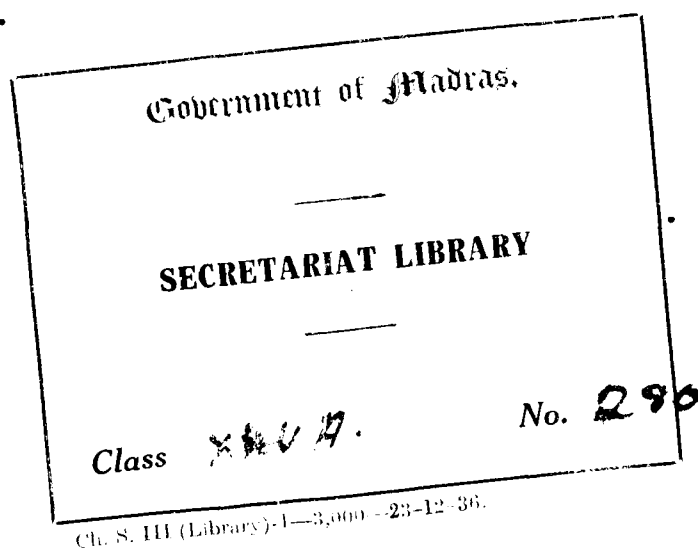


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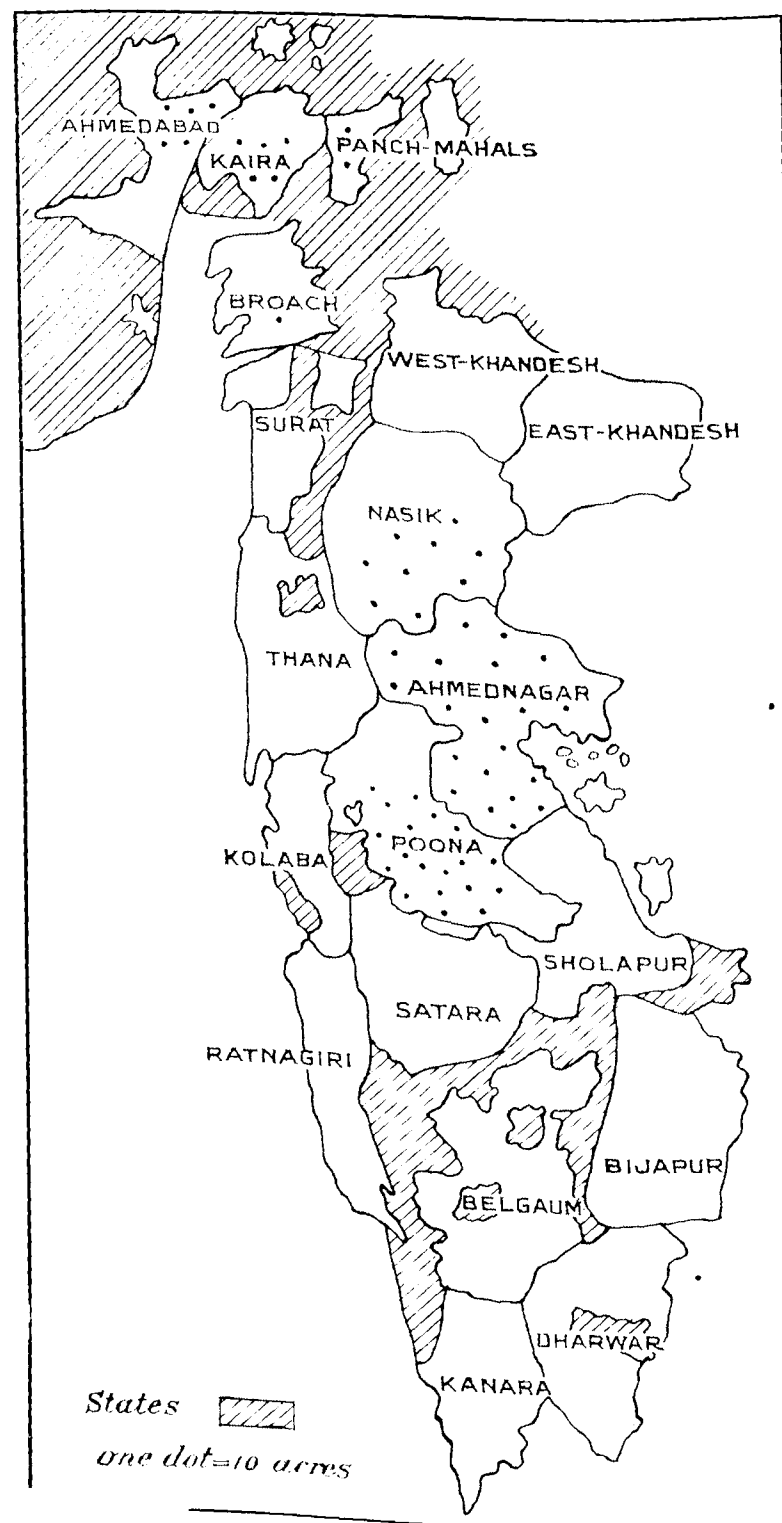
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BOMBAY PRESIDENCY PROPER SHOWING THE DISTRIBUTION OF THE PAPAYA CROP.

(To face page 1)

PAPAYA CULTIVATION IN THE BOMBAY PRESIDENCY.*

CHAPTER I.

INTRODUCTION.

Papaya (*Carica Papaya*) though an exotic plant has come to occupy a prominent position among the fruit crops of the Bombay Presidency. Its popularity is increasing day by day because of its quick and cheap production. It is one of the best paying crops in the market at present. Its gradual extension is due to the fact that it is easy to cultivate. It adapts itself to a diversity of soil and climatic conditions. It is not subject to any serious insect pests or diseases. If once the plantation is established no special skill on the part of the grower is required. The quantity of water required by it is low as compared with the other crops such as the banana. Low growing vegetables may be profitably grown with it as an inter-crop till its plantation covers the whole space. It may also itself be used as an inter-crop in young mango and other plantations without harm to the main crop.

The main limitation in the rapid extension of its cultivation is the lack of irrigation facilities. There is, however, great scope for its cultivation being extended in the canal zones. The Baramati tract is ideally suited for papaya, provided some arrangements are made for transporting it, as it needs care in handling.

There is no literature available on the subject giving detailed information suited to our own conditions. To meet this deficiency and to guide our growers for its more successful cultivation the following pages are written from experience gained and information collected from the Ganeshkhind Botanical Gardens, Kirkee, and the Modi-Bag, College of Agriculture, Poona. Our special thanks are due to Mr P. G. Joshi, the Superintendent of the Ganeshkhind Botanical Gardens, Kirkee, for making useful information available from the garden records for compilation in this Bulletin.

CHAPTER II.

DISTRIBUTION OF THE PAPAYA IN THE BOMBAY PRESIDENCY.

The following figures give an idea of the distribution of the crop in the districts of the Presidency :—

Districts	Acreage		
	1925-26	1926-27	1927-28
Poona	183	173	215
Ahmednagar	126	231	237
Nasik	83	105	87
Kaira	61	27	64
Ahmedabad	40	80	44
Broach	13	8	19
Panch Mahals	11	32	33

*(Excluding Sind).

District	Acreage		
	1925-26	1926-27	1927-28
West Khandesh	6	6	21
Sholapur	4	4	8
East Khandesh	..	12	27
Thana	..	3	14
Bombay Suburban	..	..	6
Total ..	527	681	775

The most important centre of cultivation in the Deccan is the Poona District though Ahmednagar and Nasik have fairly large areas under it. It is also grown in certain districts of Gujarat. Its regular cultivation is practically absent in the Karnatak and Konkan districts though isolated plants can be seen here and there. In addition to the scarcity of water supply the other limiting factor is the lack of dissemination of good varieties like the Washington or the Gujarat variety. Some people have also a prejudice against eating this fruit. If these hindrances and prejudices are overcome and transport facilities improved we believe that there is every possibility of the cultivation of the papaya being extended by leaps and bounds.

