PRODUCTION OF PINEAPPLES FOR PROCESSING AND FRESH MARKETS IN KENYA.

BY

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A DECLARATION

This thesis is my original work and has not been presented for a degree in any other University.

-- 8/4/91

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B.Sc. Agric.

This thesis has been submitted for examination with our approval as University Supervisors.

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B. DEDICATION

This thesis is dedicated to my parents; Teresia and Joseph Keige for their enduring love, patience, encouragement and advice they have given me all my life. Their moral, social and financial support is invaluable.

And to all the blind people in Kenya '**Never** give up for there is life and hope after blindness'.

C. ACKNOWLEDGEMENTS

My gratitude and appreciation is expressed to Professor Kimani Waithaka , Chairman, Department of Crop Science, University of Nairobi for his help and guidance given in the writing of draft manuscripts and especially reorganizing the format of writing the thesis.

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I wish to thank the German Academic Exchange (DAAD) for funding my masters. I also wish to thank them for the financial assistance they gave me for purchasing the equipments I needed and for the courage they gave me to continue. Their concern and assistance is greatly appreciated.

The author wishes to express her gratitude to the office of the Dean of students, University of Nairobi for organizing my rehabilitation to blindness. Gratitude is further expressed to staff members of Thika High School for the blind for the rehabilitation that gave me skills that I needed so desperately to be able to complete this work.

I am greatly indebted to my friends who helped me record all my references and especially Jane Thuku and Mary Kimani who sacrificed their holidays. My thanks to H.C.D.A. Del Monte Kenya Limited and Sunripe Co. Limited for providing me with some of the technical informations used in this writeup.

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I cannot forget the long hours of hard work, patience and encouragement given by my sisters Wambui and Wanja Keige during the period of writing this thesis to completion. Their love and encouragements is greatly appreciated.

I wish to thank all other people whose names are too many to mention who gave me help that made it possible to finish the research work.

Last but not least I want to thank Hellen Muthui for the great work of typing the thesis.

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G. PREFACE

I, Mary Mwihaki Keige author of this thesis am blind. I became blind during the course of my study for the Master of Science degree in Horticulture, after finishing my coursework during the later part of 1988.

I had developed serious health problems and was gradually losing my eyesight due to optic atrophy. After undergoing many medical checkups, the medical specialists discovered a tumour in my brain and I underwent brain surgery. Consequently I lost my remaining eyesight completely.

I later enrolled in Thika High School for the blind, where I underwent rehabilitation to blindness. This involved orientation and mobility, braille writting and reading and typewritting.

I resumed my postgraduate studies in Horticulture at the University of Nairobi to undertake research and thesis writting for M.Sc. degree in late 1989. Inspite of my newly developed handicap, I determinedly put a lot of time and energy in the study. The study. involved the use of recording machines, whereby I recorded all the materials read for me by friends. I also made field visits with the assistance of sighted guides, who helped me in filling the questionnaires. After recording the read materials, I listened to the tapes, put down the work in braille and typed the draft manuscript, which I submitted to my supervisors for correction. Amending corrections was hard. I always had to rely on readers who were not always technically qualified on the subject, to make the necessary corrections on the manuscript. Eventually, I finished the writting of my thesis.

It was a very expensive and time consuming exercise and I will not pretend that it was easy, however, I have convinced myself that it CAN be done by a blind person. I hope other blind people will take similar challenges.

Thank you.

H. SUMMARY

PRODUCTION OF PINEAPPLES FOR PROCESSING AND FRESH MARKETS IN KENYA

The pineapple *Ananas comosus L. Merr.* is a tropical fruit which is grown at altitudes from 100 to over 1800m above sea level with rainfall ranges of 600 to over 1500/mm annually.

Soils with high murram (high iron or manganese concretions) contents favour pineapple growing while those with high clay content are not favourable. The soil for pineapple growing must be well drained. The slope of the terrain must not exceed 5%. Monocropping of pineapples gives higher yields than intercropping. It is thus best for commercial pineapple production. A double row system of planting makes field management easier than single row planting and gives higher yields.

The use of evenly-sized planting materials as practised by large scale growers is important in the production of fruits of even weight and maturing period. This is further facilitated by the use of flower forcing growth regulators in order to ensure uniform flowering and maturity of fruits of the same age and size. Small scale farmers usually plant mixed propagules that mature unevenly. They also do not use flower forcing growth regulators.

Irrigation ensures continous production of pineapple fruits all year round. Rainfed pineapples are, however, seasonal and can fail in times of drought.

The use of fertilizers especially Nitrogen fertilizers gives higher yields than those of pineapples grown without any fertilization.

Mealy bugs and nematodes are the commonest pests of pineapples in Kenya. Their control is important in order to produce better fruit yields of high quality. Small scale farmers who do not use pesticides produce lower fruit yields of low quality. The use of Diazinon has been found to be effective in controlling mealy bugs whereas, DD Nemagen used as a fumigant controls nematodes.

Fungal attacks mainly by Phytophthora spp. are common in fields where fumgicides are not used. Control of these fungal diseases reduces losses both at the field level and after fruit harvest.

Production practises for large scale growers are mechanised while those for small growers are manual. However, planting and harvesting are manual operations of both large and small growers. Fruits for canning are however harvested differently from those intended for fresh markets.

Post harvest losses for large scale farmers are very low while those for small scale farmers are high due to poor packaging, transportation and marketing conditions. Large scale growers also have more market openings i.e. processed fruits, fresh export and local markets while small scale growers only sell to the local fresh markets.

The occurrence of multiple crowns is common when environmental conditions are unfavourable e.g. very high rainfall or a prolonged dry spell. The same factors also increase leaf and fruit spineness. Rosetting was only observed in fruits produced in virgin lands.

Fruits produced at lower altitudes have higher brix to acid ratio than those grown at higher altitudes. However, fruits produced at the same altitude may show different brix to acid ratio due to variation of other climatic factors such as light intensity and temperature. Production practises are also important in determining the final fruit quality. Excessive ratoon crops also reduce the brix acid ratio similar to close spacing which has the same effect.

Rosetting increase the acid content of a fruit. The water and sugar content of fruits rise with progressive ripening and the acid level goes down.

The scale of processed pineapple as well as export of fresh fruits is on the increase in Kenya. The sale of fruits at the local fresh market is also in the rise.

1. INTRODUCTION

Kenya's economic and industrial growth is dependent mainly on agriculture. The growth of cash crops and the intensification of production on the available arable land is encouraging. For some time, coffee tea and pyrethrum have been the major export crops. However, recently horticultural products have increased in prominence and compete favourably with these well established crops in the trade.

The pineapple (*Ananas comosus*) is one of the fruits grown in Kenya for domestic and export markets. The fruit was introduced to the country by British settlers at the turn of the century, possibly from the Islands of Guiana (Collins, 1960; Brucher, 1977) from where it has since spread to many parts of the country. Commercial production of pineapples in Kenya started in 1950 when the world supplies of canned fruits were low (FAO 1972). Presently, pineapples are exported from Kenya both in processed form (Canned) and as fresh fruit. In 1989, 2,254,575kg of fresh fruit was exported mainly to E.E.C. countries, fetching a total of Ksh. 7,915,000 in foreign exchange (H.C.D.A 1990). During the same year 2,984,656kg of canned fruit and 40,053 litres of pineapple juice concentrate were exported by Delmonte Kenya Ltd, the only exporter of processed pineapple products in Kenya.

Altogether about 40 varieties of pineapples are grown in the world, but only four varieties are important commercially. These varieties include 'Smooth Cayenne', 'Queen', 'Red Spanish', and

'Abacaxis'. 'Smooth Cayenne' is the most suitable variety for canning and is also very acceptable for fresh market. This is also the most important variety in Kenya commercially, and most of the information currently available is on this variety.

In Kenya, pineapples are grown both on large and small scale basis in several Agro-ecological zones, mainly in Central, Coast, Nyanza and Western provinces. Large scale production found only in Central province, where Delmonte Kenya Limited and Sunripe Company grow it on estates around Thika. Pineapples are also grown by small scale farmers in Central province in Kandara and Kiharu Divisions of Murang'a District and in some isolated areas of Kiambu District (M.O.A. 1980).

In other provinces, pineapples are grown only on small scale basis. In the Coast province, production is mainly in Kilifi, Kwale and Mombasa Districts, in areas that are not suitable for other cash crops (M.O.A. 1983, 1984). In Nyanza province, fruits are mainly grown in Oyugis Division of S. Nyanza District, in the lower parts of Kisii District bordering S. Nyanza and in Kisumu District (M.O.A. 1984). In Western province they are mainly grown in Bungoma, Busia and Kakamega Districts (M.O.A. 1983).

The bulk of pineapples from large scale farms are mainly for processed and fresh export markets, with only a small proportion going to local markets. Small scale growers on the other hand produce mainly for domestic local fresh markets.

Small scale pineapple producers have no organised marketing. They lack facilities for holding the produce in order to spread it over a longer marketing period than the short harvest season. Organised marketing and proper storage facilities would improve prices and give incentive to farmers to produce more fruits. Small scale farmers also need to be educated on better cultural practises for higher yields and better quality fruits that can meet the high standards for canning and export.

Most pineapples for export from Kenya are air freighted, a method of transportation that is increasingly becoming expensive.

This study was designed to look at the current status of pineapple industry in Kenya under the following:-

1) Using primary and secondary data to study the problems the industry is facing and suggest any possible solutions.

2) Study production and trade of pineapples grown under large scale (Thika) and small scale (Malindi, Sondu, Webuye).

3) Investigate the differences between large scale production where there is aggressive expenditure for profitable productivity and small scale production just for meagre earnings.

4) Analyse the quality of fruits considered marketable in different areas, for the main quality factors which include sugar and acid contents and aesthetic marketing qualities.

2. METHODOLOGY

The study, which was aimed at assembling information on the current status of pineapple production and post-harvest handling in Kenya, was based on library search for secondary data and literature. Field visits were made and a questionnaire (Appendix I) used to get information from small scale producers.

Field information was also obtained from two large scale farms around Thika i.e. Delmonte Kenya Limited and Swani Coffee estate (whose marketing arm is Sunripe). For small scale producers, three agro-ecological zones in the country were investigated, namely Malindi in Kilifi district, Coast province; Sondu in Oyugis Division, South Nyanza district, Nyanza province and Webuye in Bungoma district, Western province. In each zone, fifteen farmers picked at random were interviewed. For the large scale farms, field visits were made and information collected from the technical and management staff of the operation.

Fruits purchased from the nearest markets were analysed in the laboratory for dry matter content, total soluble solids (^{o}Brix), pH, titratable acidity, and reducing and total sugars, (AOAC, 1984) so as to bring out any differences in the quality of fruits considered acceptable for the local markets in the different zones.

2.1. Laboratory analysis

2.1.1 Materials and reagents

Fruits analysed

A Malindi pineapples:

A1 Normal crown

A2 Bent crown

A3 Mutated crown (Rosette)

B Thika pineapples

B1a Normal

B1b Full ripe

B2 Unripe

B2a Normal

B2b Baby pineapple

B2c Multiple crown

C Sondu Pineapples

D Webuye Pineapples

D1 Normal crown

D2 Multiple crown

Level of ripeness was judged on external and internal colour.

Equipment and reagents:

i) Camera

ii) Refractometer

iii) pH meter

iv) Reflux condenser

v) Sodium hydroxide (NaoH) solution 0.1N

vi) Alcoholic phenolphthalein solution 1%

vii) 15% aqueous potassium ferrocyanide solution (Carrez I)

viii) 15% aqueous zinc sulphate solution (Carrez II)

xi) Potassium Iodide solution, 166g/l

x) 25% sulphuric acid solution

xi) Sodium Thiosulphate solution 0.1N

xii) Concentrated hydrochloric acid

xiii) 40% sodium hydroxide solution

xiv) Starch solution as indicator, 1%

xv) Luff's solution
Luff's solution is a mixture of the following solutions:

- A solution of 50g of citric acid in 50ml of distilled water
- A solution of 388g of crystalline sodium carbonate in 350ml of distilled water
- A solution of 25g crystalline ion-free copper sulphate in 100ml of distilled water

The mixture was made upto 1 litre with distilled water and filtered.

2.1.2 Analyses

2.1.2.1 Laboratory analysis

Fruits purchased from the nearest market were analysed in the laboratory for moisture content, total soluble solids, pH, titratable acidity, and reducing and total sugars.

2.1.2.1 Extraction of juice

Representative pieces were cut from the fruit and peeled. The pieces are macerated and blended without addition of any water. The slurry was filtered through Whatman No. 41 filter paper and the filtrate (juice) used for analysis.

2.1.2.2. Determination of moisture and dry matter contents

About 5g were accurately weighed in a dish, dried in an air oven at 105^{O}C for 4 hours, then cooled in a dessicator and weighed. The dish was returned into the oven and dried for a further 30 minutes, cooled and weighed. This process was continued until the weights differed by not more than 0.05%. The loss in weight was expressed as percent moisture content. The percent dry matter was calculated by substracting this value from 100%.

2.1.2.3 Determination of total soluble solids (^{O}Brix)

This was determined with a hand refractometer, which was first standardized with distilled water. Two drops of the juice were placed on the refractometer and the reading taken directly as % TSS.

2.1.2.4 Determination of pH

This was done with a PYE Unicam Model MK2 pH meter. The pH meter was standardized by use of buffers of pH 4 and pH 7, before taking the pH of the juice.

2.1.2.5 Determination of total titratable acidity

Ten mililitres of the juice was pippeted into a 300ml conical flask, heated to boiling and cooled quickly. 50ml of CO_2-free distilled water were added, followed by a few drops of phenolphthalein (solution indicator). The mixture was titrated with 0.1N NaOH solution to the appearance of a distinct pink colour. The total titratable acidity was calculated as equivalent percent citric acid.

2.1.2.6 Determination of total and reducing sugars

The method used is that of Luff's school, method No. 4 of the international federation of fruit juice producers (IFFJP, 1968).

The juice was first clarified as follows:

Ten millilitres of the juice were put into a 100ml volumetric flask. Then 5ml of 15% potassium ferrocyanide (Carrez I) was added and mixed. This was followed by addition of 5ml of 30% solution of zinc sulphate (Carrez II) and mixed. The volume was made to the mark with distilled water then filtered through Whatman No. 41 filter paper. The filtrate represented the clarified solution.

2.1.2.7 Determination of reducing sugars

Ten millilitres of the clarified sugar solution were added to 25ml of the Luff's solution contained in a conical flask which had a ground joint. The mixture was made to 50ml with distilled water, then heated under reflux for 8 minutes and cooled immediately. Nine millilitres of potassium iodine (166g/l) was added, followed by 20ml of 25% sulphuric acid. The mixture was then titrated with a standard 0.1N sodium thiosulphate with starch as indicator to a cream yellow end point. A blank was ran parallel to the samples.

