EFFECT OF PRE AND POST-HARVEST TREATMENTS ON STORAGE AND QUALITY OF BANANA cv. NENDRAN

BY

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled "Effect of pre and post harvest treatments on storage and quality of banana cv. Nendran" is a bonafide record of research work done by me during the course of research work and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Vellanikkara,
7th April, 1981.

ARAVINDAKSHAN, K.

CERTIFICATE

Certified that this thesis entitled "Effect of pre and post harvest treatments on storage and quality of banana cv. Nendran" is a record of research work done independantly by Sri.Aravindakshan,K. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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We, the undersigned members of the Advisory Committee of Sri. Aravindakshan, K. a candidate for the degree of Master of Science in Horticulture agree that the thesis entitled "Effect of pre and post harvest treatments on storage and quality of banana cv. Nendran" may be submitted by Sri.Aravindakshan,K. in partial fulfilment of the requirement for the degree.

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C O N T E N T S

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

Introduction

INTRODUCTION

Banana (*Musa* spp.) is considered to be one of the most important fruits of the world. Inspite of the fact that India ranks second with respect to area (236200 hectare) under this crop, her contribution to world market is rather negligible.

Kerala grows multitudes of varieties suitable for dessert and culinary purposes and the area under banana in Kerala is estimated to be 50100 hectares with an annual production of 615227 tonnes of fruits (Anon. 1980). Regional preference for a particular variety also exists, but the only cultivar of popular widespread use in the state is the 'Nendran'.

Although there is a lot of export potential for banana, we are not in a position to exploit the same for want of sufficient knowledge of the post-harvest technology with regard to the optimum time of harvest, long storage and proper packing which can withstand long distance transport. Therefore, the standardisation of post-harvest technology to solve the problems of export is of immediate necessity. Under the above circumstances, it is also absolutely necessary to study the effect of pre and post harvest treatments on storage and quality of

banana with a view to increase the shelf life and also to increase the transport life. One of the most important commercial cultivars of the locality viz. Nendran was chosen for the study.

The biochemical changes during the pre and post harvest period of ripening and storage were found to vary considerably, depending upon the variety, specific situation, time of harvest, and method of ripening and storage. Therefore, the standardisation of the above factors are quite important for the regular supply of fruits for the internal market and also for the export. With the above objectives, a study was undertaken at the College of Horticulture during the period from 1978-1980 on the "effect of pre and post-harvest treatments on the storage and quality of banana cv. Nendran". The objectives of the study were the following.

1. To fix up the optimum maturity for harvest (cv. Nendran) based on physical and biochemical parameters.
2. To study the effect of:-
   i) pre-harvest application of growth regulators on post harvest quality of banana
   ii) different storage methods on the shelf life and the quality of banana.
   iii) different fungicidal treatments for controlling anthracnose disease of banana.

Review Of Literature

REVIEW OF LITERATURE

The palatability and taste of any fruit solely depend on its chemical constituents. Based on the chemical analysis of fruits particularly total soluble solids (T.S.S.), acidity, T.S.S./acid ratio, maturity standards for different fruits have been fixed (Randhawa et al., 1964). Studies conducted on the biochemical and physical changes associated with growth and development of banana fruits and possible correlation between chemical constituents and quality of the fruit and to determine the most appropriate time for their harvest both for local as well as for export market are reviewed as detailed below:

1. BIOCHEMICAL CHANGES DURING MATURATION

1.1 Carbohydrates

Leonard and Barnell (1939) reported that, during the development of the banana bunch, sugars remain at a very low concentration, while starch rapidly accumulated. The rate of accumulation of both starch and dry matter in the pulp was greater during the two to three weeks following the age level at which the fruit would normally be harvested for export than during the weeks preceeding this age level.

Belevel (1932) reported that there were two distinct periods in the growth of the fruit. The first period was that of starch reserve in the course of which the fruit, always low in soluble sugar, fixed its starchy reserve at the expense of the reducing sugars. Since sucrose was utilised less rapidly than reducing sugars, the former becomes predominant. The next period was one of maturation, and here soluble sugars were formed from part of starch, the former being transformed into sucrose while latter was hydrolysed to invert sugars. Simmonds (1966) reported that sugars were present in the green fruit only in very small amounts averaging about 1 - 2% of the fresh pulp, they increased to 15 - 20% at ripening, the beginning of the increase coinciding with the respiration climacteric. Starch disappeared concurrently, dropping from about 20% in the green fruit to about 1 - 2% in the ripe fruit.

