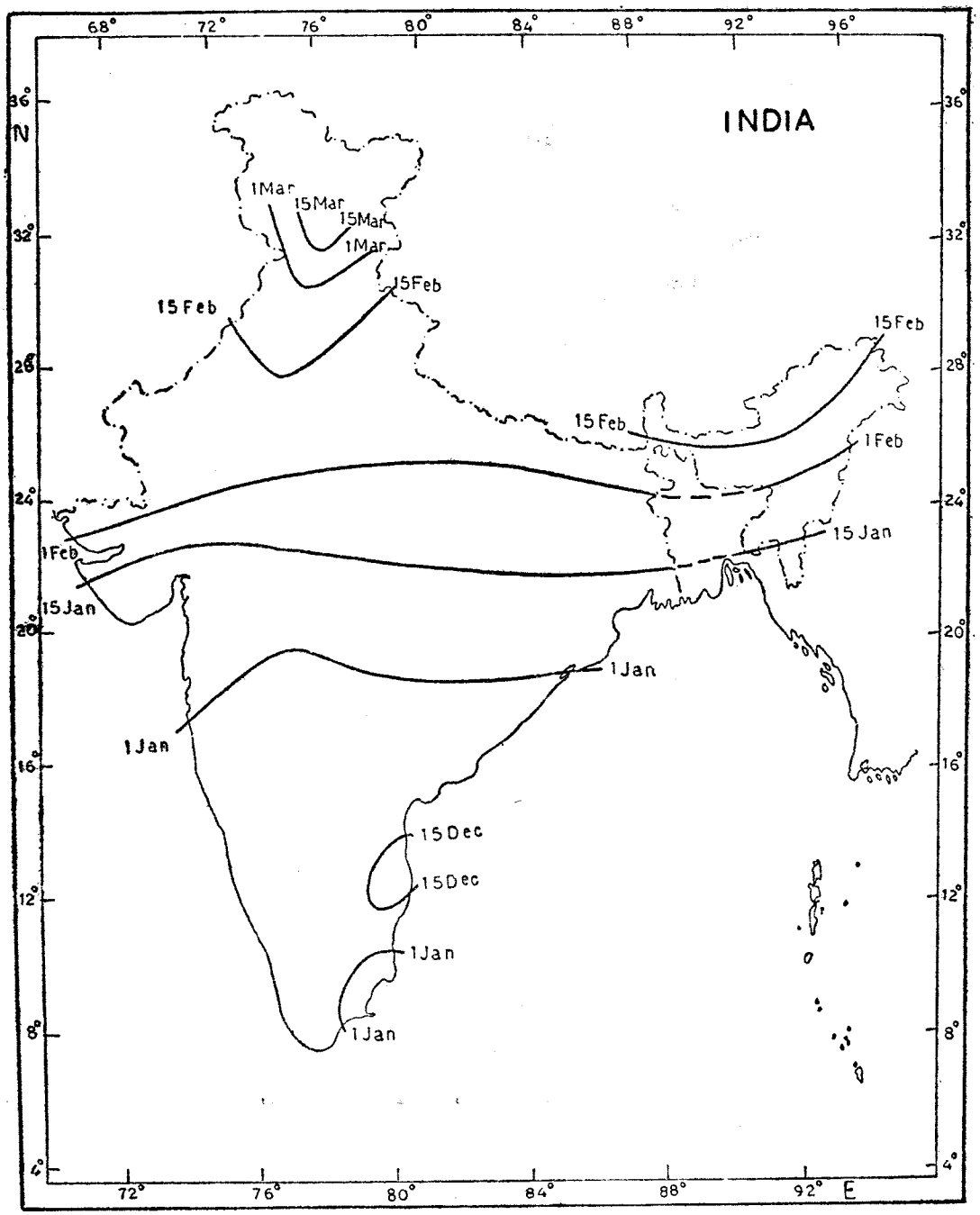


FIG. 5 DATE OF FLOWERING OF MANGO.

STATION : LUCKNOW (U.P.) N.INDIA

LAT. 26°52'N LONG. 80°56'E Mt. ABOVE M.S.L. 111 M

MONTHS		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
TEMP. °C	MAX.	23·3	26·4	32·9	38·3	41·2	39·3	33·6	32·5	33·0	32·8	29·3	24·8
	MIN.	8·9	11·5	16·3	21·8	26·5	28·0	26·6	26·0	25·1	19·8	12·7	9·1
VAPOUR PRESSURE mb	I	11·0	11·7	13·2	14·9	20·8	28·1	33·0	33·1	30·9	22·3	14·0	11·4
	II	12·6	12·1	11·9	13·5	17·6	25·6	33·4	33·4	30·6	24·3	16·2	13·6
RELATIVE HUMIDITY %	I	82	70	51	39	44	61	82	85	82	72	71	81
	II	55	43	28	23	27	45	76	79	74	60	55	58
WIND SPEED Km.p.h		2·3	2·9	3·7	4·0	4·4	4·9	4·0	3·3	3·0	1·7	1·6	1·7
RAINFALL mm		23·7	17·2	9·2	6·4	11·7	93·9	299·0	301·8	181·7	40·3	1·4	6·1
NO. OF RAINY DAYS		2·1	1·4	0·8	0·5	0·7	4·9	12·8	14·0	8·2	1·9	0·1	0·5
CLOUD AMOUNT oktas of sky	I	2·0	1·7	1·6	1·1	1·2	4·0	6·2	6·0	4·0	0·9	0·6	1·0
	II	2·0	2·0	1·6	1·2	0·9	2·8	5·7	5·5	3·8	1·5	0·6	1·3
CROP PHENOLOGY			FLOWERING					HARVEST					
				FLUSHES					FLUSHES				
									PLANTING				
STANDARD WEEKS		1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52											

I AT 08 30 Hrs I.S.T.