Calculation:

Effectively used volume of thiosulphate solution = volume used for the blank volume used for the sample.

The corresponding amount of sugar was read from a given standard table (Table 1). The sugar content of the juice was then calculated as a percent.

2.1.2.8. Determination of total sugars

Five millilitres of concentrated hydrochloric acid were added to 50ml of the clarified sugar solution contained in a 100ml volumetric flask. The flask was placed in a water bath at 70^{o}C. The mixture was then heated at 67^{o}C for exctly 5 minutes. It was rapidly cooled to room temperature (about 25^{o}C) and then neutralized to pH 6 with 40% sodium hydroxide. The mixture was then made to the mark with distilled water. Ten millilitres of the mixture was added to 25ml of the Luff's solution contained in 250ml conical flask with a ground joint. The mixture was made upto 50ml with distilled water then refluxed at boiling for 8 minutes. The mixture was rapidly cooled to room temperature, 9ml of the potassium iodine solution added, followed by 20ml of 25% sulphuric acid solution. The mixture was titrated with 0.1N sodium thiosulphate with starch solution as indicator to a cream yellow end point. A blank was ran parallel to the sample. The calculation was the same as that for the reducing sugars. The total sugar contents were calculated as percent equivalents of reducing sugars.

Table 1: Determination of the sugar content from sodium thiosulphate titres

Ml of 0.1N thiosulphate solution	Equipment mg invert(reducing) sugars
1	2.4
2	2.8
3	7.2
4	9.7
5	12.2
6	14.7
7	17.2
8	19.8
9	22.4
10	25.0
11	27.6
12	30.3
13	33.0
14	35.7
15	38.5
16	41.3
17	44.2
18	47.1
19	50.0
20	53.0
21	56.0
22	59.1
23	62.2

3. GROWTH AND DEVELOPMENT PATTERNS OF PINEAPPLE

3.1 Botany

The pineapple (*Ananas comosus L.*) is a perennial monocarpic herb and belongs to Bromeliaceae family. It is a self sterile monocotyledon. After production of a fruit from the terminal bud, the crowns and shoots fall to the ground, while the auxillary stem buds continue to develop and form new plants. The pineapple thus reproduces by successive vegetative propagation and under natural conditions this takes place where the original plant grew. When grown for commercial purposes, however, plantations are cleared and replanted with new shoots after one to three harvests (Py et al., 1987).

The leaves are long and narrow, arranged in a spiral form on a short stem, forming a rosette. Seventy to eighty leaves are formed per plant and there is always a bud in the axil of each leaf. Some buds develop into offshoots or suckers. Shoots can be seen between the leaves while a ratoon or ground sucker appears to come out of the ground and has roots (Collins, 1960; Samson, 1980). In 'Smooth Cayenne' a leaf has smooth edges except for some spines just below the tip, which can be more numerous on leaves that differentiated during periods of poor growth. Most other cultivars have spines all along the leaf edges.

The fruit tip is elongated and ends in a fine point. The stem is 20-30cm long narrow at the base (about 2cm) and wide at the top (about 5cm). The base is curved in slips but straight in other propagules. The time between planting and production of an inflorescence varies between 6 to 16 months and depends on cultivar, size of the propagule, date of planting, climate and soil (Py et al., 1987). Flowers (100-200 in number) are hermophroditic, each sitting in the axil of a bract. Five to ten flowers open every day from the base up, over a period of 10 to 20 days. The multiple fruit is formed by fusion of pathernocarpic fruitlets with bracts and the central axis of the inflorescence. The fruit takes 5 to 9 months to mature. The crop shows high drought resistance. It is a true xerophyte and has many adaptations to drought one of which is the behaviour of the stomata. The stomatas stay closed during the hot hours of the day and open during the cool hours to reduce moisture loss. The plant uses the CAM (crassulacean acid metabolism) system of photosynthesis (Kluge and Ting, 1978).

The pineapple is an efficiently built plant whereby leaf area continues to increase for 12 to 14 months and remains constant for another five months. Though net assimilation of the plant can be low (0.4-2g/m^2/day), the crop growth rate can be high (15g/m^2 or 150kg/ha/day). In a study in Hawaii, 390 tonnes/ha of fresh plant material and 62 tons of dry matter were produced in a cycle of 365 days (Bartholomew and Kardzimin, 1977).

3.2 Growth Patterns

Growth pattern of pineapples can broadly be subdivided into three phases (Etudes, 1977; Py *et al.*, 1987)

i) Vegetative phase of leaves, roots and stem growth

ii) Generative phase of flowering and fruit development

iii) Vegetative growth of shoots i.e. slips, crowns and suckers.

The three growth phases are not distinct but overlap. After floral initiation, leaf growth continues until the inflorescence appears. Flowering is usually artificially induced (forcing), usually before the completion of the rapid vegetative growth stage. Shoots can start developing before the fruit is completely mature. The weight of the plant increases regularly, with the percent dry matter of the plant remaining relatively constant. Production of dry matter per day ranges from 2g at 4 weeks to approximately 20g at 50 weeks (Sideris and Young, 1950). It has been estimated that the plant fresh weight can double every two months (Sanford, 1971).

The growth of a pineapple plant is influenced by a number of factors

- Weight of planting material (Py, 1960a; Gaillard, 1969). The higher the initial weight of planting material the earlier forcing can be carried out to give acceptable fruit weight.

- Type of shoot planted (Py, 1973; Lacoeuilhe, 1976a). Suckers have the fastest growth rate, while the crowns are the slowest, and slips falling in between. Growth is also affected by climatic and soil conditions.

3.2.1 Vegetative Growth

3.2.1.1 Growth of leaves: Until flower initiation, the leaves represent upto 90% of plant fresh weight excluding the roots (Py, 1959a) and this falls to approximately 50% by the time the fruit is ready for harvest. Increase in total leaf mass is due to growth of leaves already on the plant at planting and the newly developed leaves.

During the early plant growth, the type of shoot used for planting influences the rate of leaf emergence. When suckers are used as planting material, emergence of leaves increases regularly with age, while when crowns are used, 7-8 leaves can appear during the first month, then subsequent rate of emergence decreases. After 4-5 months the type of shoot used no longer has any noticeable influence on leaf emergence (Samson 1980).

The rate at which leaves emerge appears to increase during the months following flower induction. The last leaf to appear before flower induction is often located on the flower peduncle and it's growth is thus limited (Py *et al.*, 1987). The youngest leaf visible when the shoot is planted is often still alive when the fruit is ready for harvest, especially in the case of suckers. This means that it has an exceptionally long life of about 15 months (Py, 1959a).

Young leaves are formed at the apex. On the average , a new leaf appears every week. It is straight at first then it is pushed by new emerging leaves until it gradually hangs down. It is possible to distinguish between different categories of leaves on the basis of their position on the plant and their morphological characteristics. Samson (1980) reported the following classification of pineapple leaves done by Py and Tisseau (1965).

Classification of pineapple leaves from work done by Py and Tsseau (1965):

A- Those leaves which are fully developed when the shoot is planted. They are the oldest and outermost leaves with a zone of restricted growth near the base and are horizontal.

B- Those leaves which are present but not fully developed at planting. The neck is much higher.

C- Those leaves which have no neck and are the oldest leaves developed after the shoot is planted.

D- Those fully developed young leaves, standing at an angle of 45^{o}. Their weight, which can reach 100g, is closely related to the yield. They are the ones used for tissue analysis.

E- Those leaves that are still developing and are not yet green.

F- Those small and slightly coloured leaves standing straight in the heart of the rosette.

After emergence, maximum leaf elongation is 9cm/week and it takes 4 months to reach stage D. Each successive leaf is heavier than the previous one untill a maximum weight of 80-100g is reached (Samson, 1980).

3.2.1.2 Growth of roots: Root morphology is determined by the type of shoot used for planting. Suckers produce the fewest roots. Slips produce a bit more roots that grow faster and radially from the crook shaped base. Crowns produce the largest number of roots that grow horizontally and are only slightly branched.

Root mass increases relatively faster than leaf mass after planting (Py *et al.*, 1987). Growth of roots is shallow and limited. In the best growing media, roots go no deeper than 50 cm. In the soil, roots rarely go below 30 cm (Samson, 1980). Roots extend only upto the drip area of the plant, and for this reason therefore, pineapples can be grown at very high densities.

Three stages have been identified in the growth of pineapple roots from suckers (Hainnaux and De Ricaud, 1977 as reported by Py *et al.* (1987).

i) The first rapid growth which corresponds to the shoot's specific growth potential takes 1 to 2 months.

ii) The second intermediate stage of slow growth which under natural conditions, depends on climatic conditions.

iii) The third stage of rapid growth is when the plant growth is renewed. Its timing depends on environmental conditions and under natural conditions and takes 5-6 months.

When planting material has been stored, root initiation takes place and therefore a sucker that has been stored develops longer and more roots after planting than the one of equivalent weight, which has just been harvested.

3.2.1.3 Growth of the stem

The weight of the stem increases slowly during the vegetative growth, preceding flowering and increases sharply after floral initiation (Py *et al.*, 1987). Percent dry matter in the stem increases regularly after flower initiation then decreases sharply when the fruit nears maturity. This is because more sugars are mobilised to increase the fruit dry matter. The rate of increase in the dry matter of leaves and stems is almost equal up to flower initiation, after which the rate of increase in the stems is higher than that in the leaves. After fruit harvest the dry weight of the stem increases sharply. The stem therefore acts as a storage organ during fruit development.

3.2.1.4 Growth of shoots

Three types of shoots are common in pineapple, namely, the crowns, slips and suckers (Collins, 1960). Their growth is regarded as the second vegetative phase which occurs after floral initiation (Etudes, 1977).

The crown emerges from the terminal meristem and its development is linked to that of the fruit. Slips and suckers develop from auxillary buds which are dormant as long as the apical meristem is in the vegetative phase. They only start growing after floral initiation which breaks the dormancy. Climate and floral inducing agents affect the number and position of shoots produced (Py *et al.*, 1987). Usually the first buds to develop are in the axils of relatively young leaves. Fewer shoots develop compared to existing buds.

Under natural conditions, a mature plant will produce upto 5 slips as well as one or more (2-3) Suckers. Under favourable climatic conditions, longer vegetative phases favours development of more slips (Samson, 1980). The stage of plant growth at floral differentiation is important. In bigger plants, auxillary buds are much higher and develop more slowly as compared to smaller plants (Py and Gaillard, 1971). Growth of shoots developing on the stem inhibits development of other auxillary buds. Removal of such shoots (de-slipping), promotes development of other buds. The frequency of de-slipping determines the number and weight of shoots harvested from the plant. For instance in 'Smooth Cayene' the weights of slips vary considerably (100-300g) depending on their number. Consequently a choice between the number and weight of shoots has to be made.

Growth of slips starts after breaking of dormancy and continues upto just before fruit maturity when it stops. Slips therefore develop at the same time with the inflorescence. Slips and fruits therefore compete in their development.

Suckers start developing at floral differentiation, but undergo rapid growth only after the fruit is harvested. Their growth continues to produce a marketable fruit and the first ratoon crop.

Initial growth of the young shoot depends on reserves and on the mother plant activity which must be sufficient after fruit harvest to ensure shoot growth and restocking of stem reserves. Shoots developing on mother plants have no underground roots, except rarely in underground suckers. Shoots depend on the mother plant, particularly for their water supply. They must therefore have a healthy root system. Satisfactory control of root parasites especially nematodes is important.

3.2.2 Flowering: Plants have to develop vegetatively to build up food reserves for fruit development before floral initiation. Under natural conditions, flowering results in the death of the apical meristem and is generally irreversible once it has taken place. In pineapples, however, floral initiation does not lead to the death of the meristem. It is transitory, after which the meristem returns to vegetative state, producing a foliar organ on top of the fruit (crown). In pineapples, floral initiation can also be artificially induced. This is discussed in detail under commercial forcing.

After forcing, the first character that can be seen macroscopically is the conical shape of the apex. The bracts are initiated at a much faster rate than leaves and the first of these bracts becomes visible on the sixth or seventh day after floral initiation. The first flower then appears around the 10th or 11th day. Under conditions prevailing in Hawai described by Bartholomew and Kardzinin (1977), by the 30th day, all flowers have been initiated and the apex has returned to the vegetative phase.

Since differentiation of floral organs is sequential, flowers at the bottom of the inflorescence are never at the same stage of development as those at the top. This difference is noticeable upto fruit maturity, with the fruitlets at the bottom ripening before the ones at the top.

Natural flowering: Various factors influence natural flowering of pineapples. According to Py *et al.* (1987), these factors include:

a) Climate:

The pineapple is a short day plant and cool temperatures promote flowering. In the tropics where pineapples do well, days are generally intermediate and temperatures sometimes too high, however, reaching the flowering stage has a quantitative aspect and the shorter the nights the fewer the daytime cycles required to induce flowering.

b) Plant development:

Flowering will only occur when the plant has reached the required age and weight depending on the propagules used.

c) Nitrogen nutrition:

High nitrogen fertilization favours vegetative growth and reduces plant sensitivity to factors favouring floral initiation.

d) Type of propagule:

The lower the bud on the mother plant, i.e, the older the bud, the greater its sensitivity to floral initiation. Thus, suckers respond faster than slips and crowns.

e) Genotype:

Different cultivars have been observed to show different responses to floral initiation.

3.2.3 Fruiting and maturation: When the inflorescence starts to appear it is surrounded by purple bracts. This is the red heart stage. One to two weeks later, the inflorescence starts to come out and this is the rose or red bud stage (plate 1).

Since the differentiation of the floral organs is sequential, flowers at the bottom of the inflorescence are never at the same stage of development as those at the top. This difference persists right until harvest and represents one of the most significant characteristics of the pineapple fruit.

The number of individual flowers differentiated determines the average fruit weight and crop yield. Since the meristem subsequently returns to the vegetative state, the period during which flower primordia are formed is strictly limited. The number of flowers produced can depend on the length of this period and on the speed of differentiation.

The opening of flowers coincides with anthesis and is spread over a period of 15 days, with flowers opening successfully from the base to the top of the inflorescence (Py *et., al.*, 1987). Flower opening also coincides with the start of the crown and stem development and also to the elongation of the penduncle (Norman, 1980). Up until anthesis, growth of the fruit is mainly as a result of cell multiplication and a subsequent increase in cell size. At fruit maturity, the cells are completely distended, with the walls of some of the cells being close to disintegration and thus the marked fragility of the fruit flesh.