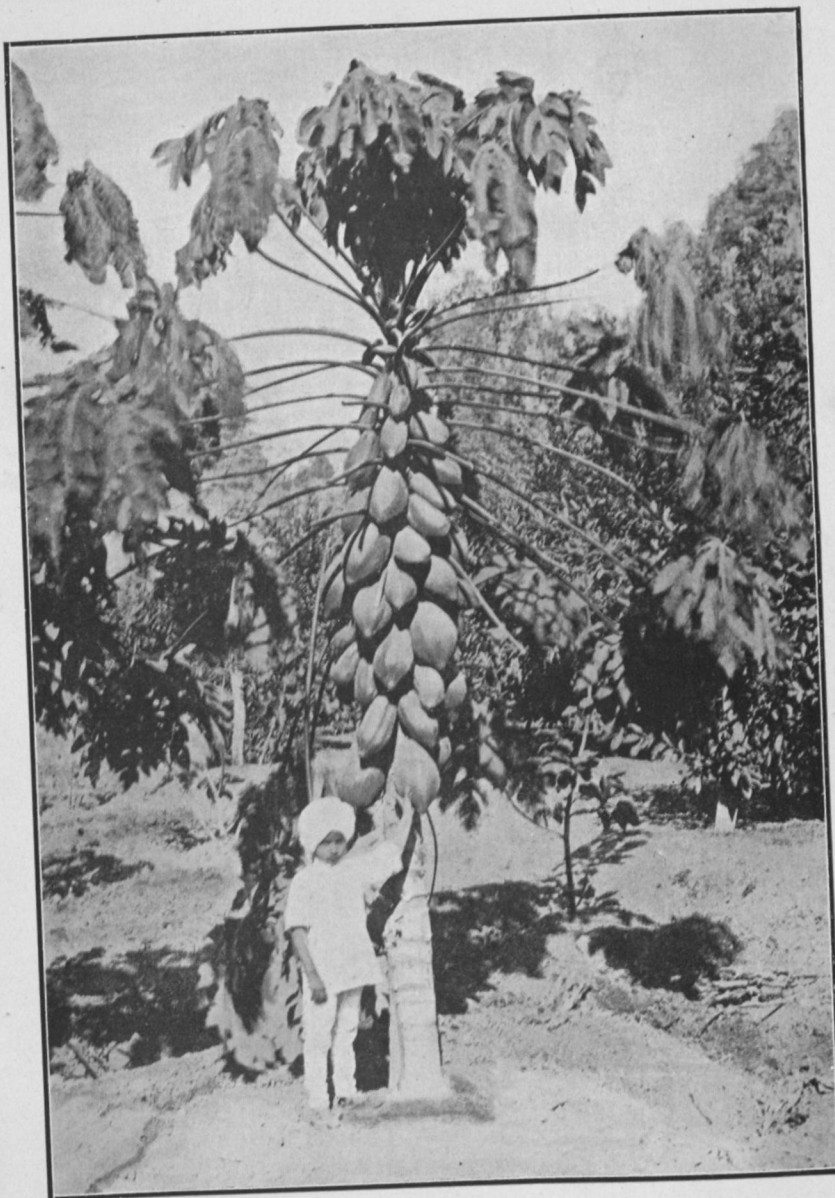
CHAPTER III.

CLIMATE AND SOIL.

The papaya is purely a tropical plant and as such requires a warm climate for its successful growth. The climate in the Presidency where no excessively low annual temperature occurs suits the cultivation of the papaya. In Poona on the 1st of February 1929 frost occurred only for a day causing the foliage of the papaya plants to wither and to droop (*vide* plate I). The temperature in the Deccan, in the cold weather, may go fairly low, the mean minimum for Poona in the month of January being 50°F. The lack of sufficient warmth in the atmosphere in this season, it is observed, retards the process of maturing and ripening of the fruits and to a certain extent the growth and setting of fruits also. Sufficiently warm and uniform temperature seems to suit it best. Dry climate with a little amount of rainfall, it seems, tends to add to sweetness of the fruit.

Soils.—Since the papaya is an evergreen plant and bears flowers and fruits for the most part of the year it is evident that it requires a good retentive soil. It may grow in poor soils with heavy manuring and watering. It grows in well drained black, medium black, alluvial and laterite soils of the Presidency. But in deep soils which are clayey in nature it does not thrive well. For instance in Khandesh, Nasik and Poona districts plants grown on such sticky soils have not given satisfactory results. Plants grown in poor limy soils give few and small fruits.

The plant is very susceptible to water stagnation round the stem and hence requires thorough drainage. The tissues of the stem are succulent and spongy. The stem easily absorbs water and begins to rot if water



EFFECT OF FROST ON THE PAPAYA TREE.

[To face page 2]

logging due either to heavy and continual rains or to heavy applications of water in ill-drained soils. The unhealthy condition of the tree is at once recognized by the foliage turning yellow and by the dropping of lower leaves prematurely. The tree thus makes a lanky growth. Under the circumstances papayas must be grown on soils having a well-drained substratum and precautions must be taken to drain off the excess amount of water either during heavy rains or heavy applications of water.

It has also been observed that the growth and vigour of the plant varies according to the depth and the richness of the soil. On shallow soils having a substratum of murum the growth of the plant is stunted and the life is short. On the whole it may be stated that the papaya likes a rich and thoroughly drained soil.

CHAPTER IV.

PROPAGATION.

Collection of seeds.—The most common method of propagation is by seeds. For this purpose, well matured big fruits borne on female plants are collected and are preserved in a safe place. When they completely ripen they are cut open and the inside seeds are carefully taken out on a tray. Then they are washed to remove the pulpy matter adhering to them. Finally they are dried in the sun and are stored in the bottles or in clean and air-tight tins, till they are used for sowing purposes. The seeds are viable for many months if they are carefully preserved from insect attacks.

Time of raising seedlings.—The best time to raise seedlings is the monsoon, i.e., from the 15th of June to the end of October or November. Any sowing afterwards will not give satisfactory results. Many seeds will then not germinate and the growth of the seedlings that do appear will be hindered by the coldness of the season. Similar will be the result on account of excess of heat if the seeds are sown in the hot weather. The moist hot climate of the monsoon favours the rapid germination of the seeds.

Preparation of seed beds.—If the seedlings are to be raised on a commercial scale, they are grown in beds on the ground. For this purpose the site selected is dug or ploughed and then made friable by keeping it fallow for some time. After making it perfectly level, raised beds of convenient size, say 6' × 3', are made 6" above the ground. Over them a layer of river soil 3" deep, mixed with half the quantity of leaf mould and farm yard manure, is spread and the whole thing is made perfectly level.

Sowing of seeds.—The seeds are sown half an inch deep and one inch apart and watered gently with a can having a fine "rose". If there be a likelihood of heavy rain or excessive sunlight the beds should be protected by thatches. The seeds take three to six weeks for germination, which may be hastened by moist heat. After about a month when the seedlings attain a height of nine inches or one foot they are fit for transplanting into their permanent places. If planted at eight feet distance the number of seedlings required is nearly 700 per acre. Two seedlings are generally planted in each place. Therefore the number

of seedlings required will be double, *i.e.*, 1,400. Four to six ounces of seeds will be quite enough for raising seedlings sufficient for one acre.

Seedlings raised in beds on the ground do not stand transport for more than two days. In the circumstances it is better always to raise them in flats or boxes. While taking out the seedlings even for local planting, much damage is done by the rupture of the roots. It is always safe to plant the seedlings raised in boxes. A suitable size of the box will be $2' \times 1\frac{1}{2}' \times 9"$. They can be properly handled and transported.