II AT 1730 Hrs I.S.T.

STATION: GANNAVARAM (A.P.) S.INDIA

LAT. 16°32'N LONG 80°48'E Ht. ABOVE M.S.L. 24 M.

MONTHS		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
TEMP. °C	MAX.	30·1	32·9	35·6	37·8	39·7	37·5	32·6	32·1	32·4	31·5	30·7	29·7
	MIN.	19·1	20·0	22·3	25·6	27·7	27·3	25·3	25·1	25·2	24·2	21·1	19·1
VAPOUR PRESSURE mb	I	21·3	23·3	27·1	30·0	29·7	27·1	28·7	29·0	30·1	29·1	22·7	20·8
	II	19·7	18·4	21·5	24·0	24·8	24·9	28·2	28·8	29·5	29·0	22·3	19·7
RELATIVE HUMIDITY %	I	74	77	76	72	65	64	79	79	81	81	70	71
	II	54	44	44	45	43	48	65	69	71	76	62	56
WIND SPEED Km P.h		9·8	9·3	10·7	12·5	15·5	17·6	16·2	15·3	11·1	9·0	10·2	9·4
RAINFALL mm		0·9	2·8	9·4	16·3	32·9	165·9	259·1	214·4	134·1	155·2	35·0	5·6
NO. OF RAINY DAYS		0·1	0·4	0·4	0·9	3·1	8·8	14·2	12·8	9·9	8·3	2·3	0·9
CLOUD AMOUNT (Okta of sky)	I	1·7	2·4	2·8	4·1	4·1	5·8	6·7	6·5	5·7	4·7	3·3	2·2
	II	1·9	1·8	1·6	2·6	4·0	6·1	6·7	6·9	6·4	5·7	4·0	2·7

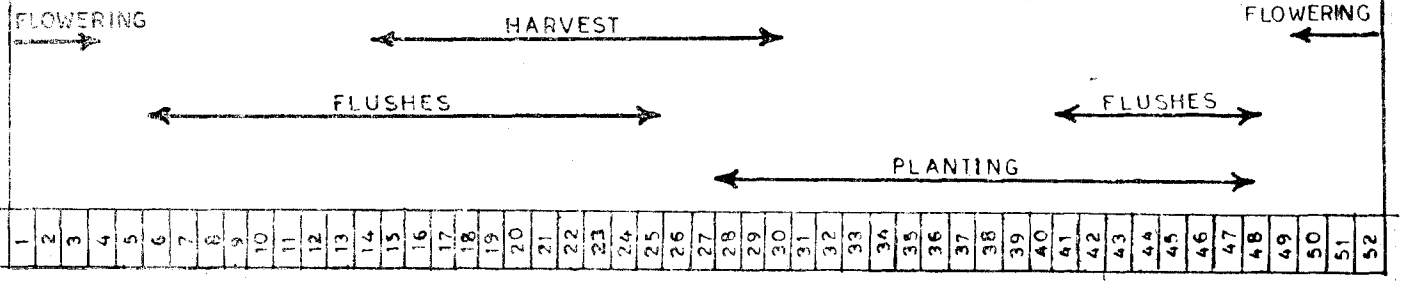


FIG. 6 CLIMATE AND MANGO IN INDIA.

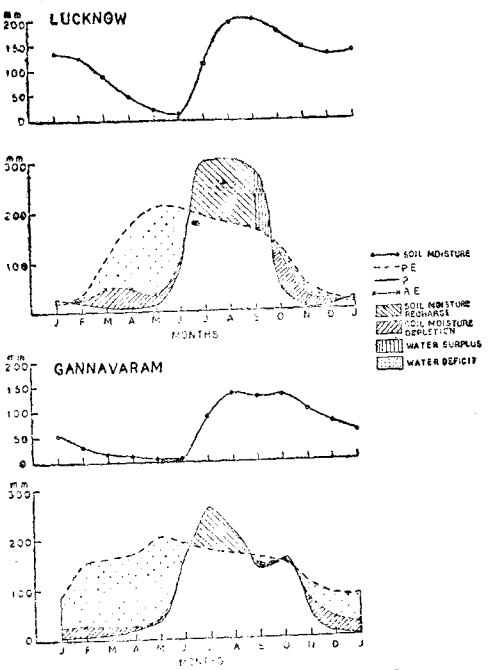


FIG.7 SOIL MOISTURE AND WATER BALANCE OF MANGO GROWING REGIONS

water resources are dry. The soil moisture status curves of Lucknow and Gannavaram in the field capacity zone have similar trends with low moisture levels in the first half and a higher moisture status level in the second half of the year beginning from June. The field capacity zone has been adopted as per the procedure laid by Thornthwaite (1957) for deep rooted orchards and garden crops.