A pineapple fruit removed from the plant when immature does not ripen normally as is characterized by lack of further increase in sugars (^{o}Brix) and decrease in titratable acidity (Singleton, 1959). The length of the fruit development stage upto maturity depends on the cultivar used. "Smooth Cayenne" has the longest cycle, while 'Red Spanish' and 'Queen' have the shortest (Py and Tisseau, 1965).

In the development of fruit characteristics, two distinct stages have been demonstrated (Gortner 1969).

Plate 1: The rose or red bud stage in floral differentiation

1) Seven weeks before harvesting the fruit shows a low concentration of soluble nitrogen and flesh pigments and a start of an increase in acids and soluble solids. The rate of the formation of crown leaves also slows down.

Four weeks latter the fruit and the whole inflorescence undergoes the following physical and biochemical changes that are probably the first signs of ripening:

i) Caretenoid synthesis in the flesh starts and chlorophyll in the epidermis breaksdown exposing the carotenoids already present (Gortner and Singleton 1965).

ii) Slowing down of the increase in fresh weight and an acceleration of an increase in dry weight. This is as a result of a decrease in water supply and an increase in the supply of synthesised substances (Pineau, 1977).

iii) A few days latter the penducle dries out. There is an increase in dry matter and the refractive index of the juice from the penducle.

2) Simultaneously, the crown stops differentiating new leaves and increases in weight. Shortly before harvest, it enters a state of dormancy.

As harvest approaches, other fruit characteristics such as colour also change markedly.

- Shortly before ideal harvest time, there is a peak in acid content (Pineau, 1977). Thus, the sugar and acid contents which are the two most important factors that determine fruit quality changes considerably and inversely with one another just before harvest and the decision when to harvest has a notable influence on fruit quality (Py *et al.*, 1987).

- As ripening process ends, proteolytic activity decreases (Gortner and Singleton, 1965; Pineau, 1977).

Filling of the fruit is a combination of a decrease in size of the locules and a displacement of air pockets between the cells. These pockets disappear completely in advanced ripening. During ripening, the appearance of the fruit changes from opaque to translucent (Bowden, 1969), while the colour of the epidemis changes from green to yellow, starting from the bottom quarter of the fruit. Plate 2 shows fruits at different stages of development upto full ripe (yellow).

Plate 2 shows different stages of a pineapple fruit development up-to full ripe.

Plate 2: Different stages of a pineapple fruit development.
A Fruit in early stage of development

B. Fruit still developing in the field

C. A mature green (unripe) fruit

D. Ripening fruit

E. Ripe fruit ready for harvesting

4. PRODUCTION PRACTICES

4.1. Site Selection

The pineapple grows mostly between latitudes 25^{o}N and 25^{o}S of the equator. It also grows in some parts of the sub-tropics which are frost free. Though widely distributed within these limits, site selection depends on a number of physical and environmental factors such as water supply, drainage, risk of frost and the topography of the locality. Other factors to be considered are of economic and social nature, such as Distance from the market, availability and quality of infrastructure (roads, ports), availability and cost of skilled labour which determines the extent of mechanization.

Other factors affecting pineapple growing are connected with legal regulations and financial policy (Land regulations, availability of loans, fiscal advantages etc). However, the main considerations are climatic adaptability and soil suitability.

4.1.1. Climatic Adaptability

The pineapple can grow in altitudes ranging from sea level to about 2000m above sea level. In Kenya, most pineapples are grown between 1400 and 1800m above sea level (Anonymous, 1957). Any pineapple production at altitude above 1800m is determined by the average temperature of the region.

Temperature is the major environmental factor determining the distribution of pineapple. The distribution area is roughly limited between the tropics of cancer and capricorn, avoiding regions within these limits that are too mountainous and too cold as well as desert areas that are too dry and sunny (Py *et al.*, 1987). For this reason, the pineapple can be an attractive crop for poor or underdeveloped areas of the tropics with a semi-arid climate (Marzola and Bartholomew, 1979).

Pineapples grow best between 26 and 32°C. Growth ceases completely below 20°C and above 36°C. Elongation of leaves and roots is optimal at approximately 29 and 32°C, respectively (Senford 1962). Differences of at least 4°C must be maintained between day and night temperatures for adequate growth (Clark, 1931; Johnson, 1935).

Pineapples can grow and produce fruits with moisture supply ranging from 600 mm p.a. with a dry season lasting several months, to over 2450 mm p.a. (Collins, 1960). The best rainfall range for commercial pineapple production is 1000-1500 mm annually. The seasonal distribution of this rainfall is very important for maximum production.

Pineapples in Kenya grow successfully in areas receiving over 760 mm of rainfall per year. Pineapples for canning are grown between the altitudes of 1350 and 1750 m, because it has been shown that below the lower limit, the fruit is too sweet for canning while above the higher limit the fruit is too acidic.

4.1.2 Soil Requirements

Pineapples are grown on a wide variety of soils. Free draining soils are essential. On heavy soils, deep cultivation is necessary to prevent water logging. "Smooth Cayenne' should preferably be grown on sandy loam soils with a pH of 5-6. The tropical red-brown oxisols have a high iron oxide or manganese content. At high pH iron becomes unavailable to plants and heavily limed soils of high pH are unsuitable for pineapples.

Because pineapples grow slowly, the soil is usually exposed to all types' of environmental hazards, such as wind and rainfall causing erosion especially during the early months. Risks of soil damage vary from one type of soil to another depending on specific soil characteristics and the intensity and frequency of rainfall. The risk is high with slopes of more than 2-3% as the volume of soil washed off increases more rapidly than in the slopes of the terrain (Py *et al.*, 1987). On slopes of more than 5%, effective erosion control measures are often more difficult and planting of pineapple is not advised (Py *et al.*, 1987). Ecological data on the research sites is in Table 2.

Table 2: Basic ecological information on research sites where pineapples are grown

Regions	Thika	Malindi	Sondu	Webuye
Altitude (m)	1524	150-200	1300-1500	1350-1550
Average rainfall (mm)p.a.	923	600-800	1300-1700	1100-1300
Temperature (^{0}C)	13.85-24.85	25.3-26.3	20.5-21.7	20.6-21.5
Soil types	Red volcanic with high murram and clay content	Black cotton soil	Sandy loams to sandy clay loam	Sandy clay or sandy loam to clay
Topography	Slope 2-3%	Flat slope 1-2%	Lower level uplands, gently undulating slopes between 2-3%	Lower level uplands, gently undulating slopes 2-4%
Drainage	Poor	Poor	Good	Good

4.2 Land Preparation

Pineapples have shallow and weak root system and require deep cultivation to facilitate drainage. The older roots which emerge at the lowest part of the stem grow into the soil and branch into a limited number of secondary and tertiary roots, to form the underground root system. Underground roots can grow to be upto 2m long but rarely grow to a depth of more than 85 cm (Krauss, 1948). The field for pineapple growing must be cultivated deep and soil clods broken up to form a fine tilth. This gives a seedbed that is well aerated and also prevents subsurface compaction.

Soil fumigation for prevention of nematodes is then carried out. Fumigation is effective when soil moisture is low, therefore land preparation should be carried out during the dry season. Decomposition of previous organic matter should be complete before soil fumigation is carried out.

In Kenya, land preparation depends on the scale and the economic aim of production . All tillage, land clearing and planting operations are carried out during the dry season to avoid soil compaction, especially in areas with high clay content e.g. Thika and Sondu. All new fields are first cleared of all bush and trees.

In large scale farms at Thika, old and new fields are prepared similarly. For a replant field, old plants are first burned before the land is considered ready for preparation. The following steps are followed in the preparation of land for pineapple planting in the large scale estates.

i) Subsoiling or ripping using ripper shunks (Delmonte) or a plough (Swani) that will penetrate the soil to a depth of 24-36 inches (70-91.4cm) across the planting direction. Large rocks are removed at this stage.

ii) Harrow pass across planting direction to break up large lumps as much as possible.

iii) Additional harrow passes (2-3) along the planting direction. This is to produce a very fine tilth

iv) A last subsoil pass done along planting direction to remove any sub-surface compaction. Wooden drag is mounted behind the subsoil shunks to smoothen out the soil surface.

The end result of this operation is a fine deep seedbed that is essential for development of a healthy root system (good anchorage) and a high yield potential.

Prepared land is then subdivided into blocks with roads between blocks. Within each block are double row beds. This is followed by soil fumigation and mulching which are done simultaneously with the application of preplant fertilizer. Telone II at the rate of 136l/acre (340l/ha) is injected into the soil at Delmonte whereas Sunripe uses methyl dibromide at 6g/m2 (600kg/ha). Mulching is laid mechanically by use of black plastic mulch of 150 gauge, 32 inches (81.3cm) wide, stretched out over the planting bed. Approximately 15cm of mulch is covered with soil on each side of the bed. (plate 3). Mulching improves the efficacy of fumigation, maintains high soil temperature, retains moisture and provides some weed control in the planting bed.

In small scale production areas land preparation is manual. This is mainly by use of hand hoe and panga. In a few places a draft (animal power) is used. In Sondu about 60.3% of farmers use small hoes or pangas, 35.7% use draft, while the rest (4%) use both. In Webuye 57.1% and 42.9% use hoes and animal power respectively. In Malindi pineapples are grown on trust land. The bush is simply burned then planting follows. Shifting cultivation is practised. The fruit size is the criterion used to determine period of cultivation. Small scale farmers do not use mulch. At altitudes above 1000m, the use of vegetative mulch is not recommited as it reduces soil temperatures and produces lower growth rate. A few farmers, however, use this kind of mulch to control weeds. At the Coast due to the high temperatures, use of mulch is not necessary (N.H.R.S 1955).

Plate 3: A plot with black polythene mulch.

4.3 Varieties:

There are about 40 varieties of pineapples but only a few are presently grown commercially. The four most important commercial varieties are "Smooth Cayenne', 'Queen', 'Red Spanish' and 'Abacaxis'. The most recent key for classification of pineapples was drawn by Leal and Anton (1980), for cultivars found in Venezuela (Py *et al.*, 1987) as shown in Table 3. It essentially uses the criteria normally followed in distinguishing between different varieties which include;

- growth habit of the plant.
- shape of fruit and fruitlets.
- number and size of tracts.
- characteristic of the flesh.
- morphological leaf characteristics, presence or absence of spines, shape, piping and non-puping.
- number of turns of the spiral of fruitlets round the fruit.

In Table 2, traditional criteria are used to give a standard description of each of the five main groups of pineapples. The table also shows the main world cultivation areas and the most appropriate uses for each group. 'Smooth Cayenne' and its local sub-varieties are grown in the major exporting countries. The fruit of 'Smooth Cayenne' has a cylindrical shape with an average weight of approximately 2.5kg per fruit and with fruit eyes that are relatively shallow. The core is small relative to the fruit. It has a good yellow colour and a pleasant flavour and aroma (King, 1972). It contains 80-85% water, 2-5% sugar (2/3 of which is sucrose and the rest glucose and fructose), 0.6% acid (of which 7% is citric acid and the rest malic acid), 0.4% protein, 0.5% ash (chiefly potassium), 0.1% fat, some fibre and several vitamins (mainly A and C) (Sampson, 1980) vitamin C content varies from 8-30mg/100g fruit weight.

The sub-varieties are rather squat with smaller crowns than the standard 'Smooth Cayenne' grown in Kenya and the Republic of South Africa. When ripe 'St. Michael' pineapple (a sub-variety of 'Smooth Cayenne'), has a bright yellow - red colour with deep yellow flesh, which is reasonably sweet. It has a small core and therefore there is less wastage when the fruit is cut into slices.

The 'Red Spanish' pineapple is grown in the Caribbean and Mexico but its colour, 'a dull yellowish-red, is not very attractive. The texture of the fruit tends to be woody and the flavour is generally considered to be inferior to that of the 'Smooth Cayenne'.

'The 'Queen' is a small fruit of average weight (0.7kg) with good sweet flavour, fine textured flesh and a small core. The small size enables the fruit to be retailed at very reasonable prices. It is therefore favoured by certain sections of the retail trade. Some 'Queen' pineapples are still grown in South Africa.

The 'Abacaxis' or 'Panambuko' is the principle variety of pineapples grown in Brazil. The fruit has an elongated cylindrical shape. The flesh is pale yellow to white, juicy and tender. Although it is less acidic than 'Smooth Cayenne', its

TABLE 3 - Common pineapple cultivars:- Major growing zones, fruit characteristics and common fruit uses.(C.Py, J.J. Lacouihle, G. Teisson, 1987)

Usual name of the group	Cayenne	Spanish	Queen	Pernambuco (1)	Perotera (2)
Main production zones	All main production centre in the world: Hawaii, Thailand, Phillipines, Taiwan, S. and W. Africa, Kenya plus the countries quoted for other groups	Carribean islands Cuba, Porto-Rico, Mexico, Malaysia	South Africa, Australia La Reunion	Brazil, Venezuela	Colombia, Ecuador, Peru
General appearance of the plant	"Open" rosette of leaves	Rosette less "Open" than Cayenne	Same as Cayenne	Erect	Rosette less "Open" than Cayenne
Shoot formation at fruit harvest - slips	Some cultivars have slips, some do not	Number and size of slips variable usually small	Number of slips variable usually small.	Numerous erect well developed slips attached regularly around the base of the fruit.	Numerous slips of different sizes.
- Suckers	Few suckers	Few suckers	Large number of suckers in some cultivars (Natal, Queen, Victoria).	- Very few suckers, develop late.	
Leaves (demensions, spiness and colour)	- Broad and relatively short - Spineless except near tip.	- Narrow and long - Usually spiny but some cultivars are spineless or have few spiness. - Colour of the non-chlorophylous basal Part: reddish green	- Narrow and short - Spiny, hook shapped spiness. Colour of the non-cholophylous basal part reddish.	- Narrow and long - Spiny but not hook shaped spines - Colour of the non-chlorophylous basal Part: pink mallow	- Broad and long - Thermous ("Piping type" except the distal spine. Colour of the non-chlorophylous basal part: Pale green.
Peduncle (length in relation to fruit length	Relatively short	Shorter than Cayenne	Short	Longer than Cayenne	Larger than Cayenne

(Table 3 Contd..)