Vegetative method of propagation. The papaya can also be propagated vegetatively by cuttings and by grafts. By doing so uncertainty as to the sex of the plant can be got over, but it remains to be seen whether the methods employed will be economic and practicable ones. The papaya plant does not freely give branches. The few branches fit for taking cuttings are hollow and when planted, absorb water and instead of producing roots, begin to rot. So the cuttings are generally prepared with "heels" attached to them. That means one cutting for one branch only. Besides the time taken for the formation of the roots is long in ordinary weather conditions. The method is laborious and costly. Looking to the large number of plants—nearly 700 for one acre—and to the short life of the plantation, *i.e.*, from two to three years, vegetative propagation will be uneconomic and unsuccessful. The question of how to eliminate uncertainty as to sex has been dealt with in a subsequent chapter. For similar reasons to raise stock by grafting will not be a commercial process for the present.

CHAPTER V.

VARIATIONS IN THE PAPAYA FLOWERS AND CHANGE OF SEX.

In the case of papaya, the problem of sex is a very complicated one. To understand it thoroughly, a knowledge of the study of papaya flowers is essential. It is not necessary to go into the details in a popular bulletin like this. However for those who are interested the following classification¹ of papaya plants according to their flowers will be of use:

1. *Diocious pistillate*: with large female flowers only on the stems in the leaf axils. This is the normal female plant.
2. *Diocious staminate*: with long narrow tubular flowers arranged on long branching peduncles growing from axils of leaves. This is the normal male plant.
3. *Andromonoecious*: male and hermaphrodite flowers on long peduncles.
4. *Polygamous*: (A) male, female and hermaphrodite flowers on the same long peduncles.
5. *Polygamous*: (B) with male, female and hermaphrodite flowers on the same plant, the latter being of two types: one with 10 stamens and the other with 5 stamens: the flowers give long fruits.
6. *Males*: (A) with male flowers on short peduncles directly in the axils of the leaves.
7. *Males*: (B) on long peduncles with many hermaphrodites.

¹ Gamble and Patwardhan—Bulletin No. 30 of 1908 of the Department of Agriculture, Bombay, pp. 54-55.

8. *Males*: (C) Separate males and clusters of male flowers with hermaphrodites. This gives long fruits.

9. *Hermaphrodites*: (A) on long peduncles.

10. *Hermaphrodite*: (B) flowers with a few female flowers.

11. *Hermaphrodite*: (C) flowers with many females.

It must be remembered that none of these types or varieties are fixed and it seems that the papaya is still in a plastic condition as to sex.

To understand the complicated classification more simplified from the average reader's point of view, we give below the following extracts from Popenoe* :—

"One of the most remarkable features of the papaya is the irregularity which it presents in the distribution of the sexes. Normally it is dioecious, with staminate and pistillate (male and female) flowers produced on different plants. Cross-pollination is necessary to enable the pistillate flowers to develop fruits. This is effected by insects. Among seedling plants the number of staminate is usually greater than that of pistillates; Only a few of the former being necessary as pollinizers (certainly not more than one in ten). This excess of staminate is, from the growers' standpoint, an objectionable feature.

"In addition to the staminate and pistillate forms many intermediates have been observed in which both the sexes are combined in one plant. Staminate flowers may occur with rudimentary stigmas and ovaries which give rise to small worthless fruits; and there is a hermaphrodite type which regularly produces perfect flowers, is self-pollinated and yields excellent fruits. Numerous other forms have been described (see the bulletin by Higgins and Holt), but the importance of these is lessened by the fact that during the life-time of a plant it may change from one form to another.

"In general it may be said that plants which develop from the seeds as pure pistillates will retain their sex without modification, but plants which commence life as pure staminate may undergo a change of sex. It has been asserted that a change of sex may be induced by topping the male tree or by breaking its roots. M. J. Loms, who studied this question in Porto Rico, reached the conclusion that other conditions than the loss of the terminal bud must be present to induce a change of sex and he suggested that the trees may pass through definitely recurring cycles of development, and be subject to the change only at certain periods. L. B. Kulkarni, who investigated the matter in India, came to the belief that change of sex is not in any way connected with the removal of the terminal bud. He found that the male plants, in the course of their development, may present a number of sex combinations as follows :—

First stage: Staminate flowers only.

Second: Staminate, with a few hermaphrodite flowers.

Third: A few staminate, with many hermaphrodite flowers.

Fourth: A few staminate with many hermaphrodite and a few pistillate flowers.

* Popenoe—Manual of Tropical and Subtropical fruits, pp. 235.

Fifth : H
 Sixth : F
 Seventh :
 Eighth : ~~as female flowers only.~~

Thus the plant in the course of its life history may change from a staminate to a hermaphrodite and then to a pure pistillate."

From the commercial point of view it is a very difficult problem how to eliminate the pure male and the hermaphrodite plants in preference to pure female plants. It is not known at the time of planting whether a particular plant will turn into male, female or hermaphrodite. It is only after about six months when the flowers appear, that the sex can be recognised. There are instances where papaya plantations have failed merely for lack of means of identifying sex at the time of planting. With our present knowledge it is not possible to do this. In the circumstances we should plant two or three seedlings in each place. After the appearance of the flowers males and hermaphrodite plants are cut out giving preference to the pure females. It has also been found that vigorous growing plants generally turn into male plants. But before discarding any such seedling, it is necessary to wait after transplanting till they blossom. If gaps are caused by all the plants in the bed turning into male the neighbouring trees may be induced to branch out to occupy the vacant space.

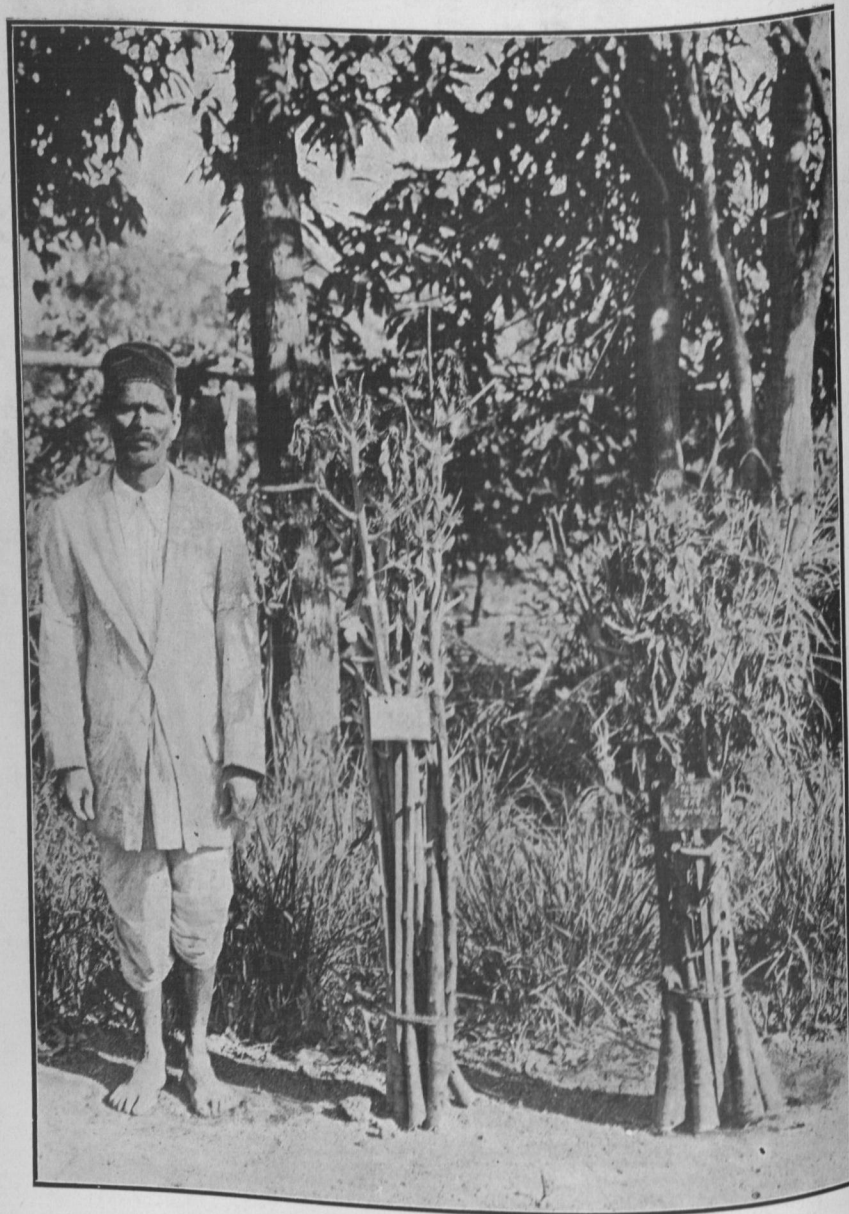
Male plants bloom earlier than female plants. Hence it has given rise to the belief that all vigorous plants are males. In one of our orchards consisting of 215 papaya plants the following percentage of sex was observed :--

Pure female plants	..	..	..	33 per cent.
Pure male plants	..	..	..	5 "
Hermaphrodite plants	..	..	..	62 "
				100

CHAPTER VI.