Grapes

The grape is a sub-tropical fruit and is most delicious, refreshing and nourishing, containing a large proportion of sugars and useful minerals. It grows well in dry climate having a short sharp winter and a long dry summer. The grape does not generally thrive well in regions of humid summer, as moisture in the air during cropping season causes fungal diseases on the leaves and fruits.

Climate of many parts of India is not very suitable for growing grapes because of the wet summers due to heavy rains caused by the southwest monsoon from June to September. However in some parts of west and south India the cropping period can be made to coincide with the rainless part of the year by adopting special methods of culture. In the north, it is mainly grown in Punjab, Himachal Pradesh and Uttar Pradesh and it grows and fruits once a year in summer and rests in winter. In Maharashtra, Hyderabad Deccan the grape vine takes no rest and grows throughout the year and puts forth two crops. The crop produced as a result of the April growth, develops its fruits in the rainy season which greatly hinders formation of sugar in the berries, with the result that the crop practically has no market value. The produce of October growth which is followed by a cool, dry weather and then by a hot dry season, is the sweet marketable crop. The high temperatures and dry weather in the months of February, and March help formation of sugar in the berries. In South, the most important grape growing areas are near the foot of the Kodaikanal hills. Grapes are also grown in Krishnagiri in Tamil Nadu and Bangalore in Karnataka. The grape grows and fruits twice in a year, one crop of better quality and other of inferior quality, as in Decean.

The grape grows best on shallow medium light loamy soils with free drainage. Heavy soils are unsuitable. Several varieties of grapes are grown in India.

The grape is usually propagated by cuttings. The nurseries are made from the cuttings from one year old wood at the time of the pruning in February in north India, and are transplanted in January-February next year. Elsewhere in India, they are obtained from the prunings in October and planted in the nursery and are transplanted in January (Anon. 1980). The training and pruning of the vine are matters of the great importance and influence very largely all other operations from planting to harvesting. (Hayes, 1966). In north India

STATION: AMBALA (PUNJAB) N. INDIA

LAT. 30° 23'N LONG. 76° 46'E Ht. ABOVE M.S.L. 272M

MONTHS		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
TEMP. °C	MAX.	20·8	23·8	29·6	36·2	40·8	40·5	35·2	33·8	35·4	33·2	28·6	23·2
	MIN.	6·8	8·5	14·1	19·7	24·9	27·3	26·0	25·4	23·9	16·4	10·2	7·1
VAPOUR PRESSURE mb	I	9·3	10·2	11·9	12·8	15·7	22·7	31·0	30·6	27·5	17·4	10·8	9·4
	II	10·3	10·1	10·9	10·6	13·5	20·0	31·0	31·5	25·5	16·7	11·5	10·4
RELATIVE HUMIDITY %	I	79	73	61	41	36	49	78	82	80	68	68	78
	II	52	44	33	22	21	32	63	68	58	41	39	48
WIND SPEED Km.p.h		5·5	6·7	7·3	7·2	8·0	8·6	7·1	5·4	4·9	4·4	4·7	4·9
RAINFALL mm		42·0	51·8	28·2	11·9	15·2	72·0	271·6	249·5	168·2	27·3	6·4	14·7
NO. OF RAINY DAYS		3·0	2·7	2·0	0·9	1·6	3·9	11·0	10·1	6·1	1·5	0·2	1·3
CLOUD AMOUNT Oktas of sky	I	2·6	2·4	2·1	1·6	1·4	2·1	4·5	4·5	2·6	0·7	0·7	1·5
	II	2·6	2·4	2·1	1·8	1·6	2·1	3·8	3·9	2·4	0·7	0·7	2·0
CROP PHENOLOGY		PRUNING ↔				RIPENING ↔							
		TRANSPLANTING (Next year) ↔											
		NURSERY ↔											
STANDARD WEEKS		1 2 3 4	5 6 7 8	9 10 11 12 13	14 15 16 17	18 19 20 21	22 23 24 25	26 27 28 29	30 31 32 33	34 35 36 37	38 39 40 41	42 43 44 45	46 47 48 49	50 51 52

I AT 0830 Hrs. I.S.T.

II AT 17 30 Hrs. I.S.T.

STATION: HYDERABAD (A.P.) S. INDIA

LAT 17°27'N LONG 78°28'E Ht ABOVE M.S.L 545 M

MONTHS		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
TEMP °C	MAX.	28·6	31·2	34·8	36·9	38·7	34·1	29·8	29·5	29·7	30·3	28·7	27·8
	MIN.	14·6	16·7	20·0	23·7	26·2	24·1	22·3	22·1	21·6	19·8	16·0	13·4
VAPOUR PRESSURE mb	I	16·3	16·1	17·4	20·6	21·7	25·4	25·9	25·3	25·4	23·2	18·6	15·9
	II	14·5	14·5	14·8	17·8	19·9	23·8	25·6	25·1	25·2	22·0	17·1	13·8
RELATIVE HUMIDITY %	I	79	64	54	51	50	71	83	82	82	73	68	71
	II	36	35	30	31	33	54	69	70	71	58	48	42
WIND SPEED Km.p.h		8·1	8·9	9·6	10·9	12·4	23·8	22·1	18·3	12·6	8·9	8·0	7·4
RAINFALL mm		1·7	11·4	13·4	24·1	30·0	107·4	165·0	146·9	163·3	70·8	24·9	5·5
NO. OF RAINY DAYS		0·2	0·8	1·1	1·8	2·7	6·9	11·5	10·2	10·1	4·9	1·7	0·4
CLOUD AMOUNT Oktas of sky	I	2·4	2·2	1·6	2·5	3·5	5·8	7·0	6·6	5·7	4·1	3·5	2·5
	II	2·1	2·1	2·1	3·7	4·4	6·2	7·0	6·7	6·4	4·8	3·7	2·5

CROP PHENOLOGY

RIPENING

PRUNING

TRANSPLANTING

NURSERY

STANDARD WEEKS 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52

FIG. 8 CLIMATE AND GRAPE IN INDIA.