Fruit - Size, weight - Shape	- Large fruit - Cylindrical	Smaller than Cayenne Globular	Small fruit Conical cylindrical	Smaller than Cayenne Pyramidal	Similar to Cayenne Cylindrical
- Fruitlets(eyes)	- Flat and wider than cayenne	Flat and wider than Cayenne and prominent	Smaller than Cayenne and prominent	Small and slightly Prominent	Flat, wide and often irrular.
Fruit Skin cobra (at complete maturity)	- orangy-yellow	- Reddish yellow	Bright yellow	Greenish yellow	Bright reddish yellow
Flesh (at complete (maturity)					
- Appearance	More or less trans-	More or less translucent	Opaque	Translucent	Opaque
- Fibrosity	- Non fibrous	Fibrous	"Crisp"	Non fibrous	"Crisp"
- Colour	- Pale yellow	Whitish	Bright yellow	Whitish to yellowish	Alternating bright yellow and pale yellow.
- Flavour	Sweet and acid	"Spicy" less sweet than Cayenne	Less acid than Cayenne	Less acid than Cayenne	Less acid than Less sweet than Cayenne-Ascorbic Acid content higher than Cayenne.
- Core (diameter)	Medium	- Diameter varies with C.V.	Smaller than Cayenne	Smaller than Cayenne	Similar to Cayenne
Resistance/tolerance to "wilt" disease nematodes	Very susceptible to wilt and nematodes	Toletant to wilt Less susceptible to nematodes than Cayenne	Less susceptible to wilt than Cayenne	Less susceptible to wilt than Cayenne	Less susceptible to wilt than Cayenne.
Possible uses	Local consumption For export canning	Local consumption Mainly for export fresh	Local consumption For export fresh	Local consumption	Local consumption For export fresh

(1) Other name "Abaxaxi" that should be avaoided as it means "pineapple" in Brazilian

(2) Camargo classified it as a subspecies of A. comosus. A. mordilonus: likewise names

flavour is good. It has a small core and in this respect resembles the 'Queen' variety.

The commercial pineapple variety in Kenya is the 'Smooth Cayenne' (Anonymous, 1957). It is grown both for processing and fresh consumption.

4.4 Planting

For propagation, crowns, slips and suckers are used (plate 4) depending on availability. These planting materials can easily be differentiated by appearance. The crown is short, stout and straight. Suckers are also straight with a clean base but longer than crowns. Some suckers such as ground suckers have roots. Slips are small with curved bases without roots. If a plantation is to be homogeneous, which is a pre-condition for rational plantation management, each type of suckers must be planted separately. It is even advisable to create a separate plot for each different weight category (Py *et al.*, 1987). Under normal conditions, crowns take a longer time from planting to harvesting (24 months) compared to slips and suckers which take 20 and 18 months, respectively. However, plants from crowns grow evenly, while those from suckers and slips show uneven growth. In Kenya, Evans (1957) and Waithaka and Puri (1971) reported that commercial growers prefer crowns over slips and suckers.

Planting material should be cured after removal from the mother plant before planting. This involves spreading the material on the sun for three days to two weeks depending on the weather. This allows the cut ends to cork over, offering resistance to bacterials or fungal infection. Every effort must be made to ensure that only healthy planting material is used as this is the most effective way of preventing disease and attack by pests (Py *et al.*, 1987). Several different types of infection start in the shoot. Therefore, the planting material should eventually be dipped in a fungicidal and insecticidal solutions in order to protect it against mealybug and fungal diseases. The choice of chemicals used is specific to different diseases or plantations.

Planting is normally done at the beginning of the long rains. Shallow planting causes weak root development, while deep planting causes the plants to be filled with soil or sand resulting later in rot. Crowns are planted 7.5-10cm deep. A double row system is most convenient with pineapples as it allows easy access between rows (Samson 1980). The double row beds are normally 1.5m apart from centre to centre. The two rows within a bed are 0.5m apart with plants spaced at 0.3m within the row to give a plant population of 47,000 plants/ha (Mwaule, 1983).

In Kenya pesticide treatment of planting material is only practised by large scale growers, where seedlings are dipped in a mixture of Alliette, Diazinon and Benlate (Delmonte). This treatment controls mealybugs, phytophthora and other fungal diseases. Sunripe treats the seedlings with Diazinon at 250ml/20l of water, in which the seedling is immersed completely for five minutes before planting. Small scale farmers in all regions do not carry out any chemical treatment of the propagules prior to planting.

Double row system of planting is used by Del Monte at 20 inches (50.8cm) between rows, 10 inches (25.4cm) within rows and 45 inches (114.3cm) centre to centre and a path of 25 inches (63.5cm) wide between double rows. This spacing gives a population of 28,100 plants per acre (70,250 plants/ha) (Delmonte 1990). At Sunripe the double row spacing is 8 inches (20 cm) within rows, 20 inches (50.8cm) between rows and 47 inches (120cm) centre to centre to give a plant population of approximately 75,000 plants/ha.

Majority of small scale growers use single row spacing. The spacing between and within rows varies between regions and also among farmers in the same region depending on the kind of farming practised. In Malindi where pineapples are grown as a monocrop, farmers use a spacing of 100 x 50cm single rows to give a plant population of 20,000 plants/ha. In Sondu and Webuye where pineapples are intercropped with subsistence crops such as maize, pigeon peas. The spacing between and within rows is farmer specific and is characterized by low plant populations per unit area. Planting is a manual operation in both small and large scale farms. In large scale planting, spots are marked on the polythene mulch and using pangas, the planter punches the mulch, and quickly inserts the seedlings into the ground. About 6,000 plants can be planted per man day. Ninety percent of planting materials at Del monte are crowns, while Sunripe plants both crowns and slips but on different fields.

Small scale growers use a combination of crowns, slips and suckers. In Malindi, farmers predominantly use slips as they are easier to transport due to their lights weight. In Sondu, crowns and suckers are planted with slips being used only when these two are scarce. In Webuye farmers use slips or suckers or both. In the three regions, preparation of planting holes is by use of hoe or panga. A sisal string helps keep the lines straight. Plate 5 shows a small scale and a large scale planting operation side by side.

Crowns establish earlier and give heavier and more uniform fruits as they show uniform growth. Slips and suckers are less uniform. Large scale farmers plant their plots at once such that the plants are at the same stage of development. Small scale growers, however, plant the same plot at different times, thus the plants are at different stages of development (Plate 6). Large scale farmers plant during the dry season using irrigation for proper crop establishment.

Plate 4: Different propagules (a) Crown (b) Suckers (c) Slip (note the curved base).

a) Crown short, stout and straight

b) Suckers long and straight

c) Slip. short, light with a curved base

Plate 5: Small scale and large scale planting operations

(a) Small scale operation

(b) Large scaleOperation

Plate 6: Small scale farmer's field showing plants at different stages of growth.

4.5 Crop Fertilization

The relative weakness of pineapple root system limits potential absorption of mineral elements. As the plant ages, its nutritional status becomes a determining factor in its development (Py *et al.*, 1987). This is as a result of increasing nutriet requirements by the plant for production of solids in the fruit.

Pineapples require heavy nitrogen fertilization for high yields. Rates of 110kg/ha in both long and short rains or a monthly foliar spray of 85kg/ha of phosphate in form of ammonium phosphate gives good responses. The fertilizer is best applied at four months after planting in the axils of the lower leaves (K.V.D.A., 1983). Pineapples do not tolerate high calcium levels. It is therefore advisable to use Ammonium sulphate nitrate (ASN) instead of Calcium ammonium nitrate (CAN) as a source of nitrogen. Nitrogen should not be applied close to flowering time as it will favour vegetative growth and may reduce yield.

Research on pineapple fertilizer application has shown that nitrogen and iron increase the proportion of heavier fruits and also promote early harvesting (N.H.R.S., 1953). Use of manganese improves fruit colour. In Kilifi, use of phosphate plus potassium gave poor results, while a combination of vegetable mulch and nitrogen gave the best yields (N.H.R.S., 1955). Iron increases the number of plants producing fruit, while magnesium improves the mean weight of fruit. Use of sulphate of ammonia and magnesium depress yield, while iron and magnesium increase mean fruit weight. Combined use of fumigant, iron and magnesium favours yield, number of fruit and mean fruit weight. Nitrogen gives a residual effect on plant vigour when sulphate of ammonia is used (21%N). Sulphate of ammonia also accelerates fruiting in plant and ratoon crops. Copper at 0.5% decreases yields and fruit weight.

Sulphate of ammonia was considered a better source of nitrogen (N.H.R.S., 1956). It increased yields by increasing the mean weight and number of fruit. Potassium accelerates crop harvest as compared to superphosphate. Sulphate of ammonia and manure increased yield and the mean fruit weight while single super phosphate increased the mean fruit weight but not the yield. In plantations with soils of low iron content, routine foliar sprays of iron as iron sulphate is recommended to reduce iron chlorosis.

The use of farm yard manure can improve production (N.H.R.S., 1957). Increased use of potassium decreases yields as it antagonises magnesium uptake. Copper (0.5%) suppresses yield of plant crop but not of ratoon crop. High levels of trace elements e.g. 0.5% copper and 0.5% manganese was found to depress fruit yields (N.H.R.S., 1957). Urea (46%N) is increasingly used (2-40% weight) when there is a lot of rain or water in the soil but is limited only upto 5% during the dry season or dry soil conditions. Nitrogen applied as sulphate of ammonia and given at the same rate as urea but as a ground application gives better results as compared to urea.

N.H.R.S. (1959) reported that pineapples do not respond to late remedial applications of fertilizer. It has to be applied in the early months of fast growth. Though Sulphate of Ammonia proved to be more effective than urea at the same nitrogen level, foliar application of nitrogen was found to be cheaper than the ground application (N.H.R.S., 1960).

At present, the use of fertilizers in Kenya is confined to the large scale pineapple growers. For small scale producers, plants are left to the mercy of the prevailing climatic conditions to determine their growth rate. In large scale estates at Thika, soil analysis is done before planting to ensure a phosphorus level of at least 12 p.p.m.. During planting, Diammonium phosphate (DAP) at the rate of 200kg/acre (500kg/ha) is used. This provides the plants with enough nitrogen for the first two months of growth. At Del monte Kenya Limited, this is followed by application of urea (46%N), ferrours sulphate and zinc sulphate as foliar sprays at the rate of 300kg, 60kg and 80kg per acre (750,150, 100kg kg/ha) respectively for the first crop. The ratoon crop receives urea, ferrous sulphate and zinc sulphate at the rates of 247, 38 and 5kg per acre (617.55, 95 and 12.5kg/ha), respectively as foliar sprays. Sunripe (Swani estate) follows the DAP application with monthly topdress of urea (46%N) at the rate of 180kgN/acre (450kg/ha), iron as iron sulphate at 3kg/acre (7.5kg/ha) and Zinc as Zinc sulphate at 4kg/acre (10kg/ha) through drip irrigation until the plant is mature for flowering.

Phosphate and potassium application is not regular as it depends on soil analysis in the course of plant development. Leaf analysis can indicate lack of a macro or micro nutrient which are then supplied either as foliar sprays or side dress.

Small scale farmers in Malindi use no fertilizers either at planting or during the growth and development of the pineapple plant. In Sondu, a few farmers (30%) use farmyard manure at planting but at rates that are not uniform depending on availability. In Webuye 57.1% of farmers interviewed use farmyard manure at rates that depend on availability, 14.3% use different fertilizers mainly Diammonium phosphate at the rate of 1 table spoonful/hole. However, 28.6% of Webuye farmers do not use fertilizers or manure. For this reason fruits grown by small scale farmers vary in size depending on the inherent soil fertility.

4.6. IRRIGATION

The use of irrigation depends on the availability of water from dams and boreholes, soil types and depths and age of plants. Pineapples require 50-60g of water for the production of one gram of dry matter (Sideris and Krauss, 1928), as compared to 200g of water required by mesophytic plants such as mangoes, oranges etc. At Delmonte Kenya Limited, where planting is done in the dry season (Delmonte, 1988), 2 inches (5.08mm) of moisture is applied by splinkler irrigation immediately after planting. This sets the plant and establishes good seedling to soil contact. It also facilitates early development of roots for good anchorage and mineral absorption. Thereafter, the soil water reservoirs in the main root zone is not allowed to dry out before the next irrigation. For young plants the frequency of irrigation rather than the volume of moisture supplied is more important for optimum plant growth.

As plants grow older, irrigation frequencies are reduced. Irrigation is particularly important in the dry season and for the improvement of the ratoon crop. At Delmonte and Sunripe, both drip and overhead irrigation are used. Foliar fertilizer application is combined with irrigation. Small scale farmers in Kenya do not irrigate their pineapples.

A Pineapple plant maybe drought tolerant but growth and fruiting maybe delayed if such conditions last for 3-4 weeks continually (K.V.D.A., 1975).

Although the plant uses water efficiently, water supply around the root zone should be assured for proper plant growth. When soil water pressure reaches 15 bars (Lindford, 1934a), root elongation stops and root tips become suberised. A water deficit reduces the number and average length of roots (Kadninim, 1975). Growth may be renewed when soil becomes moist again but the roots are spidly and fragile. A more prolonged drought can lead to the death of the plant, but before this stage is reached, the plant can switch to CAM type of photosynthesis until conditions become more favourable for the development of new root primordia on the stem.

According to Combres (1979c), pineapple growth is reduced when water pressure in the soil is less than 15 bars at a depth of 15cm. This value is considered to be a warning sign for possible need for irrigation. Evapotranspiration decreases with an increase in leaf coverage of the soil inspite of an increase in foliar transpiration area with the age of the plant (Ekern, 1965). Covering the soil with plastic mulch is an effective way of reducing water loss and maintaining the humidity of the superficial layer of soil penetrated by the roots until the surface of the soil is sufficiently protected by plant foliage. Under Hawaian conditions, the use of plastic mulch throughout the whole cycle reduces evapotranspiration from 1/2 to 1/3 of pan evaporation (Ekern, 1967).

A satisfactory supply of water to pineapple plants while fruits are developing means photosynthesis can take place at a higher rate and also improves the mobility of sugars (Sideris and Krauss, 1933). Moisture supply also plays an important role in fruit filling and its final weight (Su, 1961). Plants that have received comparable irrigation during the vegetative period, but have their water requirements fulfilled at different rates, from true flowering until harvest produce fruits with marked differences in weight even during periods with little water stress (Combres, 1980).

In case of severe drought, fruit filling and fresh weight is poor, the crown is weak and the fruit shell lacks lustre. Irrigation improves all these characteristics particularly the appearance of the shell (Combres, 1981). Irrigation on well established plants with 50 mm of water per fortnight is adequate to improve all the above mentioned characteristics (Py *et al.*, 1987).