CULTIVATION.

Preparatory tillage.—In the hot weather the land is ploughed and harrowed as many times as possible until a good tilth is obtained. Then it is made perfectly level. Pits of the dimensions $2\frac{1}{2}' \times 2\frac{1}{2}' \times 2\frac{1}{2}'$ should be dug at 8' distance either way. The size of the pit may vary according to the nature of the soil. In loose soils it is not necessary to make big pits. The surface soil should be thrown on one side and the subsoil separately. Pits may be left exposed for a few days. Then they must be filled with surface soil mixed with well rotten farm yard manure at the rate of 80-100 lbs. per pit. If possible bone meal at the rate of 3 lbs. per pit may be added to achieve better results. After this treatment the pits may be marked with small sticks and left till the planting season. At the advent of the first monsoon rains *san* should be grown for green manuring purpose. After a month and a half's time when it comes to flowering it may be ploughed in. This will add to the fertility of the soil.



(a) Stems of papaya plants planted at 2' distance showing greater height and lesser thickness. (b) Stems of papaya plants planted at 8' distance showing lesser height and greater thickness than the above.

[To face page 7]

Spacing.—We have hitherto made a few observations on the spacing of papaya plants. Plants were planted at various distances ranging from 2 feet to 8 feet from plant to plant. As a result it was found that the thickness of the stem was inversely proportional to the spacing. (Vide Plate No. II). This may be due to the lack of sufficient nutrition on account of overcrowding. Border plants were not taken into consideration. It was also observed that as spacing decreased the height of the plant increased to a certain limit.

As has already been stated the papaya does not generally branch. It resembles a palm tree in the habit of its growth. The plantation also does not last for more than three years. The normal distance 8 feet is generally quite sufficient. To facilitate intercultural and other operations by bullock power the distance may, if necessary, be increased to ten feet each way.

Planting.—There are two methods of raising papaya plantations and they are as follows:—

1. Planting seed *in situ*

versus

2. Transplanting of seedlings.

Planting seeds *in situ* relates to the sowing of a few seeds in the bed or the basin direct where a plant is desired to be grown. This is the practice in Khandesh. After the germination of the seeds all extra seedlings are taken out retaining two or three vigorously growing ones.

The other method is transplanting. This involves raising of seedlings as described already. They are also planted in the pits already taken in twos or threes at the usual distance of 8 feet apart.

Raising of seedlings *in situ* is a more expensive method than transplanting. It involves more labour for watering, weeding and for taking care in the early stages, while raising seedlings in beds requires less labour as they are all in one place. From the observation made on a few self sown papaya trees in Modibag, the writers have come to the conclusion that the time taken for flowering is late and the fruits borne are rather smaller than those borne on transplanted trees.

There is another practice of establishing papaya specially where originally the plot is meant for vegetable growing and it is the intention of the grower to turn it into a papaya plantation afterwards. Simply seeds are thrown into the beds at random along with the vegetable seeds. Here it is quite true that it involves no extra expense. But the defect lies in encouraging a larger number of trees to grow in each bed. If by chance all of them turn out to be female plants the planter always hesitates to thin them. As a result overcrowding of plants takes place and consequently smaller fruits are borne by the trees. Interculturing also becomes difficult and its neglect leads to unhealthy condition of the plantation.

The other method where two or three seedlings are transplanted in the same bed is also open to the same objection.

Irrigation and Drainage.—The papaya responds easily to liberal application of water on well drained soils. The fact that it grows on rich soils without much water and bears a fairly good crop goes to show that at least it will not require as much quantity of water as other orchard crops like the banana, citrus, etc. However if the plants are regularly irrigated they produce big and sweet fruits. Watering is required all the year round except in the rainy season if there is proper and well distributed rainfall.

The papaya is exceedingly sensitive to stagnation of water round its collar and roots. This happens either during heavy rains or when plants are irrigated constantly with an excessive supply of water. The general practice followed in preparing beds for this crop is to make either round or rectangular beds. These beds are filled to the brim with water. As a consequence the roots and the succulent and hollow stump absorb more moisture than required and they begin to rot. The rot on the collar first appears at the base of the stem and then gradually spreads upwards, and the plant dies. To avoid this trouble the following improved system of preparing beds for irrigation should be adopted.

The suggested method consists in digging a circular concentric trench leaving a radius of space about two feet from the stem. The trench should be a foot and a half wide and about 8" deep. In the year 1917-18 certain experiments were carried out in the Ganeshkhind Botanical Gardens, Kirkee, on the ring and basin systems of irrigation. The following results were recorded:—

1. As to the quantity of water the basin system of preparing beds received more water than the ring system.
2. The growth of plants was more vigorous in the ring than in the basin.
3. There were more bearing plants in the ring method of irrigation.
4. The fruits were bigger in size in the ring method than those in the basin irrigation.
5. Plants in the ring irrigation produced flowers early by one month than those in the basin irrigation.

Besides, the ring system of irrigation, is an indirect method of irrigation. The water does not come into direct contact with the tree which receives water by percolation thus avoiding the rotting of it by excessive application of water. The health of the plants is also maintained by proper aeration.

Water is given once in 10 days according to the soil and weather conditions. In all about 24 waterings may be required in a year.

In a heavy rainfall tract or in a year when there is heavy rain the stagnation of water is sure to take place. As a precautionary measure, just before the beginning of rains the prepared beds should be destroyed and all the ground made perfectly level. Otherwise water will accumulate constantly in the beds. If the tract has very heavy rainfall, then small trenches should be dug between the rows to drain off the excess of water.

Manuring.—From the fact that the papaya bears flowers and fruits for a fairly long period, it shows clearly that it requires heavy manuring of one kind or the other.

The following manures have been found to be used by the cultivators with success in various districts of the Presidency: (1) Farm yard manure, (2) Cow-dung, (3) Sheep-dung, (4) Wood ashes, (5) Bone meal or bone ash.

The general method of manuring the papayas in the Deccan is to apply about 20 lbs. of farm yard manure at the time of transplanting of the seedlings. If the pits are already manured as stated previously it is not necessary to manure at the time of transplanting. The second dose at the rate of 80-100 lbs. of F. Y. M. may be given after about four or five months before the appearance of flowers. The third and last application of equal quantity is given after one year before the rains set in.

Round about Bombay and Poona where there is a good market for fruits, bone meal or bone ash is generally used in September after the rains are over. In Nasik District cow-dung or ash or both are the chief manures used for this crop once in a year. At Ahmedabad excellent papayas big in size and sweet in taste, are grown with success on the effluent only. In Sind sheep-dung or ash or both are made use of twice in a year.