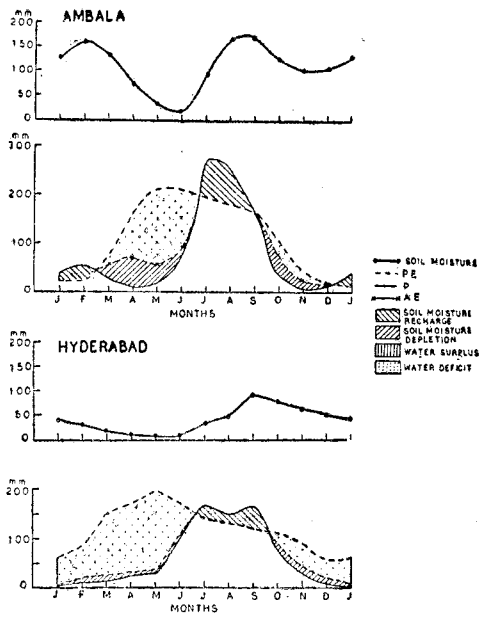


FIG.9 SOIL MOISTURE AND WATER BALANCE OF GRAPE GROWING REGIONS.

pruning is done once a year in the month of February and fruit is ripened in May-June. In Hyderabad pruning is done in October-November and the crop is harvested by March-April. In south India, pruning is done in May-June and December-January, and harvested in October-November and March-April respectively, later being the best.

The climatic data of Ambala (Punjab, north India) and Hyderabad (Andhra Pradesh, south India) are presented along with different growth phases of grape in Fig. 8. The grapes at Hyderabad are found to ripen at lower temperature and higher humidities compared to the ones grown at Ambala.

Fig. 9 shows the climatic balance for Ambala and Hyderabsd, which show greater water deficiency at Hyderabad as compared to Ambala. The soil moisture status curves also indicate poor water profile at Hyderabad when compared to Ambala.

Cashew

The cashew which was introduced into India in the 16th century is an important commercial crop grown both for its fruit (cashew apple) as well as for its nuts. Its juice is good and is a fairly good source of vitamin C. India is the largest producer of rawnuts in the world and efforts are being made to improve the crop by studying in depth all aspects of cultivation management, technology and marketing of cashew (Hameed Khan, 1979). The cashew is ordinarily a rather small, spreading tree although it may reach a height of 40 ft. A mild tropical climate is most suitable for cashew cultivation. Since cashew cannot tolerate the severe winters and summers of north India, it is chiefly grown in the coastal areas of peninsular India. It is tolerent to all soils, but does best on deep loam.

It is propagatd through seed. The seeds are sown in the month of May or June with the first showers. In a majority of the cashew growing areas of India, there is no further field operation. The first bearing is normally secured in about four years after planting and attains the full bearing age by 9th or 10th year. The flowering starts in the month of November and extends up to February. Crop is harvested from March to May. A heavy monsoon rainfall helps in good crop setting, while cloudy weather and rains during flowering, generally spoil the crop.

The climate and crop phenology of cashew at Cochin and Visakhapatnam and their water balances are shown in Figs. 10 and 11. It can be seen from the figures that the availability of abundant soil and groundwater supplies due to heavy rainfall in the preflowering season at Cochin makes it the best cashew producing region in India, whereas at Visakhapatnam the deficiency of water can be clearly seen from the water balance. The soil moisture status curves also indicate a high level of availability at Cochin as compared to Visakha patnam.