4.7 Weed Control

Weed control must be achieved to prevent competition for sunlight, water and nutrients between weeds and the pineapple crop. Several methods of weed control have been used in different areas. These include:-

i) Bio-ecological approach by encouraging the growth and development of pineapples so that they gain the upper hand over the weeds or Use of a cover crop that eliminates the weeds before planting the pineapples and or tilling the soil to allow seeds to germinate, then destroying the weeds' reproductive organs and organs of conservation (Py *et al.*, 1987).

ii) Chemical weed control by use of herbicides: This can be carried out at four distinct stages in the plant cycle as follows:
   - Soil preparation
   - When shoots are planted
   - In the course of vegetation
   - After the fruit is harvested

The most popular herbicide is Bromacin as a pre-emergent herbicide which is applied to the soil and suppresses weeds for about 6 - 12 months. Herbicides are now rarely used on their own. Very frequently the combinations of mechanical and chemical weed control has proved to be most effective. In most pineapple growing areas weeds are controlled by a combination of mulch, herbicides and hand cultivation (Mwaule, 1983). In Kenya, large scale pineapple growers use herbicides for weed control. The herbicide is applied just after mulching and before planting. Del monte Kenya Limited applies Diuron at the rate of 0.6kg/acre (1.5kg/ha) and Branzion at the rate of 1.2kg/acre (3kg/ha).

Sunripe uses both pre and post-emergent herbicides. Karmex at 2kg/200l of water and Hyvar at 1kg/200l of water are used as pre-emergent herbicides. Roundup (100ml/litre of water) is used for control of couch grass. Gesapex at 2kg/200l of water is used for the control both broad and narrow leafed weeds. The later two are postemergent. Del monte also does some hand weeding.

Small scale growers use only hand weeding. The main annual weeds in pineapple fields are Cleone, Euphobia and Potulata. Perennial weeds are mainly grasses. Thus, weed control in Kenya combines herbicides, mulching and hand weeding.

4.8 Commercial Forcing.

Planted under normal growing conditions, pineapples from crowns will change from vegetative to reproductive phase between 11 and 13 months and for ratoon crop between 26 and 28 months (Del Monte, 1988). Flowering is normally non-uniform and can be adversely affected by weather conditions thus spreading the maturity and harvesting period over a long uneconomical period (Samson, 1980). Irregularity in pineapple flowering, fruiting and ripening can be corrected by use of growth regulators (Norman, 1972).

Forcing is an artificial method of inducing flowering. It involves the use of ethylene, synthetic ethylene generators or synthetic hormones. It started with the use of smoke in green houses (Adams, 1935; cited by Py *et al.*, 1987) and later it was discovered that ethylene was the active ingradient. In its pure form etheylene is very expensive and therefore its generating agents e.g Ethrel (ethephon) and other unsaturated hydrocarbons Acetylene are used instead (Py and Guyot, 1970; Py *et al.*, 1987). Hormones such as Naphthalene acetic acid (NAA) have been found to have the same effect as ethylene (Burg and Burg, 1966).

Ethylene and other flower inducing agents give good results when applied early in the morning or late in the evening. They, however, give best results when applied at night. This is because at this time the temperatures are low and there is reduced evaporation and loss of the ethylene gas. Also the stomata are open allowing better absorption of the gas by the plant.

Ethylene is slightly soluble in water and is applied in large amount of water. A rate of 800g per application per hectare in 8000l of water is required (Py *et al.*, 1987). Application at night should be repeated every 2 to 3 days.

Calcium carbide is applied in the heart of the rosette stage either as a pellet or in solution. Calcium carbide produces acetylene gas when it comes into contact with water. The solution form is preferred to the pellet form because the latter can cause burning. A solution of 500g of crushed calcium carbide in 150l of water is prepared (Py *et al.*, 1987). Fifty to 100ml of saturated acetylene is applied in the heart of the plant (Samson, 1980). Application of acctylene is also best carried out at night.

Ethrel (Ethephon) is the most commonly used forcing agent for pineapples. This is because repeated application of Ethrel is not necessary and it can be applied at any time of the day unless the temperatures are very high (30^{o}C or more). It releases ethylene slowly but it's effectiveness can be increased by addition of urea. Urea also makes the solution ice-cold, (0-2^{o}C) thus reducing evaporation. A solution of 100-500 ppm Ethrel and 2.5-5% urea in 2000-3000l of water per hectare is made and is broadcast over the whole field (Py *et al.*, 1987). Ethrel reduces mean fruit weight and slips and suckers production. It increases acid and total soluble solids content of the fruit but does not influence the ^{o}Brix to acid ratio (Mwaule, 1983).

Reduction in fruit weight could be due to plants still undergoing vegetative growth and not being physiologically mature for fruiting (Evans, 1957).

Naphthalene acetic acid (NAA) which is a synthetic anxin is only applied during periods close to natural flowering. It acts by changing the balance of indogenous hormones in the plant and thus induces flowering. It is applied at the rate of 0.25-1.0mg per plant (Py *et al.*, 1965). It can be broadcast over the whole field or applied in the heart of the rosette stage. Treatment should be repeated after one week. NAA is not favoured as a flower inducing agent because it results in production of a pointed fruit which is not good for canning. The fruit also ripens unevenly (Samson, 1980) and its peduncle is long, increasing the risk of lodging. Also fewer slips are produced (Py *et al.*, 1987).

Flower inducing agents are most effective if supplied abruptly to the plant. Absorption appears to be extremely rapid and takes place near the apex. It has been shown that treatment is most effective when the product is placed in the heart of the rossette.

Numerous similarities exist between natural and artificially induced flowering of pineapple (Py *et al.*, 1987). These similarities include:

i) Stimulating the plant to counteract the strong tendency to remain in the vegetative phase. In both cases nitrogen nutrition has to be lowered or stopped as it favours vegetative growth.

ii) The age and size of the plant is significant, There is both a lower and an upper limit, above which only natural flowering can take place (Py & Guyot, 1969).

The upper limit of artificial flowering coincides with the lower limit of natural flowering.

iii) The type of shoot used influences flowering in a similar manner in both natural and artificially induced flowering i.e. suckers flower faster than either crowns or slips.

These similarities indicate that the primary mechanisms in both natural and artificially induced flowering in pineapples are similar. Forcing should be carried out at least twelve months after planting.

In Kenya, forcing is a commercial practice in pineapple estates. Del Monte uses ethylene at 1kg/acre (2.5kg/ha) while Sunripe uses Ethrel at 20cc/20l of water per acre, mixed with urea to make it ice cold. In both farms, application is done at 12 months after planting for crops to induce uniform flowering. Ethylene is applied at night by Del Monte in order to prevent excessive evaporation due to warmer temperatures during the day. Sunripe sprays Ethrel in the evening and urea helps reduce evaporation.

After forcing, weekly surveys are made to check the success of flower induction. The time from application of the forcing agent to the first sign of flowering (red bud) is dependent on temperature and takes between 45-75 days with the longer time being taken during the coolest period of the year.

Ethylene application ensures uniform flowering of plants that are well developed i.e. 38-40 inches (96.5-101.6cm) high and can give a fruit of good weight. Also, the fruit develops and matures at almost the same time and harvesting can thus be organised well in advance. The ratoon crop is forced to flower 6 to 7 months after harvesting of the first crop when the developing sucker has attained a height of 35 inches (88.9cm). The main crop takes 18 months from planting to harvest, while the ratoon crop takes 14 months from the harvesting of the main crop (Evans, 1951; Waithaka and Puree, 1971). Application of forcing agents to induce flowering is staggered over blocks so as to have ready fruits at different stages and times of the year to regulate constant supply.

4.9 Pests and Diseases

Mealy bug (*Dysimicoccus brevipas*) is the commonest and most damaging insect pest of pineapples and especially the "Smooth Cayenne' (Collins, 1960). The insect is found in the roots, leaf bases or in the fruit. Mealy bugs spread a virus disease, mealy bug wilt (Pink disease), whereby the leaves turn red or yellow followed by stunting and dieback from the leaf tips. As the disease progresses the roots cease to grow and the plant collapses.

During the dry season, the bugs can commonly be found on the roots and at the base of the plant, whereas during the wet season, they can often be seen on the underside of leaves.

Mealy bugs are spread from one focal point in the field by attendant ants that feed on their sugary secretions. On appearance of the wilt symptoms, insects move to healthy plants.

The initial chemical treatment of the propagule before planting is quite effective in controlling mealy bug attack. In the field the bugs can be controlled by spraying of chemicals such as Diazinon. Infected plants should also be logged out of the field. Attendant ants can be destroyed by use of insecticides such as Dusban. They can also be prevented from entering the field by leaving a barrier between the field and any nearby bush.

The mealy bug is the most damaging pest of pineapples in Kenya. At Thika, field control is carried out by use of Diazinon at the rate of 0.77l/acre (1.9l/ha). Other chemicals e.g. Vyadat at 2l/acre (5l/ha) can also be used. Attendant ants are controlled by use of Dusban at the rate of 0.6 l/acre (1.5 l/ha).

Small scale farmers rarely use control measures for the mealy bugs or attendant ants. Nematode control at Thika is carried out by use of Telone II nematicide as a fumigant by Del Monte at the rate of 130 l/acre (325 l/ha) as a pre-planting fumigant. This gives control for at least 3 years.

Thrips, spread a virus which causes yellow spots on pineapple leaves. The virus is spread from host plants e.g. the weed, *Emelia santifolia*. It can be controlled by eliminating the host plant.

Many species of nematodes are found in all types of soils. They can number upto 100,000/dm^3 of soil (Samson, 1980).

However, only a limited number of nematode species attack pineapples. They damage the root system and can have a marked impact on production by retarding growth and development of the plant. The Nematode species include *Meloidgyne spp* (root knot nematodes), *Pratylenchus spp* (root lesion nematodes) and *Rotilenchus spp* (spiral) (Samson, 1980; Mwaule, 1983). Nematodes prefer light soils to heavy ones (Samson, 1980). Their increase in number slows down plant growth, leading to a complete loss in production. In 'Smooth Cayenne' losses of 30-40% of the main crop can be incurred. The ratoon crop is even more sensitive. Production can be as low as 20% of expected tonnage, or even negligible, unless nematode control is effective during the course of the main crop cycle. Nematodes can be controlled by soil fumigation. This is done during land preparation by use of chemicals such as D.D. Nemagon. It is important that these chemicals penetrate the whole layer of soil to be penetrated by the roots. Since these chemicals can be irreversibly absorbed on all types of organic matter which is responsible for their breakdown, it is important that all residue from the previous crop be well decomposed. Moisture levels should not be too high to prevent dilution of the fumigant. Therefore, fumigation is best carried out during the dry season. Soil temperature is also important for fumigation to be effective. If temperature is too low, the fumigant remains within the immediate vicinity of the point of insertion, which can cause localized phytotoxicity. On the other hand, if temperatures are too high volatization can take place too rapidly with loss of the product to the atmosphere. D.D. Nemagon remains in the immediate vicinity of the point of insertion with no diffusion at temperatures below 7°C. Diffusion then increases with temperature, with optimum diffusion at 18-20°C. Materials infected with nematodes should be destroyed before planting (Samson, 1980; Py *et al.*, 1987). Planting pineapples in rotation with some other crops has also been found to be effective in controlling nematodes, e.g. sugarcane planted 3 or more years before pineapple planting (Samuels *et al.*, 1976).

Psymphilids are millipedes that attack and feed on the root system of pineapples. They are also controlled by fumigation. Other minor insect pests which have been reported include. scales, aphids, mites, crickets, fruit flies etc. (Sampson, 1980). Among these, scales, can be very demaging under certain conditions. If present in large numbers they reduce the photosynthetic surfaces of the leaves resulting in slow plant growth. In extreme cases yields can be greatly reduced and death of the plant can result. Pests can also be found on the fruit where they not only spoil the appearance but are also believed to promote the development of tiny cracks between the fruitlets.

Scales are controlled by spraying with Marathion mixed with white oil. The white oil helps to penetrate their hard covering.

Heart and root rots are fungal diseases caused by *Phytophthora sinamoni* and *Phytophthora parasitica*, respectively. The latter is more prevalent in warmer regions.

Phytophthora attack is particularly common in wet weather and at cooler sites on poorly drained soils (Samson, 1980). The use of an untreated planting material can result to the rot (Py *et al.*, 1987). These fungal diseases mostly attack the young leaves.

Nematode attack can precede Phytophthora attack, leading to drying up of plants before fruiting as observed at Sondu in South Nyanza (Plate 7). This happens when rain is excessive and drainage is poor. Roots of uprooted dried plant have bundled up at the centre. Laboratory analysis, showed that the roots and soil surrounding them were found to be infested with both Meloidgyne spp (root knot) and Platelenchus spp (root lession) nematodes. Nematodes bruised the roots giving way to Phytophthora attack (*Fusariuma spp*, *Phoma spp* and *Vercicillium spp*).

Improved drainage by use of raised beds are recommended together with planting during the warmer season. Shoot treatment with appropriate fungicides before planting is quite effective in controlling the root rot. In the field, a rot can also be controlled by use of similar fungicides. Fruit rot caused by *Theraviopsis paradoxa* affects fruits after harvest. It starts from the base of the fruit (where it was detached from the mother plant) upwards. It can be controlled by dipping the fruit stalk or base in benzoic acid (Samson, 1980).

Gummosis is another fungal disease of pineapples but 'Smooth Cayenne' has been found to be resistant.

Plate 7: Nematode attack followed by Phytophthora which leads to the drying of the plant.

A Plant roots bundled together

B. Nematode followed by phytophthowa attack leading to drying of the plant

4.10 Harvesting

The stage of maturity at which the pineapple fruit is harvested depends on its ultimate destination, which can be either the cannery or to the fresh market (local or export). The stage of maturity or ripeness is judged by colour change that starts from the bases of fruits upwards. Heavy fruit ripen fast.

Fruits for canning must be picked half to three quarters ripe (Collins, 1960). For sea shipment, fruits are harvested at colour break to quarter ripe whereas for air freight they are harvested at half to full ripe. The ripeness is determined by skin colour which is dependent on cultivar, fruit size and weather. Internal colour can also be used as a measure of ripeness (Akamine, 1976). At Thika in Kenya, during cloudy periods, fruits don't develop yellow colour. Under this circumstances, a random sample of fruits are cut open to examine the internal ripeness. Those fruits that resemble the ripe ones are harvested. In other regions in Kenya where pineapples do not change colour e.g. Malindi in Coast province, a technique of pulling a leaf from the middle of the crown is used. If the leaves fall out easily the fruit is considered ripe. Yellow colour is, however, the clearest indication of ripeness. Plate 8 shows the external and internal colour of fruits from different zones in Kenya. At Sunripe, fruits at 1/4 - 1/2 colour break are sprayed with Ethrel to give uniform colour. This makes the fruit very attractive for fresh export market.