The best fertilisers for papaya have been found to be dead vegetable, animal matter and house waste. Once a year a sprinkling of bone ash over the surface around the base of the tree produces sufficiently good results.*

Sub-crop.—When Papaya is grown as a main crop low growing vegetables like chillies, onions, tomatoes and others may be taken as inter-crops for about six months with advantage. Afterwards the trees grow bigger and shade the space below rendering it impossible to grow any vegetables.

The Papaya itself serves as a good inter-crop in many of the fruit crops. We have observed that in the case of young fruit trees where spacing is more than 15 feet or in young mango plantation a row of papayas between two rows of such trees can be profitably grown. As the papaya is only a two or three years' crop it does not much interfere with the main plantation. All such trees as for instance citrus and guavas take more than three years before they are subjected to the treatment of root exposure. In the case of mango, citrus and guava orchards, wherever irrigation facilities are available, the papaya makes a profitable inter-crop.

Interculture.—If sufficient spacing, i.e., ten feet, is given, the annual cultural operations can be carried out by bullock power. In a year two ploughings and two harrowings crosswise are necessary. Only

* Bulletin of the Department of Agriculture, Jamaica.

the space left unploughed may be dug by manual labour. After manuring, beds and water channels should be laid out. Besides, occasional stirrings and weedings must also be attended to. As already mentioned under irrigation, the beds should be broken before the rains and the whole ground be thoroughly levelled. If the tract is a heavy rainfall one, trenches between the trees should be dug to drain off the excess of water.

CHAPTER VII.

DEVELOPMENT OF FRUITS.

Flowering.—After about five months from the date of transplanting of the seedlings flowers begin to appear. If, for instance, the papayas are planted in November after the rains, flowers appear next April or May. The fruits become ready in October or November, *i.e.*, the time taken for the fruits to develop is about six months. It will be evident from this that the ripe fruits may be expected in about a year from the time when the plants are set in the orchard. Flowering, development of fruits and the harvesting of matured fruits continues for about nine months, *i.e.*, till the end of June or July. In the Deccan it invariably happens that there are no ripe fruits of papaya available in the market till about the end of October. This goes to prove that on account of cold the tree will not produce flowers profusely and if produced they will not set into fruits. This state of affairs will happen from January to the beginning of March. So naturally a gap in the harvest is caused during the months of August and September.

Thinning the fruits.—In the dioecious pistillate or the pure female plants the flowers are commonly borne on short peduncles in the axil of each leaf. The number of flowers on each peduncle varies from three to four the terminal flowering being the oldest and the biggest. Normally it is this terminal flower that sets and develops into a fruit unless damaged. As this flower develops vigorously the other branching flowers are automatically suppressed. As a general rule only one fruit develops into natural size in the axil of each leaf. Sometimes if there is scope, other flowers also develop into fruits. So naturally the crowding of fruits takes place in the limited space. It becomes intense as the tree grows older. In the young stage the tree is making rapid growth and the space between each node is longer and sufficient space is afforded for the fruits to develop. As the tree grows older the growth is stunted and the inter-nodal space is limited and there sets in competition between the developing fruits. As a consequence some fruits do not make proper growth and they remain small and compressed. To avoid wastage and to allow a certain number of fruits to develop properly, thinning becomes one of the essential operations. This operation is easily and quickly performed with a knife when the fruits are still in the young stage.

Experiments* on thinning of papaya fruits were carried out in the Ganeshkhind Botanical Gardens, Kirkee, in the years 1910 and 1912. In the year 1910, 10 plants were operated upon, one plant being the control, with the result that the process caused much greater development of the individual fruits, one being as heavy as 8 lbs., and the remainder ranging from 6-8 lbs. The unthinned tree had many fruits which had crowded and deformed one another. The experiment in 1912 was conducted on a set of 10 plants and a set of equal number being control. The results obtained were that the average number of fruits from the thinned plants was much less than that of the unthinned, but the average weight was correspondingly greater. But the increase in weight was not sufficient to compensate for the loss of fruits. So in conclusion it may be said that thinning the fruits increases their size and prevents crushing of fruits though it may not pay in every case. The difficulty is to hit on exactly the exact number of fruits to be thinned out to get the greatest weight compatible with the greatest number of fruits. This can only be obtained by practice and it may be recommended to remove only such fruits as are expected to go bad by crushing.

CHAPTER VIII.

SEEDLESSNESS IN PAPAYAS.†

Observations made by the writers and by Mr. P. G. Joshi, Superintendent of the Ganeshkhind Botanical Gardens, Kirkee, show that perfectly formed papaya fruits containing no seeds are of not uncommon occurrence. During the months August 1923 to February 1924, these appeared in the Ganeshkhind Botanical Garden orchard on eleven female trees in the following numbers:—

Month	No. of fruits harvested	No. seedless
1923—		
August	14	0
September	40	0
October	26	4
November	21	8
December	9	7
1924—		
January	18	9
February	14	11

* L. B. Kulkarni—Article entitled "Investigation on Papaya" Agri. Jour. of India, Vol. IX, Part IV, October 1914.

† This appeared as a note written by the authors in the Agricultural Journal of India, Vol. XXIV, Part III, May 1920.

The question arose: "Is this lack of seeds due to lack of pollination, or has there been pollination but no fertilization?" To settle this point flowers on pure female trees were bagged with paper envelopes or cloth bags (Plate III, Fig. 1). In every case of bagged flower, a fruit was formed containing no seeds and smaller in size than a fruit developing seeds in the usual way.

In the Montgomery District in the Punjab, there are no plants of papaya for a radius of 200 miles from the Government Farm, and on this farm female papayas (there were no male ones retained) all developed fruits, and these were seedless.

It appears then that the fruit as apart from the seed of the papaya tree can develop without pollination. Davies * confirms this, but Popenoe † and Higgins ‡ state the contrary. It is just possible that as these observers refer to conditions outside India, while Davies and ourselves refer to Indian conditions, this may be the explanation of the disagreement.

We have also proved that partial pollination (*i.e.*, pollinating only certain branches of the stigma) results in partial fruit setting, the carpels corresponding to the pollinated stigma branches alone setting seeds. The weight of fruit is, as one would expect, more or less proportionate to the number of seeds developed (Plate No III, Fig. 2).

None of our observations bear out the contention of Higgins and Holt § that a parthenocarpic tendency is inherited. Moreover, on one and the same tree are found fruits (*a*) fully seeded, (*b*) with seeds at the stigmat end, (*c*) without seeds.

We conclude therefore that for the trees which we have observed in India seedlessness is due to lack of pollination and to nothing else, and that the weight and size of the fruits is proportional to the number of seeds set. If it is desired to produce seedless papayas, all that is necessary is to exclude pollen.

CHAPTER IX.

VARIETIES.

The following variety trials were conducted in the Ganeshkhind Botanical Gardens, Kirkee, to ascertain which of the varieties will suit the tract and the market. Seedlings were imported from the Superintendent, Lalbag, Bangalore, in the month of July in the year 1915:—

No.	Name of the variety.	No. of seedlings.
1	Washington	12
2	Hawaii	4
3	Peradeniya	5
4	Bangalore	5

* Davies. Bulletin No. 37 of the Department of Land Records and Agriculture, U. P. Notes on the History, Uses and Cultivation of Papaya, p. 3.

† Popenoe. Manual of Tropical and Sub-tropical Fruits, p. 235.

‡ Higgins. Annual Report of the Hawaii Agricultural Experimental Station for 1911, p. 30.

§ Higgins and Holt. The Papaya in Hawaii, Bulletin No. 32 of Hawaii Experimental Station, p. 41.