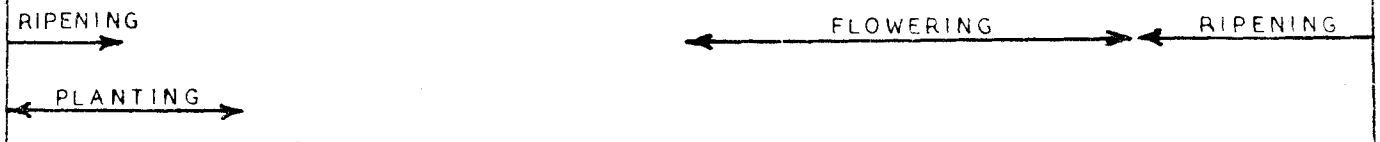
Vegetable Crops

Vegetables are the essential items of food

STATION: VISAKHAPATNAM (A.P.) EAST COAST. LAT. 17°43N LONG. 83°14 E Ht. ABOVE M.S.L. 3M

MONTHS		MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR
TEMP °C	MAX	34·0	33·7	31·7	32·0	31·6	30·9	29·3	27·7	27·7	29·2	31·2	32·8
	MIN	27·8	27·4	26·0	26·0	25·6	24·5	21·2	18·3	17·5	19·3	22·6	25·9
VAPOUR PRESSURE mb	I	35·8	36·3	33·9	34·1	33·3	30·3	23·5	21·3	22·1	24·6	27·9	32·4
	II	37·6	37·2	34·2	34·8	33·7	30·7	25·1	23·1	24·6	26·1	27·9	34·6
RELATIVE HUMIDITY %	I	75	80	84	82	81	78	68	70	77	77	74	73
	II	83	83	82	83	84	79	73	74	78	73	71	80
WIND SPEED Km.p.h		15·9	13·7	16·5	13·5	9·5	8·1	8·1	7·5	6·3	6·4	9·6	14·7
RAINFALL mm		53·5	87·8	121·9	132·2	167·3	259·3	90·6	17·5	7·2	14·9	8·7	12·7
NO. OF RAINY DAYS		2·5	6·1	8·5	7·2	9·6	9·0	3·2	0·9	0·6	0·9	0·6	1·0
CLOUD AMOUNT oktas of sky	I	4·4	6·1	6·9	6·4	5·8	4·5	3·5	2·5	2·0	2·1	2·1	3·1
	II	4·7	6·5	7·0	6·5	6·4	5·2	3·7	2·7	2·0	1·7	2·2	3·9

CROP PHENOLOGY



STANDARD WEEKS	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18

I AT 08 30 Hrs I.S.T

I I AT 1730 Hrs I.S.T.

STATION: COCHIN (KERALA) WEST COAST

LAT. 09° 58N LONG. 76° 14E Ht ABOVE M.S.L. 3 M

MONTHS		MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR
TEMP. °C	MAX	30·9	29·0	28·1	28·1	28·3	29·2	29·8	30·3	30·6	30·7	31·3	31·4
	MIN	25·7	24·1	23·7	24·0	24·2	24·2	24·1	23·5	23·2	24·3	25·8	26·0
VAPOUR PRESSURE mb	I	31·3	29·9	29·2	29·3	28·7	28·9	27·6	24·2	22·2	25·5	28·4	30·3
	II	32·0	30·1	29·6	29·7	29·4	29·3	28·1	25·5	25·0	27·4	30·0	31·5
RELATIVE HUMIDITY %	I	81	88	89	88	84	83	78	71	68	72	74	75
	II	78	84	87	86	84	80	74	66	64	68	70	74
WIND SPEED Km.P.h		10·9	9·1	9·6	9·9	9·1	7·8	6·7	7·1	8·0	9·3	10·6	10·7
RAINFALL mm		364·3	155·9	571·9	385·7	234·8	332·7	183·7	36·8	9·6	34·2	50·0	139·5
NO. OF RAINY DAYS		12·8	25·0	23·9	19·3	14·1	14·3	8·9	2·1	0·6	1·6	2·6	7·5
CLOUD AMOUNT oktas of sky	I	6·3	7·3	7·2	6·9	6·2	6·0	5·2	4·2	3·4	3·7	3·8	5·2
	II	6·3	7·2	7·2	7·0	6·4	6·7	5·7	4·4	3·2	3·2	3·6	5·3

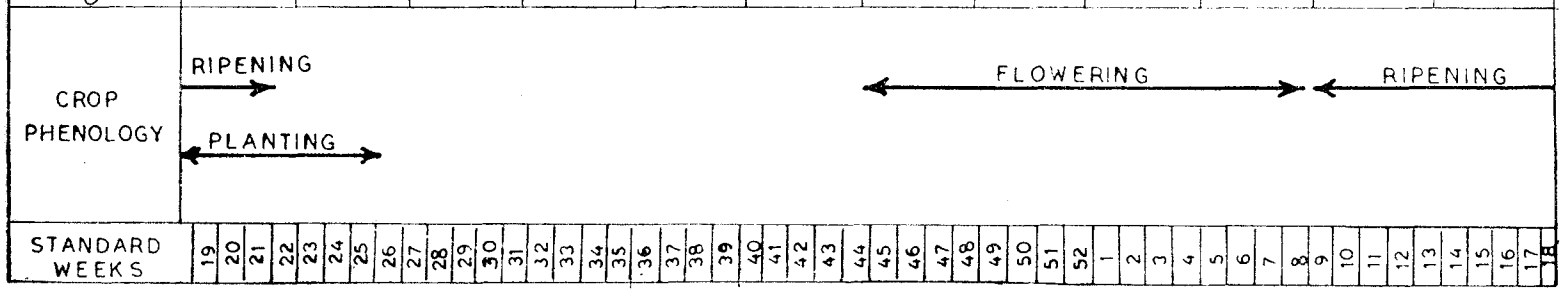


FIG.10 CLIMATE AND CASHEW IN INDIA.