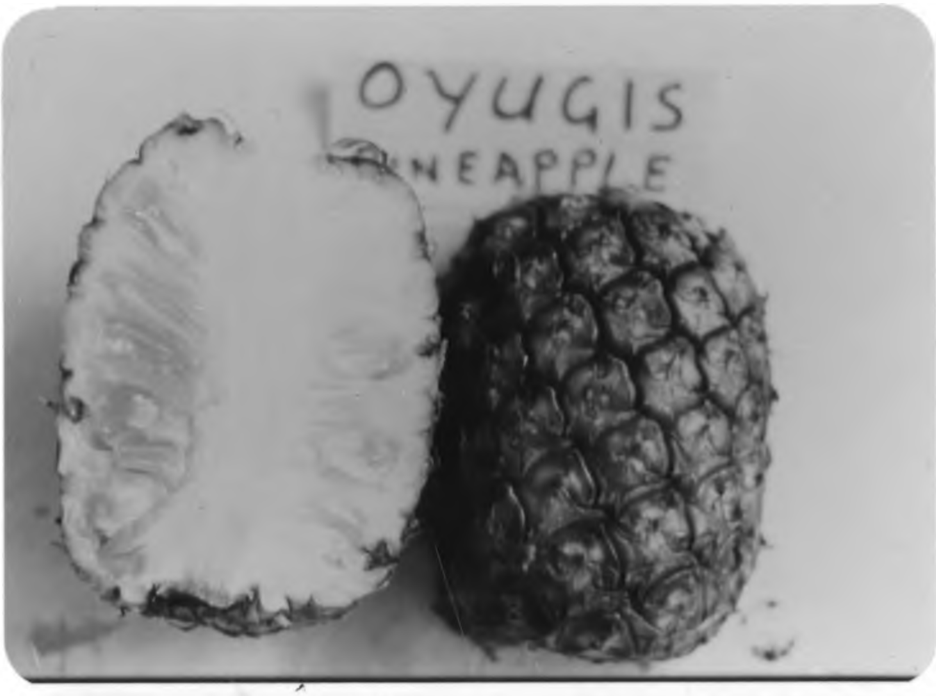
Harvesting methods depend on ultimate destination of the fruit. For fresh market, fruits are best harvested by hand. This is

Plate 8: External and internal colour of fruits from different zones

A. Kenya Canners Pineapple

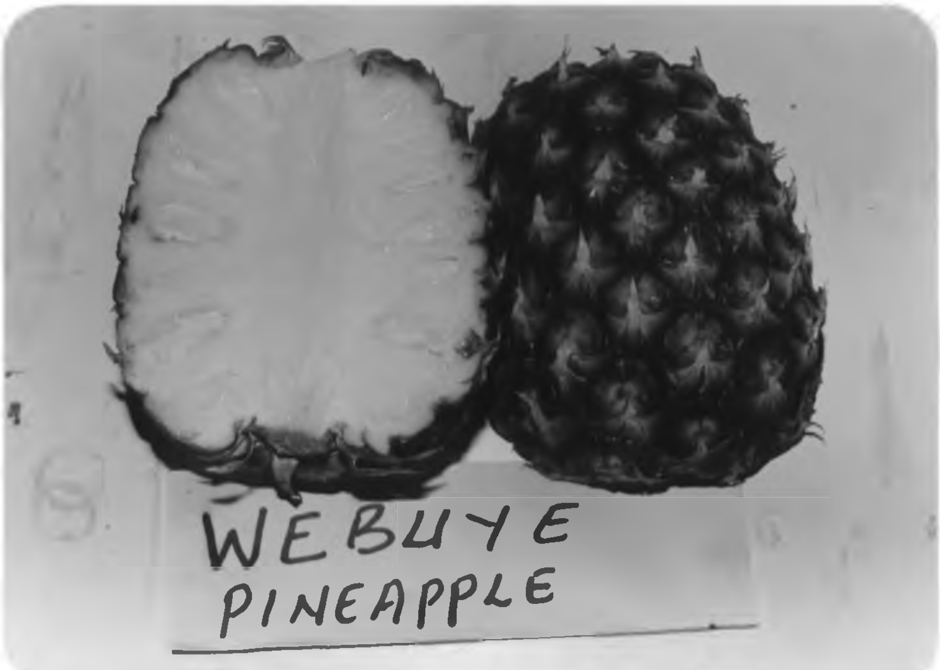
B. Sunripe Pineapple

C. **Oyugis Pineapple**



D. **Malind Pineapple**

E. Webuye Pineapple



done by holding the fruit by the crown and snapping it off the fruit stem by bending it sharply sideways as practised at Malindi, Webuye and Sondu in Kenya. Where export specifications require that a portion of the stem be left on the fruit the harvest must be done with a knife. This is the case for fresh fruit for export from Thika. Plate 9 shows fruits harvested by snapping off the mother plant.

In Kenya, fruits harvesting is done manually by hand. However, harvesting aid i.e. a long conveyor belt is used in harvesting fruits for cannery (Plate 10). Fruits are snapped off the mother plant and crowns are detached from them. They are placed on the conveyor belt that helps to load them onto the truck. A lot of care is taken in harvesting fruits for fresh market. Fruits are harvested with sharp knives with part of the peduncle attached and crowns are left intact.

The level of damage at harvesting is minimized by reducing the number of persons handling the fruit. Approximately 80% of fruit for cannery at Thika is harvested with the mechanical aid of a boom harvester to reduce bruising and double handling of fruit. The remaining 20% is harvested by hand and placed on field roads for truck loading by hand.

A yield of at least 40 tonnes/ha may be expected in a well managed field. Under optimal conditions the yields may rise upto 70 tonnes/ha. A ratoon crop can yield upto 50 tones/ha if well managed (K.V.D.A., 1983).

In Kenya, yields of upto 60 tones/ha have been reported from the coast and 70 tones/ha from Thika (M.O.A., 1983). By

Plate 9: Fruits harvested by snapping off the mother plant

A Fruit just harvested by snapping

B. Snapped fruit on the table

Plate 10: Harvesting process of fruits for cannery

A. Harvesting with the aid of a boom harvester.

B. Fruits transportation by conveyer belt

1990, the yields on average at Thika had risen to 165 tones/ha with the main crop yielding 90 tonnes/ha and ratoon crop 75tonnes/ha. The average production levels for small scale farmers remain low e.g. 37.5 tonnes/ha at Malindi for the plant crops and 23 tonnes/ha for the ratoon crop. The yield levels for Sondu and Webuye cannot be determined independently because the pineapples are intercropped with other crops.

At harvest time several plant anomalies are observed in pineapple fields.

1.) Multiple crowns.

These have been found in all the pineapple growing regions. The appearance of multiple crowns has been found to be seasonal and occurs more frequently when climatic conditions are unfavourable for pineapple production. High rainfall and excessive nitrogen application also influence production of multiple crowns. The effects are strongest at flowering. The condition can be controlled through selecting crowns, slips or suckers for planting from plants with single crowns. In small scale farms where little or no fertilizers are used occurrence of multiple crowns is low. In Malindi occurrence of multiple crowns is estimated at 8% and is confined to ratoon crops.

A study carried out by Del Monte over a period of five years gave percent occurrence of multiple crowns as shown in Table 4.

Table 4: Percent occurence of multiple crowns at Del monte,Thika

Month of forcing	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
% Multiple crowns	2	17	5	0	0	0	0	0	7	2	4	19

Multiple crowns do not affect the quality of fruit since the fruit has only one core at the middle and can thus be cut into slices.

2.) Rosetting (Large fruit with a small crown):

Though formerly thought to be a mutation, rosetting is presently considered a physiological disorder that is rampant among pineapples grown on virgin land. This is due to high soil fertility of the virgin land. It has been observed at Malindi and Webuye. At Malindi, occurrence of rosetting has been estimated to be 3%/ha in the plant crop.

3) Spineness:

As with multiple crowns spineness is common when climatic conditions are unfavourable for pineapple production e.g. at Webuye it was observed in plants grown off-season. Spineness slows down the harvesting operation as it pricks the farmers' hands.

4) Bent Crowns:

This occurs when the fruit is very heavy and cannot be sufficiently supported by the penduncles, thus causing bending. Under sunny conditions, this causes sun scortching of the fruit, rendering it unusable. Sunscorching can be prevented by wrapping the fruit with its leaves.

5 POST HARVEST HANDLING

The pineapple is classified as a non-climacteric fruit. Once harvested. There is no further increase in sugar content, or flavour of fruit although changes in colour of the skin and some softening of the tissues could be observed. For this reason, the pineapple can only be harvested at an advanced stage of ripening.

Classification of fruits into climacteric and non-climacteric is based on the rates of respiration of the ripening fruit. In non-climacteric fruits, such as pineapples the rise in respiration is gradual such that, ripening and senescence occur at the same time (Mwaule, 1985). This is in contrast to climacteric fruits that ripen after detachment from the mother plant. There is a decrease in respiration rate once the fruit is detached to the lowest level referred to as pre-climacteric minimum. This is immediately followed by a sudden rise in respiration to reach a maximum level referred to as the climacteric peak. This is followed by a post climacteric fall in respiration and the advent of senescence. Therefore, in climacteric fruits, senescence only occurs after full ripening (Biale, 1976; Alkamine and Goo,1971 and 1975; Mac glossen *et al.*, 1978).

A major problem in fruit production in Kenya is overabundance in the season of maximum production and low or no supplies during off-season (Cossey *et al.*, 1976). Production of pineapples all year round is rare. During harvesting season, production exceeds demand by the local market leading to a surplus.

The pineapple is a very perishable fruit. Therefore, it is important to have good transportation and storage technologies inorder to reduce post-harvest losses and maintain fruit quality over a long marketing period thus maximizing profit. This is especially important for fresh fruit for local and export markets. Harvested fruits continue to be metabolically active. Endogenous physiological processes proceed through ripening to senescence (Cossey *et al.*, 1976).

Pre-harvest factors are important in determining the,post harvest behaviour of the fruit. These factors include maturity at harvest, environmental conditions (climate, temperature, soil type etc), cultural practices and pre-harvest pest and disease control (Samson, 1980). These factors affect the attainment of maximum yield and quality of fruit at harvest and subsequent post-harvest behavior.

Mechanical injury of the fruit during harvesting and transportation is also important. Damaged skin and tissues increase the respiration rate of fruit leading to a shortened storage life. It gives unsightly skin blemishes spoiling the appearance of the fruit. It also acts as sites of entrance by micro-organisms leading to rotting of fruit (Cossey *et al.*,1976)

Once harvested, fruits are transported to the side of the field manually or by using machine. This can be done immediately or soon after harvesting. Too many fruits should not be transported at once and should be carefully packed to prevent jolting. Padded trucks can be packed at right angles to the rows of pineapple plant to shorten the distance of manual transportation. There should be minimum handling between picking and delivery into trucks. On highly mechanised plantations where the ground is flat, fruits are transported directly from the field to trailers by means of conveyor belts. This method is only used when the fruit is firm enough to withstand such treatment. Pineapples for cannery can be transported to the side of the field using sacks or baskets as there is no need to leave the flesh fruit intact, as is required by the fresh fruit market. Fruits can be transported in bulk in trailers but should not be packed to a depth greater than 80 cm, otherwise the fruit underneath will be crushed (Py *et al.*, 1987).

Crowns should be removed by bending them sideways without twisting as this always leaves fragments of flesh attached to the bottom of the crown that can subsequently lead to disease infestation. When knives are used it is recommended that they should be sharp so as to leave a clean cut (Akamine, 1976). For fruits for fresh markets, crowns should not be detached from the fruit as the market requires them.

Fruit flies attack the pineapple in the field, but for some unknown reason, they do not survive in the mature fruit. Therefore, the fruit needs no disinfestation for fruit flies. Fruit are brushed to remove the fruit flies and other particles on the shell. Fruits for canning are then washed, ready for processing. Fruits for fresh market are treated with Domicide A at the rate of 7.2g/litre of water to control rotting caused by *Theraviopsis paradoxa*. Fruits are then packed according to size and colour, ready for storage and transportation (Akamine, 1976).

Processing involves peeling, decoring and slicing of the fruit using the ginaca machine which works at the rate of 125 fruits/minute (Samson, 1980). Slices are then packed into cans. The skin is pressed to give juice which is then used to make syrup which is used for canning pineapple slices. The skin residue can then be used as cattle feed, manure, etc. The following are representative percentages of products, from processed "Smooth Cayenne' pineapple in Hawaii (Py, *et al.*, 1987).

Whole slices	25-35%
Parts of slices (half slices, broken slices, chunles, tidbits, cubes etc)	10-16%
Crush	4-8%
Juice	12-20%

Wastes	30-40%

Two general solutions to the problem of perishability have been adopted. These include air freighting with short transist time and the use of refrigerated shipment by land or sea. Air shipment results in high quality fruits of high cost. Transportation by sea or land for long distance using refrigeration is limited by inherent high perishability combined with susceptibility to chilling injury.

The pineapple, like other tropical fruits is very sensitive to low temperatures. Below 10°C, and especially near freezing, the pineapple suffers from chilling injury. This is a physiological disorder that develops during cold storage at temperatures below 15°C. Optimum temperatures for pineapple transportation in cold storage is 7.2°C and above.

For long shipment of ten to twenty days, endogenous brown spot (EBS) of pineapples may be a problem. This is a physiological disorder that occurs in the field when temperatures are very low but is expressed after cold storage of fruits (Akmine, 1976). It starts as dark spots at the bases of fruitlets near the core that emerge and coalesce (Cossey *et al.*, 1976). EBS can lead to 75-100% loss of the pineapple fruit (Akamine, 1976; Py *et al.*, 1987). This disorder can be controlled by use of dry heat at 35-40°C before or immediately after cooling. The latter treatment gives better results (Akamine, 1976).

Sea shipment is cheaper but takes longer and gives a fruit a lower quality. The high cost airfreight and bulk of pineapples favour sea shipment (Akamine 1976, Py *et al.*, 1987).

Controlled atmosphere storage (2% oxygen and 98% nitrogen) has been found to extend the shelf-life of pineapples by upto three days over the cold storage (Akamine and Goo, 1971). This method has, however, not been adopted as it is not commercially viable in Kenya. In Kenya, pineapples for processing and for fresh export market are produced by large scale growers. Fruits for the local fresh market are mainly produced by small scale growers with only a small fraction (2%) coming from the large scale growers. Harvested fruits are treated differently depending on whether their destination is the cannery or the fresh market.

5.1 Fruits for the cannery

At harvest, fruits are swapped off the mother plant and crowns detached. They are then placed on a conveyer belt which helps load them into the padded trucks. The fruits are transported to the cannery in padded trucks to reduce bruising and multiple handling. Each truck has a carrying capacity of 9 tons. On average, pineapples for canning weigh 3kg or slightly more per fruit.