PLATE No. III



Fig. 1—SHOWING HOW UNOPENED FLOWERS ARE BAGGED.
[To face page 12]

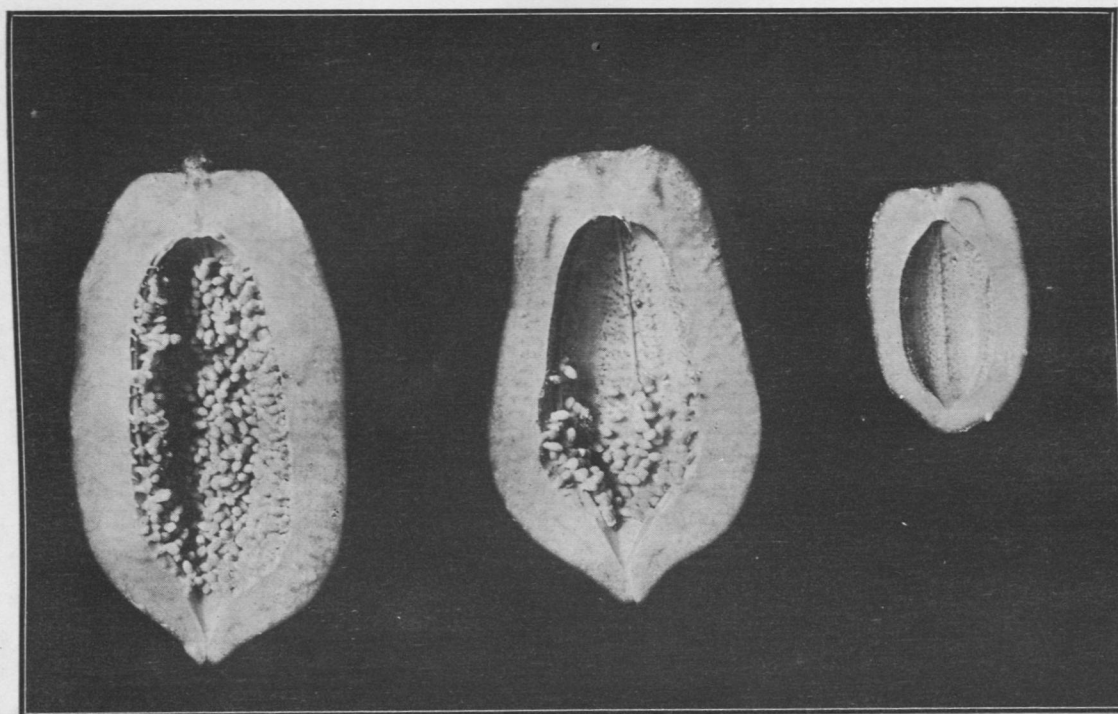


PLATE No. III

1 2 3
Fig. 2—SHOWING VARIATION IN SEED CONTENTS OF FRUITS ON ONE AND THE SAME TREE.
 1. Fully seeded fruit ; 2. Intermediate type having fewer seeds. (Note the bulging out of seeded portion) ;
 3. Seedless fruit found without bagging.

[To face page 12

PLATE No. IV



WASHINGTON PAPAYA TREE IN FULL BEARING.

[To face page 13]



VARIETY—GUJARAT PAPAYA ROUND FRUITS.
Note the development of fruits.

[To face page 13

The seedlings were transplanted in plot No. 15 having medium black soil 3 feet in depth. The cultural treatment given to all was the same.

The Washington variety alone grew rapidly and vigorously. Trees grew a height of about 10 feet and produced flowers freely and in abundance. From October 1916 onwards ripe fruits were harvested.

Description of the variety.—Stem with red spots at every node petiole dark pinkish in colour and still darker towards the lamina, petals of the flowers deep yellow; fruits produced in large numbers; shape of the fruit ovate; sweet in taste; keeping quality much better than the local variety. One more point that was noticeable in the variety was that it was free from the smell which is the characteristic of the local variety (Plate IV). It was liked much more by the visitors and growers and since then there has been a great demand for its seeds and seedlings. They are freely distributed to cultivators annually by the Horticulturist.

The Hawaii, Peradeniya and Bangalore varieties grew slowly, made poor growth and ultimately succumbed before fruiting.

2. *The Singapore variety.*—This variety has also been in existence for a long time. The peculiar characteristics of this are that it produces long fruits containing very few seeds. Botanically it is a monieious type and thus produces both staminate and hermaphrodite flowers, the latter having either 10 or 5 stamens and a syncarpous ovary. The average dimensions of the fruit are 8" x 5". The taste of the fruit is sweet.

3. *The Ceylon Papaya.*—The variety also grows fairly well. The characteristics of this are that the internodes are longer than those of the local variety. The petioles are thin and short. The peduncle in the male flower is shorter and thinner than in the local. Female flowers are smaller. The most common shape of the fruit is oblong or oval. The average number of fruits per plant per annum is about 60. The average weight is 3 lbs. per fruit. The average size of the fruit is 8" x 6". The pulp varies from 1 to 1½ inches and is often of orange colour. Plenty of seeds are found at the top. The fruit is much more piquant in taste than the local variety. In taste it is luscious but not too sweet. Its flavour is moderate and pleasant. It has the consistency of a well boiled potato with considerable water.

4. *The local variety* grown for the last so many years is called the *Gujarat variety*. This is also a dwarf variety like the Washington and bears very heavily (*vide* Plate No. V), the only distinction being that the petiole of this variety is green or yellowish green and the flowers are white while in the Washington variety the petioles are pinkish and the flowers yellow. The fruits of the local variety are bigger than those of the Washington. The fruits also are fairly sweet, but it has a slightly objectionable flavour.

The principal commercial types for the present are only Washington and Gujarat. But the market popularity of the Washington is increasing day by day. Other strains are not known in our cultivation as yet.

CHAPTER X.

INSECT PESTS AND DISEASES.

There is hardly a fruit crop in this presidency which is free from insect pests or diseases but the papaya affords an unique example of comparative immunity from insect attacks from fungoid diseases. From the time of the germination of the seedlings till the complete harvesting of the fruits there is little trouble from disease. This is one of the main reasons why the papaya has found its place among the main cultivated fruit crops and why its popularity is increasing. However the following, though of minor importance, are included among the enemies of papaya in this part of the country:—

1. Trees are occasionally attacked by the caterpillar of *Dasytes rugosellus* which bores below the bark. The direct damage done is slight and the larval workings are easily seen and can be cut out and the wound tarred over.*

2. *Ripe rot*.—This is a common malady in ripening fruits of papaya. The young fruits are not generally attacked. The infection invariably starts at a spot which is directly exposed to the sun. The first symptom is the appearance of a whitish yellow patch on the rind of the fruit, followed slowly by softening of the tissue at the point. The affected part soon changes to light brown and spreads rapidly until it covers nearly half the area of the entire fruit; the fruit now begins to shrink and produces groves or folds at this point. This shrinking is soon followed by the appearance of the tiny round black acervuli in concentric rings over the sunken area and pinkish pustules of the causal fungus. The fruit at this stage is soft and pulpy and if allowed to stand will soon be reduced to a mummified appearance with the entire surface covered over by the pink pustules of the fungus.

In a severe form, the fungus *Gloeosporium* attacks the leaf-stalks as well as the stem of the plant and probably survives by means of the acervuli on these parts.

Experiments carried out at Nasik have shown the efficacy of Burgundy mixture in controlling the malady. Affected fruits and leaf-stalks are the main sources of infection and should be destroyed.

CHAPTER XI.

HARVEST AND YIELD.

The ripening test of the fruits is that they show first yellowing combined with a light green colour. Such fruits are carefully picked and are kept for curing for a couple of days when they are ready for table use. The fruits may even be allowed to ripen on the tree itself but the

* Report of the proceedings of the second Entomological Meeting held at Pusa, 1917, p. 257.

damage by birds and wild cats is great, and harvesting of fruits without damage becomes difficult. So it will always be wise to harvest the fruits in a slightly raw condition. The test to see whether the fruit is ready or not in curing, is to press it with finger. If the finger makes a small depression on the skin then it is ready for table use.

The slightest damage to the fruit at the time of harvesting or curing will spoil the appearance of the fruit. So the precaution to pick the fruit carefully and to preserve it in good condition is essential. When the tree grows high, growers pick the fruit with a stick and thus allow it to drop on the ground. In this way fruit receives injury and the affected part becomes soft and the fruit becomes unmarketable. So a ladder must be made use of to pluck fruits from high trees.