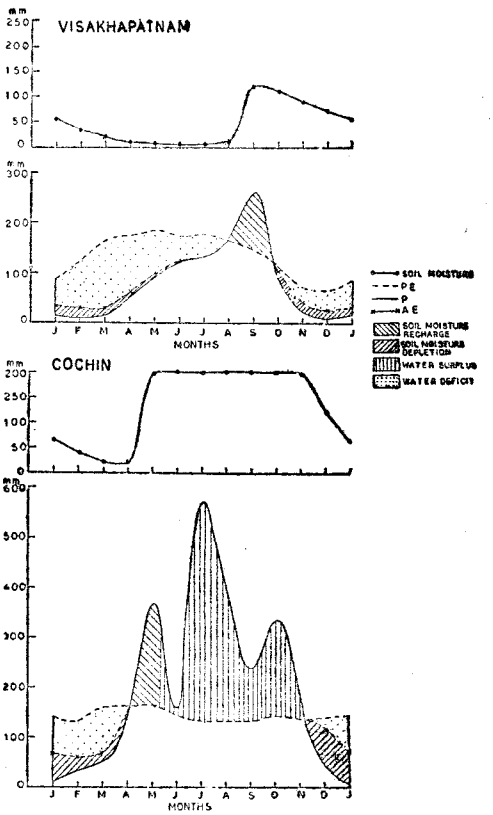


FIG.11 SOIL MOISTURE AND WATER BALANCE OF CASHEW GROWING REGIONS

and play an important part in human nutrition as they are rich source of proteins, carbohydrates, fats, minerals and vitamins. According to the latest information available, the area under vegetables is of the order of 2.5 percent of the total cropped area in the country (Katyal, 1977). Being a tropical country, India with varied types of climates has a great potential to develop vegetable crops, which at present are very inadequate being only about one-fourth to one-third of the requirement. The influence of climate on different vegetables is predominent in different regions of the country. The crop weather calendar of some Important vegetables that are grown in south India with recommended varieties is given in Table II Climate and potato crop in India alone is discussed in this paper as information on other crops is scanty.

The potato is one of the most important tuber crops grown in India. It is a native of South America and was introduced in India by Portugese in the 16th century. It is grown both in the plains and in the hills up to an altitude of 9000 ft.

Potato is adopted to a wide range of climatie conditions. However It thrives best in the cooler regions and is grown as a summer crop in the hills and as a winter crop in the plains. A temperature of 18° to 20° C is best for its growth. Low temperatures and adequate moisture are important for the tuber formation. Light loamy soils in humus are best suited for potatoes. Potatoes do not grow well on clay soils, as they are not well drained and the tubers are very sensitive to excess of moisture.

Table II

Vegetable Calendar

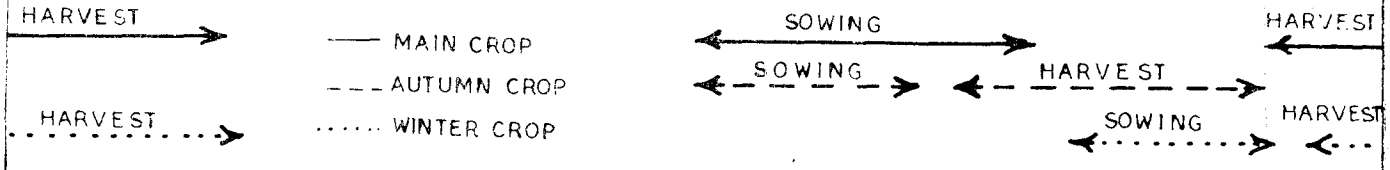
No.	Crop	Variety	Sowing time	Planting time	Period of harvest
			Summer vegetables		
1.	Brinjal	Pusa purple long, Pusa purple round, Some recent high yielding varieties. Araka sheel (PPL). Arka Shcrish (GL) Arka Kusmakar (GLC)	February–March May–June september-October	March–April June–July October-November	3-4 months after transplanting
2.	Bhendi	Pusa Sawani, Pusa Makhamali	January-March June-July September-October	–	3-4 months
3.	Cluster beans	Pusa Navabahar P. Sada bahar P. Mosania	March-April June-July December-January	–	2 months
4.	Bottle gourd	Pusa summer, Proli fic long, Pusa summer, Prolific round	February-March June-July October-November	–	3-4 months
			Kharif (Rainy season) vegetables		
1.	Cauli-flower	Pusa kathki (Early D-96) Snow ball (Late)	June-July July-August September-October	July-August August-September October-November	3-4 months
2.	Tomato	Pusa Ruby Pusa Early dwarft, Mareglobe Sioux-Pusa Red Palm	June-July October-November	July-August November-December	3-4 months
3.	Snake gourd	Stout and short time Long white type	May-June October-November February-April	–	3-4 months
4.	Pumpkin	Large Red Large Round, Yellow flashed Red flashed Arka Suryamukhi, Arka Chandan	Jan-Mar June-July December-January January-March June-July	–	3 months
			Rabi (or) Winter vegetables		
1.	Potato	Lankar Chandermukhi Great scot '	October-November	–	2 months
2.	Cabbage	Golden Acre Pride of India	August-October	September-November	3 months
3.	Carrot	Puja Kyar, Nanteb, Barly gem	August-November		2 months
4.	Beet-root	Early wonder Crimson Globe Detriot Dark red	October-December	–	2 months