Once in the factory, fruits are washed clean. As the volume of fruits is large a conveyer belt is used to carry fruits into the washing tanks (plate 11a). They are then peeled with a ginaca machine. This machine has the core tubes used for removing

Plate 11: Pineapple processing; 11a: Conveyor belt carrying fruits to washing tank; 11b: Slices being packed into cans by women packers.

the core. The smaller of the two tubes is 1.25 inches (3.2cm) and the larger one is 1.375 inches (3.5cm). Bigger fruits go to the bigger tube.

After peeling the fruits are sliced into large slices of 0.5 inches(1.27 cm) thick and smaller slices of 0.4 inches (1.02 cm) thick. The big slices are from the base and the small ones from the tip of the fruit.

After obtaining slices for canning, the flesh left on the skin is used for making juice. The juice, mixed with sugar is used to make syrup. The skin is used by farmers as cattle feed.

The slices and juice are packed into cans (Plate 11b). The cans containing slices are filled to capacity using syrup. The cans are then sealed.,The norminal capacities of cans used for packing slices or juices are 3.1 litres, 850ml, 580ml, 446ml and 236ml. Pineapple products processed by Del Monte are slices, desert bits, tidbits, crush pin, juice and concentrate (Plate 12).

Quality of slices, syrup, and juice is constantly monitored in the laboratory. The shelf life of canned juice is three years, while that of canned slices is four years. De-tinning of cans is checked constantly. Canned product are stored at $5^{o}C$. Stored products are analysed for quality after every 3 months.

Plate 12: Pineapple products processed by Del Monte.

5.2: Fresh export market for pineapples

Sunripe is the main producer of pineapples for the fresh export market, with a small quantity coming from Del monte. After harvesting, the fruits are transported to the packing sheds in padded trucks to reduce bruising. They are cleaned sized, then packed in fibre board cartons, ready for transportation. Four to six fruits are packed in each carton (Plate 13). Grading is based on size and colour with fruits in the same carton being of uniform grade. There is no pre-cooling or storage facilities at the farm level. Fruits are also not given any treatment before packing. The total post harvest losses incurred during transportation and packing is estimated to be 5%.

Fruits are transported to the airport in lorries or pick-ups. The fibre board cartons which weigh 10-12 kgs each are packed at a maximum height of 5 cartons in lorries and 3 cartons in pickups to reduce damage of the bottom layers. At the airport, the fruits are loaded into cargo planes immediately. If the cargo space is not available, the packed fruits are stored in cold rooms at the airport at temperatures of 7-10^{o}C. As cargo space is a recurrent problem in Kenya, quite commonly, fruits stored for a maximum of two days after which they are considered unsuitable for the luxury market for which they were intended. Such fruits are then removed from cold storage and sold to the local market. Losses during transportation from the packing plant to the airport are negligible.

Sea shipment of pineapples from Kenya has not been very successful (FAO, 1985; Del monte, 1990). Fresh fruits meant for

Plate 13: Packing of fresh fruits for export market

sea shipment are cleaned, then drenched in fungicide solution and wax. This prevents fungal attack during transportation and loss of weight due to transportation. Fruits are carefully selected by size and colour and packed in lay flat cartons of 20lbs (9.07kg) each. Cartons are palletised by fruit size and complete pallets transferred to containers. Containers are refrigerated as soon as packing is over and transported by rail from Thika to Mombasa, to be loaded into ships.

In a study carried out by FAO in conjunction with HCDA on pineapple sea shipment from Kenya, the fruits reached Europe in a barely marketable state (Graham and Dixie, 1985). The reasons for this were low shipping temperatures (7-8^{0}C), long shipping periods of five weeks, lack of pre-cooling facilities, wrong stage of ripeness (the fruits were under-ripe) and poor packaging. The viability of sea shipment of pineapples is thus not promising for Kenya unless the above problems are overcome.

A programme of post-harvest research on the proper storage temperatures, harvesting stages, pre-cooling techniques, production zones and the time of harvesting is recommended. Also research on fruit treatments with such chemicals as fungicides, use of ethylene for degreening and horticultural practices e.g. crown reduction need to be done. Together with this, studies on technical and financial feasibility of refrigerated shipment should be carried out (Graham B.R. and Dixie, 1985). Improving the existing shipping lines and attraction of new shipping lines could also improve sea shipment of Kenyan pineapples.

Fresh market for pineapples in Kenya

5.3 Fruits for local fresh market

Fruits for local fresh market are predominantly produced by small scale farmers. Generally, these fruits are of low quality. Fruits from large scale farms which do not meet the requirement for cannery or fresh export market, also go to the local fresh market.

After harvesting, fruits are transported manually from the field to the market in sisal sacks, baskets or wooden crates, which can carry 10-30 fruits. These containers are not cushioned and therefore heavy losses are sustained during packaging and transportation.

Most fruits for the local fresh market are sold to middle men at the farm gate level. Storage at farm level is poor and varies between regions. At Malindi and Sondu, fruits are heaped at the side of the farm and covered with green or dry plant material. In Webuye fruits are stored inside grass thatched structures in either fibre board, sacks or laid on the floor. One farmer stored the fruits by putting individual fruits in polythene bags which were then packed in sisal bags tied tight at the open end. This is a kind of localised modified atmosphere storage. Fruits are stored for a period ranging from 3 to 14 days.

Fruits are transported to distant markets usually through rough roads using public means of transport. There is no storage exposure to outdoor heat. Roads are poor, thus some fruits get crushed during transportation. Crushing and bruising of the fruit eventually leads to rotting. Losses vary with the area with Malindi recording an average loss of 10% as most fruits are sold to middle men at the farm gate. In Sondu and Webuye, where some farmers take their fruits directly to the market, losses are estimated to range between 2 to 40% from harvesting to the market.

The problem of high looses at the small scale farmers level can be solved by the formation of a marketing cooperative. This would make it possible to form a collective marketing stategy which would improve prices by reducing exploitation by middlemen. It would also make it easy to raise funds to buy better transportation equipment which would reduce bruising and crushing of fruit during transportation. Cooperatives can also build better storage facilities and perhaps a processing factory.

5.4 Laboratory Analysis

The results of analysis of fruits selected at random from the local market within the production zones to show the quality of fruits for the fresh local market are summarised in Table 5. Analysis were carried out on fruits at the same level of ripeness as judged by external and internal appearance.

Fruits grown at lower altitudes had higher ^{o}Brix to acid ratios than those grown at high altitudes. Full yellow fruits from Malindi (150-200m), Sondu (1300-1500m) and Thika (1524m)

Table 5

Levels of some constituents of pineapples from four production areas in Kenya

Place of origin	Type	Sugar reducing (%)	Total sugars (%)	Water content (%)	Dry matter (%)	Brix (%)	pH	Acid (%)	°Brix acid ratio
A	A1	2.88g/100g 18.95	11.2g/100g 73.7	84.8	15.2	12.2	3.3	0.79/100ml 5.2	15.4
A	A2	4.1g/100g 26	12.5g/100g 78.6	84.1	15.9	14.5	3.65	0.51g/100g 3.2	28.4
A	A3	3.0g/100g 20.6	11.2g/100g 77.2	85.5	14.5	13.2	3.45	0.92g/100g 6.4	14
B1	B1(a)	3.85g/100g 27.3	11.2g/100g 79.4	85.99	14.01	13.5	3.13	1.08g/100g 7.6	12.5
B1	B1(b)	4.7g/100g 29.2	12.5g/100g 77.6	83.9	16.13	14.5	3.30	0.97g/100g 6.4	15.1
B2	B2(a)	3.88g/100g 23.8	12.2g/100g 87.1	86.01	13.99	13.6	3.10	0.9g/100g 6.4	15.1
B2	B2(b)	3.3g/100g 23.6	9.9g/100g 70.7	86.01	13.99	13.1	3.0	1.3g/100g 9.3	10.1
B2	B2(c)	3.3g/100g 27.5	6.99g/100g 57.5	88.04	11.86	11.5	3.0	1.02g/100g	11.3 8.5
C	C	5.0g/100g 33.6	12.5g/100g 83.9	85.1	14.9	14.5	3.55	0.85g/100 5.7	17.1
D	D1	2.65g/100g 20.3	7.84g/100g 60.0	86.93%	13.07	12.1	3.45	0.68g/100g 5.2	17.8
D	D2	2.6g/100g 20.7	7.6g/100g 60.6	87.45	12.55	11.7	3.40	0.76/100g 6.06%	15.4

KEY:

A - Malindi pineapple B2 - Sunripe pineapple B - Thika pineapple c - Sondu pineapple

A1 - Normal crown B2(a) - Normal crown - B1 - Kenya Canners D - Webuye pineapple

A2 - Bent crown (full ripe) b2(b) - Baby pineapple B1(a) - Normal crown (half ripe)
D1 - Normal crown (half ripe)

A3 - Mutated crown B2(c) - Multiple crown B1(b) - Full ripe D2 - Multiple crown had ratios of 28:1, 17:1 and 15:1, respectively. These ratios decreased more as a result of a rise in the acid content than as a result of a decrease in the sugar content.

Pineapples of the same level of ripeness grown under similar climatic conditions (rainfall, temperature etc.) showed the same quality e.g. at Thika, full yellow fruit from Del monte and Sunripe had ^{o}Brix : acid ratios of 15:1 and 15.1:1, respectively.

Pineapples grown at the same altitude but different climatic conditions showed different ^{o}Brix : acid ratio, e.g Webuye and Thika. Although pineapples from Thika had higher levels of both acid and sugar contents their ^{o}Brix: acid ratios were lower than those of the pineapples from Webuye. This suggests that apart from altitude, climatic conditions and cultural practices play an important role in the final quality of pineapple fruit.

Successive ratoon crops seem to have lower Brix : acid ratio under the same altitude, climate and cultural practises. Close spacing also has the same effect. This is as shown by the Sunripe baby pineapple as compared to the normal fruit., This decrease in ^{o}Brix: acid ratio results from an increase in acid content with successive ratoon crop or closer spacing at planting. The decrease in sugar content though observed is more gradual. The same was observed for multiple crowns. Rosetting seems to increase the acid content of the fruit without necessarily increasing the ^{o}Brix proportionately. Thus, Malindi rosette pineapple had lower ratio than the normal crown (Table 5).

Water content of the fruit increased with progressive ripeness, while the acid level decreased as shown by both the Thika and Malindi pineapples. Water content was also higher in fruits with multiple crowns than in the normal fruits, as observed in Sunripe and Webuye fruits. The ^{o}Brix: acid ratio was, however, lowered by the development of multiple crowns.

If fruits were harvested near ripe, it was found that the Malindi pineapple would be very good for juice production. Sondu and Webuye pineapples would be most appropriate for fresh market and if grown under better cultural practises could also be canned. Besides being suitable for canning, fruits grown at Thika would also be acceptable for fresh market because they would be as acceptable as the Sondu and Webuye fruits.

6. MARKETING

Pineapples are marketed either as fresh fruits or in processed form. Fresh fruits can be destined either to the local or export market. Fresh fruits are sold singly with the crowns intact or slightly reduced. Fruits for processing have their crowns removed during harvesting.

Among the tropical fruits the pineapple has the largest utilization in processed form worldwide. Processing of pineapples started in Hawaii at the beginning of the century due to, invention of the ginaca machine in 1912 which improved mechanised peeling and coring, and the development of 'Smooth Cayenne' variety which is adaptable to many areas in the world and is good for canning (Henry, 1976). Other cultivars suitable for fresh market have been used for canning e.g. 'Queen' in Australia, 'Abacaxi' in Brazil, even though these varieties are inferior to 'Smooth Cayenne'.

Fruits for canning should be cylindrical and are generally of a higher weight than those fresh export market. Under efficient processing conditions a ton of fresh 'Smooth Cayenne' yields 35% solid pack and 40% juice.

Internationally, canned pineapples are sold sterilised in metal cans that guarantee long-term conservation of top quality product. These are available to the consumer, ready for use.

Trade in canned pineapple products increased after world War II (King, 1972). Before world war II, Hawaii, Malaysia and Taiwan were the major traders in canned pineapple products. The war disrupted trends in production and trade in canned pineapple. After the war, trade in these products increased from 380,000 tonnes in 1949-51 to 880,000 tonnes in 1969-71.

A wide range of canned pineapple products are marketed in the processed form. These include:

a) Pineapple slices in syrup and broken slices which are by-products of slices. Broken slices include half slices, broken slices, segments (Chunks, tidbits, cubes) that are commonly used in pastry making and confectionery.

b) Juice which can be sold as single strength or concentrated form.

c) Frozen and or dehydrated products e.g. sorbets, dried pineapple slices etc.

d) Other products such as jams, alcoholic drinks, pineapple clips etc.

Almost a quarter of the total world pineapple production is used in the processed form.

Export trade in fresh pineapple shows a distinct pattern. Exporters supply countries which are either nearest e.g. Mexico suppling U.S.A. or countries with whom they have traditional trade ties and or tariff advantages for instance Ivory Coast, Kenya and Republic of South Africa trade with European Economic community (E.E.C.) countries.

Quality factors for fresh export market are mainly colour, shape, external site and condition of the fruit. Consumers prefer bright yellow or orange coppery shade. Green colour is associated with under-ripeness while limp leaves reduce the market value. Flavour is of secondary importance.

The weight of fruits vary mainly between 0.7-1.5kg with the luxury market taking a larger fruit of upto 2.7kg Consumers prefer fruits weighing 1-1.25kg.

For the luxury market pineapples should arrive in the consuming country within a few days after harvesting. They should be large fruits of high quality characterized by fresh, bright and turgid leaves and full natural colour with full bloom. These fruits are airfreighted and are mainly for catering units. These fetch better prices which compensate for the high cost of airfreighting. The main supplier of the luxury market are Kenya and the Azores. Kenya has better quality produce and is reliable to its markets (King, 1972).

Fruits for long sea shipment are underripe at harvest. They fetch lower prices since their colour and condition is poor when they reach the market. They have limp leaves, lack bloom, and natural colour.

Approximately 5% of the total world pineapple production is exported. There is a fall in the luxury market share of fresh fruit as consumers are tending to prefer the cheaper sea slipped fruit of low quality.

The local fresh market takes fruits that are either too large, too small or unacceptable for cannery or fresh export. Fruits are generally nearly completely ripe. There is a preference for large fruits near production areas. Prices of these fruits are lower near production areas and higher elsewhere. The only technical problem involved are potential delays in transport and unsatisfactory storage condition (Py *et al.*, 1987). While export figures are available, statistics on local consumption and production figures are not well established.

In Kenya, Pineapples are produced mainly for canning and for fresh consumption.

I. Canning

This is a monopoly of Delmonte (Kenya) Limited. Table 6 gives the levels of production and cost expenditure covering 1983-1989. It should be noted that production per unit area and therefore volume of the canned fruit continues to rise. Table 7 shows the area under pineapples for processing.