Fruits after harvest should not be allowed to press against each other or against any hard thing that leaves marks on them. Collected fruits are sent to market packed in bamboo baskets.

The total yield for the two fruiting season together recorded is 13,677 lbs. for 2/5 acre. The average weight of fruit is calculated to be 2.2 lbs. per fruit. The average number of fruits per tree is 27. The maximum yield for specimen tree recorded is 104 fruits weighing 203 lbs. The yield may vary according to the soil and treatment.

As to the details of cost of cultivation and return an appendix has been added to this bulletin. On examining the figures of the different statements it may be seen that the papaya is a paying crop in the neighbourhood of big markets.

CHAPTER XII.

MARKETING OF FRUITS.

For the present it is only in the big markets like Bombay, Poona and Ahmedabad that the marketing of papayas on anything like the big scale takes place. There is no taste created as yet in the mofussil. Some people feel disgusted if this fruit is offered to them. Still it is gratifying to see that the people are gradually appreciating the value of it. It is hoped that in the near future there will be a great demand even in small markets and there is a likelihood that the plantations will be extended. This may be accelerated if a better quality of fruits like the Washington is grown universally.

The fruit for distant markets is picked while still firm and just beginning to turn yellow. The marketing of the papaya fruit is a very difficult task. The fruit is not easily portable. It requires very careful handling as stated elsewhere. Generally these fruits are packed in bamboo baskets. Matured fruits ripen quickly and due to the defective method of packing the lower layers of fruits are pressed too much and become unmarketable. That is why, as stated above, fruits are harvested in a slightly raw condition that can withstand the rough handling of transshipment in the railways. Even in such conditions and in the present method of packing, the fruit can travel very well for short

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distances. If they are properly packed in well ventilated crates and packed in a soft medium, they can be sent to long distances, *i.e.*, Bombay to the Punjab. From the time of harvest the fruit cannot keep for more than four or five days at ordinary temperatures. Hence shipping of papaya fruits to other countries is impossible unless cold storage is available.

Each basket can hold about 20 fruits of ordinary size. Packed baskets are sent to the agents who sell them wholesale either by a secret method or by open auction sale. The price realised fluctuates according to the season and supply. In the beginning of the season, *i.e.*, in November and in December, when the fruits come in limited quantity the prices offered are high. As the season advances, *i.e.*, in the months of March and April, markets are glutted and very low prices are offered. On an average a basket may fetch from Rs. 2 to Rs. 3. The retail price will vary from annas $1\frac{1}{2}$ to 3 per fruit. On our stall the fruit is sold at $\frac{1}{2}$ anna per lb.

CHAPTER XIII.

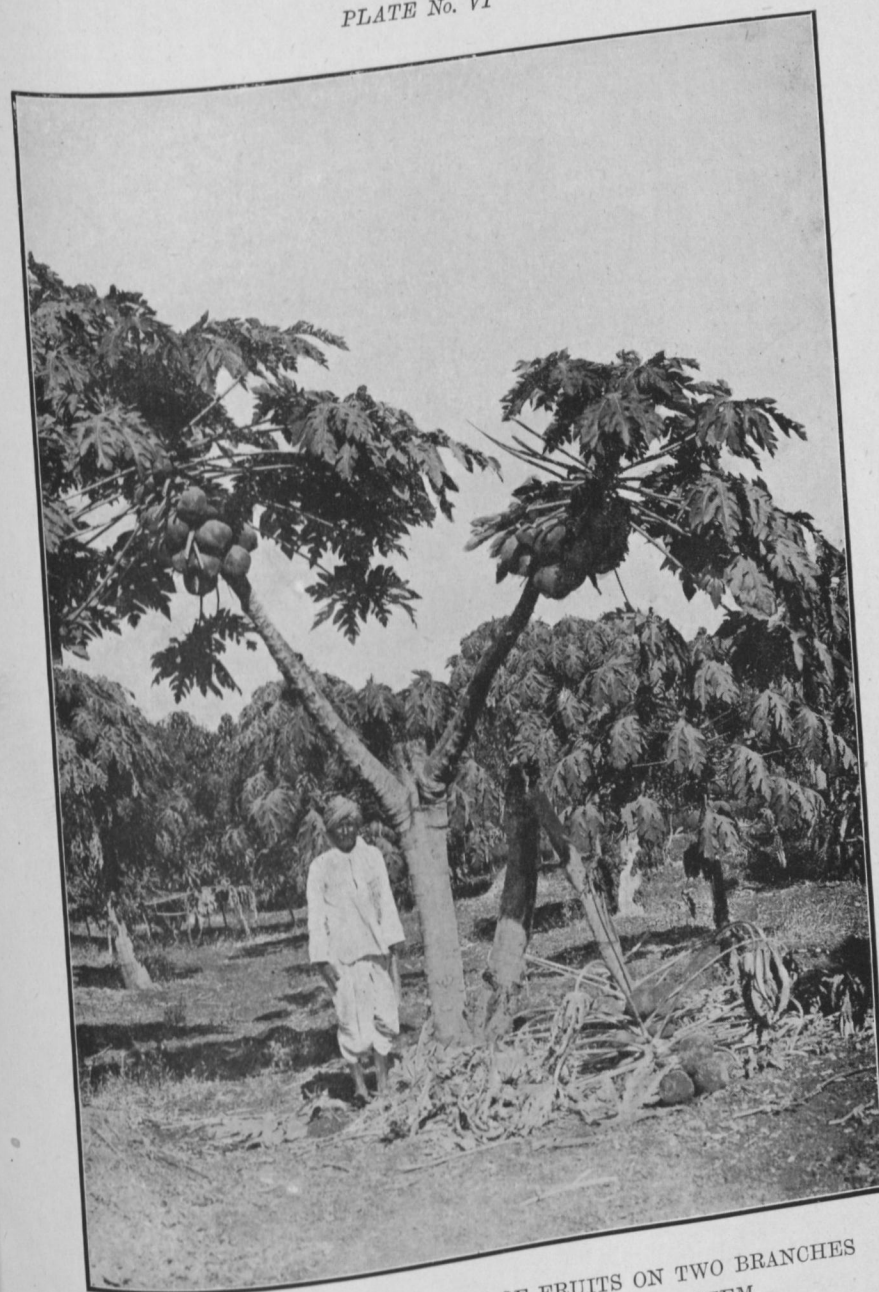
AGE AND RENEWING OF OLD PAPAYA PLANTATIONS.

Age of the plantations.—Papaya trees do not last long. Their life is of a very short duration. There are instances where papaya trees are kept for more than six or seven years. But the period of prolific productivity is usually not more than three years. As the tree grows older the fruits become smaller. The papaya trees are very quickly and easily grown and hence it will not pay to keep a plantation for more than three years. After this period the plantation is destroyed and a new one is renewed in its place.

Renewing of old plantations.—As stated above, after a period of about three or four years from the starting of the papaya plantation, the trees grow long and lanky and the harvesting of fruits becomes almost impossible on account of the height the tree assumes. If it is not desired to open up a new plantation, the existing one may be renewed for a year more by heading back the old trees. It is good to have a new plantation altogether but where the question of the difficulty of labour comes in and early fruiting is desired this method may be practised. In brief it is as follows :—

It is generally observed that at a distance of about 6' from the ground small branches are given out on the old stumps. The advantage of these already existing branches may be taken by cutting the main papaya stem. Care should be taken to cut the tree at a sufficient distance, say 2' above the branches. Otherwise the decaying and drying of the hollow stem soon reach the branches and cause them to break by the force of the winds and by the weight of fruits. The cut surface may be plastered over with mud mixed with cowdung. If there is crowding of many branches they may be pruned keeping only one or two vigorous growing and sufficiently matured branches. This operation of renewing old plantations was very much successfully practised in Modibag several times. The yield and the development of fruits was most satisfactory. (*Vide* Plate No. VI).