STATION: MAINPURI (U.P.) N. INDIA

LAT. 27°14'N LONG. 79°03'E Ht. ABOVE M.S.L. 157 M

MONTHS		MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB
TEMP. °C	MAX.	32·5	38·5	42·2	40·9	35·0	33·1	33·7	34·0	30·0	24·8	22·7	26·0
	MIN.	14·9	20·9	26·2	28·6	26·7	25·9	24·7	18·9	11·7	8·2	7·7	10·1
VAPOUR PRESSURE mb	I	12·4	13·8	17·7	25·2	32·6	32·6	29·9	20·5	12·3	10·4	10·3	11·1
	II	11·7	13·0	15·6	22·8	32·4	32·3	30·3	21·3	14·1	12·5	12·3	11·8
RELATIVE HUMIDITY %	I	52	37	35	51	79	85	80	67	63	75	80	70
	II	29	23	23	37	69	76	69	50	44	52	53	40
WIND SPEED Km.p.h.		4·7	4·9	5·8	6·2	4·7	3·8	3·7	2·4	2·2	2·3	3·0	3·9
RAINFALL mm		11·6	5·6	10·7	64·2	196·4	247·3	151·9	40·2	2·2	5·5	17·4	8·9
NO OF RAINY DAYS		1·1	0·7	0·9	3·4	9·9	12·1	7·2	1·3	0·2	0·6	1·9	1·0
CLOUD AMOUNT Oktas of sky	I	1·9	1·4	1·4	3·5	5·8	5·9	3·7	1·1	0·7	1·5	2·5	2·2
	II	2·2	1·8	1·5	3·5	5·7	5·4	3·9	1·2	0·8	1·8	2·4	2·3

CROP PHENOLOGY



STANDARD WEEKS

10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 1 2 3 4 5 6 7 8 9

I AT 0830 Hrs. I.S.T.

II AT 1730 Hrs. I.S.T.

STATION: OOTACAMUND (T.N.) S. INDIA

LAT 11°24'N LONG 76°44'E Ht ABOVE M.S.L. 2249M

MONTHS		MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB
TEMP °C	MAX	21.9	22.1	21.8	18.0	16.4	17.3	18.2	18.7	18.9	19.7	19.9	20.6
	MIN	8.4	10.2	11.2	11.1	10.9	10.9	10.4	10.0	8.3	6.3	5.1	6.3
VAPOUR PRESSURE mb	I	8.9	11.8	13.5	13.8	13.7	13.7	13.2	13.3	11.8	9.1	8.0	8.5
	II	11.4	13.8	15.0	14.4	14.2	14.4	14.3	14.4	13.2	12.0	11.5	11.3
RELATIVE HUMIDITY %	I	61	71	76	88	91	91	88	86	82	72	67	67
	II	56	68	75	85	89	88	85	85	80	71	66	60
WIND SPEED Km.p.h		4.2	3.9	4.2	10.0	10.9	8.9	6.5	3.4	3.0	3.2	3.2	3.3
RAINFALL mm		29.5	108.5	172.6	139.2	176.6	128.2	109.7	213.3	126.5	59.1	25.8	12.0
NO OF RAINY DAYS		2.0	7.5	10.8	11.4	14.8	11.4	8.4	13.6	8.3	3.3	1.5	1.0
CLOUD AMOUNT Oktas of sky	I	1.5	2.9	4.1	5.8	6.5	6.1	5.0	4.5	3.9	2.6	1.8	1.7
	II	3.5	5.3	5.6	6.7	7.1	7.0	6.5	6.3	5.5	3.9	3.2	3.5

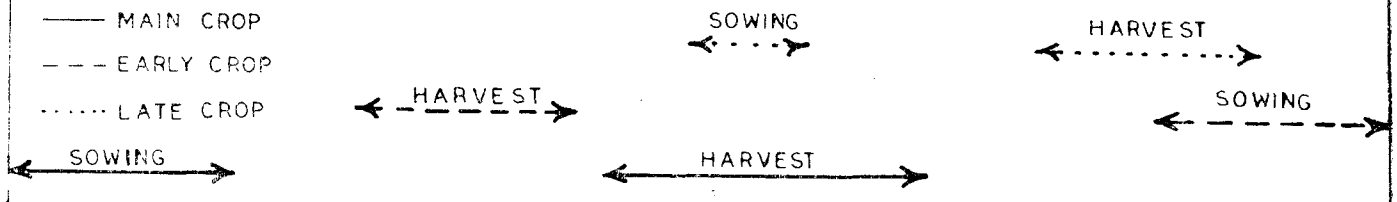


FIG.12 CLIMATE AND POTATO IN INDIA.

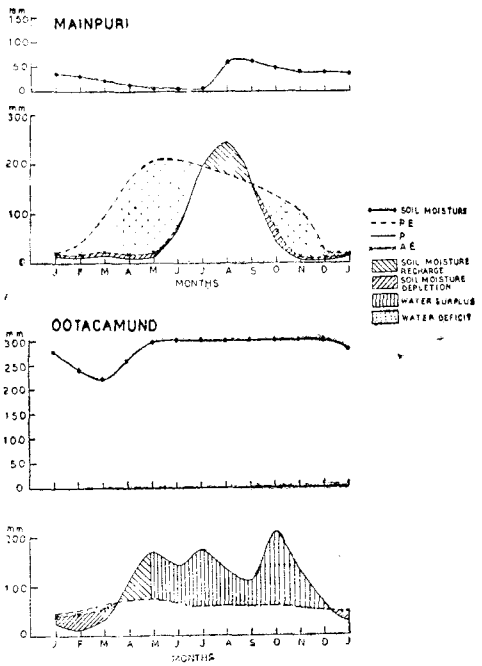


FIG.13 SOIL MOISTURE AND WATER BALANCE OF POTATO GROWING REGIONS.