All canned products from Del monte are transported by sea. Major buyers of slices are Germany, France, Italy and Spain. Concentrates are mostly exported to U.S.A. and Canada.

Table 6: Delmonte Kenya Limited Pineapple Data

	1983	1984	1985	1986	1987	1988	1989	Totals
Tonnes processed	174,781	82,913	170,341	231,847	215,021	198,380	239,538	1,412,812
Solids recovery (cc/ton)	13.9	13.4	13.2	11.3	11.0	10.9	31.1	12.32
Juice recovery (cc/ton)	16.3	17.3	17.5	19.0	20.7	21.8	20.4	19.16
Combined recovery (cc/ton)	30.2	30.7	30.8	30.3	31.7	32.7	33.5	31.49
Sales/cases	3,304,253	3,438,768	2,925,589	3,176,617	3,013,287	2,719,484	3,511,360	22,089,258
Sales-concentrate	2,561	28,161	29.673	33,233	37,617	32,880	40,053	231,178
Cost of production (Kshs.)	382,240,505	405,651,423	393,198,106	447,338,235	421,439,906	437,753,444	702,951,228	3,190,572,837
Rail transport Thika/MSA %	80	80	80	80	80	80	80	80
Road transport Thika/MSA %	20	20	20	20	20	20	20	20

NB: (1) No freight costs included as majority of shipments are F.O.B
(2) Transportation is based on:80% of sales by rail, and 20%of sales by road

Table 7: Area under pineapple for canning at Delmonte (K) Ltd.

Year	1983	1984	1985	1986	1987	19881	989
Acres	2668.4	2779.8	2458	3220.1	2718.3	2648.6	3135.3

c.c is common case per tonne. One case has 24 cans of nominal capacity of 850ml.

Sales cases: Number of cases sold per year.

Sales concentrate - number of drums or boxes of concentrates per year of weight (drums - 268 kg; Boxes - 550kg)

One drum is 110.9 c.c

One box is 226.9 c.c

To get number of acres planted

$$\text{Acres} = \frac{\text{Tonnes processed}}{\text{Tonnes/acre}}$$

to give only area for processed fruit.

II. Fresh Market

This can be further sub-divided into local and export fresh markets

a) Export fresh market. This market requires very high quality fruit that can compete well in the world market. Table 8 gives the quantities exported and the F.O.B. value for sales in the years 1980-1989. Fruits for export are mainly from the large scale growers but sometimes bought and exported by private exporters, probably because quality is easier to control. All these exporters, have to be licensed by Horticultural Crops Development Authority (HCDA, 1989). All fruits for export are airfreighted and are mainly destined for the luxury markets of the E.E.C. countries as is shown in Table 7.

Table 8: Quantities of fresh pineapples exported from Kenya and their F.O.B. value.

Year	QUANTITY EXPORTED (Metric tonnes)	F.O.B. VALUE (KSh x 10^3)
1980	1,882	
1981	687	2,339
1982	517	2,455
1983	1,093	
1984	804	4,035
1985	98	5,499
1986	864	5,182
1987	925	6,182
1988	16,745	133,961
1989	3,255	7,915

b) **Local fresh market:**

This is supplied mainly by the small scale growers and to a lesser extent by the large scale growers (less than 10%). Appendix II gives the production of pineapples over the years 1981-1989 from the various growing areas.

From these Tables, the figure for Murang'a district is consistently higher than those of other districts because it includes production by Delmonte (K) Ltd. The levels of production of the small growers are quite low. Some production figures by the small scale farmers are rising because data on small scale production of pineapples is not taken consistently. The figures given are estimates and it is assumed that a much higher tonnage is produced and consumed locally.

In Kenya, fruits for local fresh market are neither stored for long periods nor given any post harvest treatment to maintain the quality. This is because the market is not particularly sensitive to quality. Prices of these fruits vary depending on availability, distance from production point to markets and seasonality. For instance in Malindi, in 1990 farm gate prices of a fruit of an average weight of 2kg costed Ksh. 1.80. The same fruit cost Ksh. 3.00 at Malindi market, whereas in Nairobi 600km away, the fruit cost Ksh. 15.00. At Sondu, during the production season, farm gate price (1990) was Ksh. 2.50/kg at harvest but later when fruits were few the cost rose to Ksh. 4.00/kg.

7: CONCLUSIONS AND RECOMMENDATIONS

In Kenya, production of pineapples by large and small scale growers is on the increase. Trade in processed and fresh fruit is increaseing both locally and in the export markets. There is thus need for improved technology to support the industry.

Small scale growers show a lower yield per unit area and produce fruits of a lower quality as compared to large scale growers. Large scale farmers use aggressive capital expenditure for high production. They also have facilities e.g. irrigation that allow production of off-season fruits for better market prices. The small scale producers only get about half the yield by large scale growers per unit area in a given period of time. These fruits thus fetch better prices.

Losses during harvesting and subsequent post harvest handling and transportation upto the final disposal of the fruits is high for small scale growers. Losses for large scale producers are lower except when fruits are shipped by sea where losses of upto 100% have been reported.

There are no storage and precooling facilities for pineapples in Kenya. Fruits have to be picked ready for marketing. Large scale growers however have more options for marketing their fruits either as processed fruit, or fresh export and local markets. Small scale growers have only the option of the local fresh market for which they compete with the large producers.

The problem of diseases and pests attack is higher in small scale farms than in large scale ones. This is because small growers use no pest and disease control measures.

There is therefore need for research in:

1. Improved agronomic practices at small scale production level to catch up with large scale producers. Such research should include:
   - Spacing studies in order to evoluate the appropriate plant densities
   - Best planting materials
   - Pest and disease control practices
   - Use of fertilizers and/or manure at levels specific to different growing zones.

This research can be done through cooperation between the relevant ministries parastatals and private arganisations.

2. As chemicals used for the control of nematodes and other pests are specific to pineapples, research into other control methods are necessary. Such research include:
   - Pesticides that are not crop specific thus allowing intercropping
   - Rotation of pineapples with other crops that reduce or destroy the pest population.
   - Intercropping pineapples with plants that offer a favourable environment for pineapple growth etc.

This would improve production levels for small scale growers and offer different options of control methods to large scale producers.

3) Marketing of fruits from small scale producers needs to be improved eg. by forming marketing cooperative inorder to control movement and prices of fruits.

4) Storage facilities for pineapples need to be designed. This would hold the fruits when supply is excessive and maintain their quality for release to the market when the supply is low.

5) Post harvest treatments of fruits for long transit and/or storage needs to be investigated.

6) Research work into the best shipping temperature for fruits at different levels of ripeness should be determined. This way, fruits can be shipped by sea, expanding the export market and reducing transpotation costs for the export market.

7) The effect of zonation on the keeping quality of pineapples both at ambient temperature and in cold storage needs to be investigated.

8) Finally it is necessary to make provision for social and economic facilities that would act as incentives especially to small scale farmers to increase pineapple production. This would include

1. Expanding export market policy to include small scale farmers.
2. Improvement of rural infrastructure eg. roads to reduce losses during transportation.
3. Controlling prices of fruits in the local markets.

The future favours an increase in pineapple production in Kenya. This is due to increasing emphasis on horticultural crop production for export. Also the population of Kenya is increasing and awareness of improved diets for better health is being emphasized. Cooperation between the Ministry of Agriculture, Horticultural crop Development Authority (H.C.D.A.) and Kenya Agricultural research institute (K.A.R.I.) will ensure the production of high yields and better quality fruits in the future.

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APPENDIX (i)

"PRODUCTION AND POST-HARVEST HANDLING OF PINEAPPLES IN KENYA"

QUESTIONNAIRE

CONFIDENTIAL

1. Respondent - (Decision maker)
2. location (District) --
3. What is the size of the land under pineapples ? --------------
4. What is the size of the land under pineapples ? --------------
5. Which method was used for land preparation for the land under pineapples ? --
   i) Hand preparation ------------------------------
   ii) Machine preparation -------------------------
   iii) Animal preparation -------------------------
   iv) Other (specify) ------------------------------
6. How did you dig the holes for planting the pineapples ?
   i) By hand -------------------------------
   ii) By machine --------------------------
   iii) Others (specify) -----------------------------------
7. What was the spacing between the rows ? ----------------
8. What was the spacing between the plants ? ----------------
9. Did you use fertilizers during planting ? ----------------------

   If yes, which one and at what rates ?

   Type --------------- -------------- ----------- -----------

   Rate --------------- -------------- ----------- -----------
10. What material was used in propagating the present crop ?
    i) Crowns -------------------------------

ii) Slips ------------------------------

iii) Suckers ------------------------------

11. Is the present crop a main or a ratoon crop ?----------------

12. i) What is the estimated volume of fruits harvested per season ?

----

ii) How many fruits does that container hold ? ----------

13. What is the estimated average weight of a fruit ? ------------

14. What are the common pests and diseases on your farm ?

i) Pests --

ii) Diseases --

15. Do you use any chemicals for controlling the pests and diseases ?

If yes, which ones and at what rates ?

Chemicals				
Rates				
Frequency				

16. How do you control weeds ?

i) Hand control --

ii) Using herbicides --

iii) Mulching --

iv) Others (specify) --

17. What harvesting method do you use ?

i) By hand ----------------------------------

ii) Machine ----------------------------------

iii) Others (specify) ----------------------------------

18. What containers do you use to carry the fruit from the filed ?

i) Sisal sack --

ii) Baskets --

iii) Wooden boxes --

iv) Others (specify) ---

19. How do you sell your fruits ?

i) Wholesaling -----------------------------------

ii) Retailing -----------------------------------

iii) Others (specify)

20. Where do you sell your fruits ?

i) At the farm gate ------------------------------------

ii) At the Local market ------------------------------------

iii) Exports --

iv) Others (specify) --

21. How do you transport your fruit to the market ?

i) On the back ---

ii) On the animals --------------------------------------

iii) By road --------------------------------------

iv) Others (specify)

22. How many fruits do you estimate get destroyed per container before you sell ? ----------------------

23. What was the average price per fruit which you fetched during the immediate past season or during the current season ?

Appendix (ii)

Area and production levels of pineapples in Kenya

CENTRAL

PRODUCTION IN TONNES
1,000

	1980	1981	1982	1983	1984	1985	1986	1987	1988
KIAMBU	122	9600	10800	6800	6240	4050	3420	18990	13725
MURANGA	166028	168055	168000	168192	168164	1734567	1799600	180369	1803690
NYERI			315	315					
TOTAL PRODUCTION	166150		177655	179115	175307	174404	1738619	1803020	1817415

Appendix ii

Area (H/a) and production (tons x 10^3) levels of pineapples in Kenya.

CENTRAL

HECTARES

	1980	1981	1982	1983	1984	1985	1986	1987	1988
KIAMBU	102	120	128	150	130	135	1285	635	305
MURANGA	4160	4206	4500	42042	4104	4241	4400	4410	4410
NYERI			29	30					
TOTAL HECTARES	4262	4326	4628	4384.2	4334	4376	5685	5045	4715

Ministry of Agriculture : Central province annual reports

COAST

HECTARES

	1980	1981	1982	1983	1984	1985	1986	1987	1988
TAITA TAVETA	7.5	8	9.4	9.0	1	5	5	7	2
KWALE	134	190	219	3	54	81	113	113	130
KILIFI	602	660	670	338	420	525	880	900	920
MOMBASA	60	3	3						
LAMU	4	-	43						
TANA RIVER		-	-						
TOTAL	807.5	861	905	350	475	611	998	1020	1052

COAST

PRODUCTION IN TONNES

'000

	1980	1981	1982	1983	1984	1985	1986	1987	1988
TAITA TAVETA	120	120	282	90	8	8	40	16	20
KILIFI	22	28	44	60	86	10	17	19	22
KWALE	1236	850	4235	637	550	810	410	410	780
TOTAL	1378	998	4561	787	664	828	467	445	822

1987 - Short of planting materials
- Marketing system is poor

1985 - Kilifi : high potential to grow.

Ministry of Agriculture : Coast province annual reports

WESTERN

HECTARES

	1980	1981	1982	1983	1984	1985	1986	1987	1988
KAKAMEGA	40	68	73	90	93	100	187	210	390
BUNGOMA	66	66	-	185	520	147	220	257	234
TOTAL HECTAREGE	116	141	85	275	613	250	425	477	639

1981 (- Poor management
(- Single row spacing practised
1984 (- Aphids and stem root
(- Change of crop cycle

1980 - There us a great potential which can be exported

Busia - - 1987: The project was funded by D.D.C. but stopped in 1985. Therefore the farmers neglected the product although the district has the high potential.

Busia - 1981: Lack of planting material.

PRODUCTION IN TONNES

,000

	1980	1981	1982	1983	1984	1985	1986	1987	1988
KAKAMEGA	432	696	876	1170	1209	2000	4500	7000	7700
BUNGOMA	70	121	240	189	370	418	525	595	700
TOTAL PRODUCTION	600	1095	1506	1879	2099	2638	5172	7763	8580

TOTAL PRODUCTION

	1987	1988
Coast	20,900	22,760
Central		1,819,415
Rift		1,500
Western	9,400	15,200
Nyanza		11,984

The major parts of pineapple were *** and nematodes. Sea freight exports of pineapples were undertaken, but for serious marketing infrastructure problems which made the exercise expensive.

Ministry of Agriculture : Western province annual reports

NYANZA

HECTARES

	1980	1981	1982	1983	1984	1985	1986	1987	1988
KISII	288	491	700	1607	1338	1600	191	139	282
SOUTH NYANZA	168	272	300	542	600	551	369	427	627
KISUMU	22	20	23	34	26	37	41	45	33
TOTAL HECTARES	476	783	1023	2183	1964	2188	601	611	942

PRODUCTION IN TONNES

1,000

	1980	1981	1982	1983	1984	1985	1986	1987	1988
KISII	4780	8640	14751	25380	20070	24000	2865	3475	4170
SOUTH NYANZA	4870	5440	6000	10,840	12,218	1020	1380	5124	7514
KISUMU	170	210	250	340	260	370	756	405	300
TOTAL PRODUCTION	9820	14290	21001	36560	32548	25390	5001	9004	1984

Ministry of Agriculture : Nyanza province annual reports

KENYA POUNDS FARM VALUE

	KISII	KISUMU	SOUTH NYANZA	TOTAL VALUE
1980	9575			
1981	21600			
1982	36877			
1983				
1984				
1985	3,600,000	32,480	661,000	4,293,480
1986	477,500	5,672	369,000	852,172
1987	608,125	30,375	512,400	1,150,900
1988		22,375	1,127,100	1,150,900

Oyugi's division/Migori
Lack of streamlined production and marketing system
- Early problems harvesting before maturity
- Crop pest attach mainly in*****