PLATE No. VI



SHOWING THE DEVELOPMENT OF FRUITS ON TWO BRANCHES ALLOWED, AFTER CUTTING THE MAIN STEM.

Note a similar tree fallen close to it, by the force of the wind.

[To face page 16]

CHAPTER XIV.

THE EXTRACTION OF PAPAIN FROM PAPAYA.

The extraction of papain is unknown in this part of the country. However enquiries are always made by enthusiastic growers about it. To meet such enquiries the following summary from Higgins and Holt* is given for general information.

Papain, the active principle in the juice, can be separated from it by means of alcohol and either the juice itself or the separated ferment is now well known to possess the power of digesting proteids. It is freely used in medicine and hence the industry is flourishing to a great extent. The term "papain" formerly applied to the ferment is now applied to dried juice either crude or manufactured. This product is supplied to the American trade chiefly from the West Indies and Ceylon. The following in brief is the method of collecting and preparing the juice.

The fruits that abound in juice are generally tapped, in warm weather when the tree is young. The morning is always preferred as the flow at that time is profuse. Very shallow incisions $\frac{1}{8}$ of an inch deep $\frac{1}{2}$ " apart from each other are made lengthwise on green mature fruits. This process may be repeated once in three or four days. Care should be taken to use non-metallic instruments and vessels. It is better to use a bone or ivory blade for making incisions and glass or earthenware vessels for collecting the juice. Immediately after the incision coagulation of the juice takes place and it must be scraped from the surface of the fruit.

The juice is immediately dried as it is being collected. Otherwise decomposition of it begins. If evaporators are not available for drying the juice sun-drying is preferred. When the juice is completely dried it may be ground in a coffee mill. The cream coloured powder thus prepared should be preserved in bottles. The product is further exported to America and Europe for purification.

It is expected in Ceylon that each tree to yield on an average 4 ozs. of dry powder and this is sold at Rs. 6-4-0 per lb. Our local variety Gujarat gives an equal quantity of papain per tree while the Singapore, it was observed, gives double the quantity. Calculations show that a net income of Rs. 200 per acre can be realised by carrying this industry.†

* Bulletin No. 32 of Hawaii Agri. Ex. Station "The Papaya in Hawaii" p. 16.

† L. B. Kulkarni—Poona Agricultural College Magazine, Vol. XVII, No. 1, Article entitled "Papain Extract" p. 16.

APPENDIX.

The following data are used in the appended statement :—

1. Cost of labour—Man charged at 10 annas per day, woman charged at 5 annas per day, boy charged at 5 annas per day and bullocks charged at 10 annas per day.

2. Cost of material—Farm yard manure at Rs. 2 per cart-load, bonemeal at Rs. 85 per cart-load.

Two cart-loads are equal to one ton (2,240 lbs.).

One iron basket of manure weighs 20 lbs.

3. Supervision charges—Calculated at $1\frac{1}{2}$ annas per rupee of the cost of cultivation.

4. Marketing charges—Charged at one anna per 100 lbs. or 100 in number of the total yield.

5. Assessment of the land—Average figure of Rs. 3-11-3 per acre calculated from the assessment figures of the surrounding survey numbers.

6. Value of the land—The land is valued at Rs. 1,800 per acre round about Poona. (Figures were got from the land acquisition file of the Principal, College of Agriculture, Poona.)

7. Interest—Interest is charged at 9 per cent. on the sum invested.

APPENDIX No. 3(a).

Statement showing figures of cultivation for Papaya crop for three years from 1921-1924.

(Area :—16 gunthas, i.e., $\frac{2}{3}$ acre. Spacing 8' either way. Life of the plantation 2 years and 4 months.)

No.	Operations, etc.	1921-22.		1922-23.		1923-24.	
		Labour.		Labour.		Labour.	
		M. W. B.	Rs. a. p.	M. W. B.	Rs. a. p.	M. W. B.	Rs. a. p.
1	Ploughing	4 0 8	7 8 0	3 0 7	6 9 0	2 0 5	4 11 0
2	Harrowing and levelling	7 3 11	12 3 0	3 0 6	6 1 6	2 0 5	4 11 0
3	Cost of plants (500 seedlings).	....	5 0 0	....	..	....	....
4	Planting	6 0 0	3 12 0	....	..	....	....
5	Manure manuring*	....	5 0 0	13 8 0	41 11 3	8 0 0	36 0 0
6	Preparation of beds	9 0 5	8 12 0	58 5 2	39 13 6	31 5 1	21 9 0
7	Irrigation and watering†	13 0 0	23 7 6	21 4 4	31 7 8	21 3 0	29 14 6
8	Interculture	0 12 0	3 14 6	7 72 0	26 14 0	11 86 0	33 15 9
9	Intercrop	30 16 19	39 8 6	1 3 0	1 4 0	....	....
10	Harvesting	....	..	11 1 0	1 4 0	6 2 0	4 11 0
	Total	75 31 43	109 1 6	109 89 20	155 0 11	80 97 6	130 12 9

* In the second and third year the amount contains the value of manure Rs. 31.

† For the whole period, the irrigation charges are Rs. 15-3-0.

Years.	Total cost.	Cost calculated per acre.
	Rs. a. p.	Rs. a. p.
1921-22	109 1 6	272 11 9
1922-23	155 0 11	387 10 6
1923-24	130 12 9	326 15 10

N.B.—The above statement is taken from Bulletin No. 153 of 1928 by the same authors. It does not contain the cost for digging pits.

APPENDIX No. 3(b).

Statement showing figures of return for papaya crop for three years from 1921-1924.

No.	Name of the crop.	1921-22.			1922-23.			1923-24.		
		Quantity.	Rate.	Value.	Quantity.	Rate.	Value.	Quantity.	Rate.	Value.
	Yield of the main crop Papaya.	..	..	Rs. a. p.	2,335 No. of fruits.	At 2 as. per fruit.	Rs. a. p. 291 14 0	3,882 No. of fruits.	At 2 as. per fruit.	Rs. a. p. 485 4 0
	Yield of the sub-crop.	4,375 lbs. (brinjals).	At 9 pies per lb.	205 1 3	..	..	..	..	..	..
	Total ..	..	..	205 1 3	..	..	291 14 0	..	..	485 4

Calculations per acre.

Years.	Yield of the main crop in numbers.	Yield of the sub-crop.	Value per acre.
1921-22	..	10,973 1/2 lbs. (brinjal).	Rs. a. p. 512 11 0
1922-23	5,837 No. of fruits.	..	729 11 0
1923-24	9,705 No. of fruits.	..	1,213 2 0

APPENDIX No. 3(c).

Statement showing annual net profit.

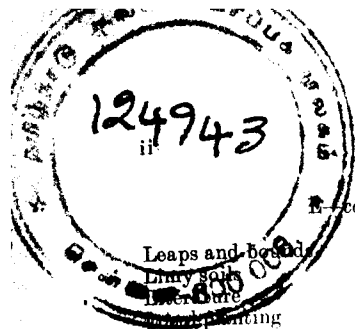
No.	Items per acre.	1921-22.	1922-23.	1923-24.
		Rs. a. p.	Rs. a. p.	Rs. a. p.
1	Cost of cultivation ..	272 11 9	387 10 6	326 15 10
2	Supervision charges ..	25 9 0	36 5 6	30 10 6
3	Marketing charges ..	2 11 9	1 7 3	2 6 9
4	Assessment of land ..	3 11 3	3 11 3	3 11 3
		304 11 9	429 2 6	363 12 4
5	Interest at 9 per cent. on the sum invested ..	27 7 0	38 10 0	32 12 0
		332 2 9	467 12 6	396 8 4
6	Value of the yield ..	512 11 0	729 11 0	1,213 2 0
7	Gain ..	180 8 3	261 14 6	816 9 8

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