In India, potato is grown in many parts of the country, and the major producing states are Uttar Pradesh, Bihar, West Bengal Assam, Gujarat, Punjab, Maharashtra, Karnatka, andl Tamil Nadu. The bulk of the seed potato is produced in Himachal Pradesh. The yields vary from 9 to 12 tonnes/ha in Bihar, Uttar Pradesh and West Bengal and from 4 to 5 tonnes/ha in other states. Yields as high as 25 tonnes/ha are obtained in Gujarat because of better crop management. The average yield in India is 9 tonnes/ha.

In the north Indian region it is possible to grow potatoes twice in a year first in summer and the second in the autumn. The summer crop is planted early in the spring (end of the January to end of the March) and harvested 4 or 5 months later. The autumn crop is planted in July to August and harvested in winter. Some times the antumn crop is being killed by the frost several weeks before it is due to ripen, and hence there is a need for frost control measures. In the plains of north India the sowing time can be extended from mid-September to almost mid-January. In the Punjab, Rajasthan, Delhi, Western Uttar Pradesh and south India two crops in succession, can be raised. In the Nilgiri hills in south India three crops are raised in succession, the planting times being April, August, and January.

Potato varieties in India are broadly divided both by farmers and the trade in the two sharply divided groups: (1) The Vilaiti (European) potatoes and (2) the Desi or country varieties. The former is also alternatively known as Pahari or hill potatoes, because of the fact that they are extensively cultivated in the hill regions.

The Desi varieties are cultivated mainly the plains and appear to owe their popularity to their ability to withstand heat and drought and to some extent diseases, especially those caused by the viruses, which are common in the plains.

Climate and potato crop in India at the two representative stations selected from North and South India, Mainpuri in Uttar Pradesh and Ootacamand in Tamil Nadu (Fig. 12) show cultivation of three crops in both the regions. The phenological calendar is illustrated in the figure. Ooty being located in the Nilgiries suffffers from lower temperature compared to Mainpuri which is almost on the plains and hence the potato crop takes graeter time to reach harvesting at Ooty for all the three crops.

The water balance shown in Fig.13 indicates almost eight months of water surplus from end of April to beginning of January at Ooty, whereas Mainpuri suffers from water deficiency throughout the year except in the months of June to September. The soil moisture profiles also show a poor status at Mainpuri and a very rich one at Ooty ; however potato is densely grown in Uttar Pradesh where Mainpuri is situated, in entire India indicating the suitability of a low soil moisture profile for growing potatoes.

In this paper an attempt has been made

Table III

Climate and Horticultural Crops at Selected Stations in India

S. No.	Station	Climatic water need (Thornthwaite mm.)	Rainfall mm	Moisture index % Im	Moisture adequacy % Ima	Summer concentration % S. C.	Climatic type: Thermal Type	Thermal Subtype	Moist Type	Moist Subtype	Crop	Popular varieties
1.	Lucknow (UP)	1483	992	-33.1	65.6	39.9	A' Megathermal	a'_3	C_1 Dry subhumid	d	Mango	Langra Duschri, Malda
	Gannavaram (AP)	1800	1031	-42.7	57.3	30	A' Megathermal	a'_7	D semi-arid	d		Banganapalli, Suvarnarekha
2.	Ambala (Punjab)	1400	959	-31.5	68.5	41.4	A' Megathermal	a'_2	C_1 Dry subhumid	d	Grape	Blac prince
	Hyderabad (AP)	1473	764	-48.1	51.9	35	A' Megathermal	a'_5	D semi-arid	d		Anab-e-shahi
3.	Visakhapatnam (AP)	1641	975	-40.6	59.4	31.9	A' Megathermal	a'_6	D semi-arid	d	Cashew	
	Cochin (Kerala)	1695	2501	+47.6	84.0	28.3	A' Megathermal	a'_8	B_2 Moist-humid	s		
4.	Mainpuri (UP)	1489	762	-48.8	51.2	39.6	A' Megathermal	a'_3	D semi-arid	d	Potato	The vilaiti, Phulwa, Darjeeling Red-Round
	Ooty (Tamil Nadu)	706	13038	+84.6	98.2	29.5	B' Megathermal	a'_8	B_4 humid	r		Gola

to present the impact of climate on fruit and vegetable crops grown in India. Detailed discussion has been made to the extent information is available for mango, grape and cashew among fruit crops, and potato in vegetable crops. The agro-climatic zones, the areas of frost occurrence, the hours of bright sunshine, moisture adequacy as derived from climatic water balance data and soil moisture status have been discussed. Detailed information on crop yields on an year to year basis along with crop weather records are not available. It appears that such data is not being collected. India will do well to establish crop weather stations with emphasis on horticultural crops all over the conntry to obtain detailed phenological records and to obtain the effect of weather on crop yields, occurrence of pests and diseases. Collection of such information will facilitate evolving of suitable forecast formations for the benefit of the farmer and timely advice in various phases of horticultural operations. A beginning in this direction is the urgent need for horticultural development.

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Address of the authors

A. R. Subramaniam, A. V. R. Kesava Rao, K. Bhaskara Rao ; Deptt. of Meteorology and Oceanography Andhra University, Waltair.