The fortnightly analysis of developing 'Hindi' bananas done by Wally et al. (1969) revealed that the starch content of the pulp reached a maximum level of 16.15%; eighty three days after flowering and that this stage did not coincide with any particular stage of

maturation. The level declined thereafter to 14.31% at maturity. Lodh et al. (1971) reported that the total sugars were low until 100 days and increased markedly after picking in Dwarf Cavendish banana. Pulp starch concentration reached a maximum after 70 days and declined thereafter.

An investigation carried out to study the growth behaviour and maturity index of 'Basrai' banana by Singh et al. (1976) revealed that starch and dry matter contents nearly stabilised as the fruit approached maturity. They also reported that results of chemical analysis of artificially ripened fruits plucked from same bunches at different intervals revealed that T.S.S. (16.0 - 17.0%) and total sugars (9 - 14) were somewhat less in the initial samples at early stages of maturity. On the other hand, both T.S.S. (18.5 - 19.5%) and total sugars (15.9 to 16.2%) showed an appreciable increase in the later stages of maturity.

Singh et al. (1980), based on their biochemical studies on the developing and ripening bananas, reported that there occurs a linear increase in starch content from immature to mature stage. It was reduced

to 40% on ripening which indicate a rapid change in carbohydrate metabolism during ripening.

1.2 Acidity

Barnell (1940) reported that there was not much increase in acidity of fruits during early stages of development. His studies revealed that simultaneous with the synthesis, of starch, continuous fall in acidity occured throughout the development until starch hydrolysis began when rising values for acid content were observed.

Walf (1958) reported that fruit of bananas cv. Colombia contained malic acid and citric acids. In large fruits malic acid predominated while in smaller fruits citric acid was present in greater quantity than malic acid. He further specified that the acid content reached maximum levels when the fruits began to turn yellow. Simmonds (1966) reported that the acidity of the pulp of bananas, whether measured as pH or as titrable acidity, rised to a maximum at or soon after the climateric and showed a slight fall as ripening progressed.

Lakshminarayana et al. (1970) found that in Alphonso mangoes acidity reached a peak around the 7th week but had decreased at ripening. Elobi and Khan (1974) also reported similar changes in ripening mango fruits.

But Singh et al. (1976) reported that in banana acidity did not indicate any relationship with maturity or quality of ripe fruits.

1.3 Maturity indices

The study of the maturation of the banana with a view to improving transport conditions (Anon 1952) revealed that maturation after cutting consists of a preclimacteric phase of low respiration activity during which composition remains practically unchanged followed by a climacteric phase of higher respiratory activity and rapid physiological change which begins when the fruit is dark green and ends before it is completely yellow. Hence it is suggested to cut the fruit at highest weight permitting a preclimacteric phase equal to transport period.

As the length of preclimacteric phase depends principally on the stage of maturation of fruit when

out, various workers have suggested different criteria to assess the maturity index at harvest of the fruits to suit different purposes.

Decillin and Monnet (1960) reported that the fullness in bananas can be determined based on the surface median transverse section of the fruit.

Beccari and Ascani (1963) developed a colour scale to judge the maturity of banana fruits which makes use of the indirect determination of the approximate sugar content from the results of pulp tests with iodine solution. They suggested to make use of a blotting paper impregnated with 0.1 N iodine to distinguish fruits ready to harvest for artificial ripening or export.

Wally et al. (1969) suggested to make use of the number of days from flowering to maturity as an index for harvesting. He reported that the fruits of 'Hindi' bananas takes 128 days after flowering to reach full maturity and the climacteric occured at 145 days when fruit was over ripe. The starch level reached a maximum (16.15%) by 83 days after shooting.

Lodh et al. (1971), reported that in banana the

fruit size, weight & pulp/peel ratio increased steadily for 130 days when fruit began to turn yellow. Pulp dry matter content increased for the first 85 days of growth except at 40 to 55 days but fell after picking at 130 days. Total sugars were low until 100 days and increased markedly after picking. Pulp starch concentration reached a maximum after 70 days and declined thereafter.

Singh et al. (1976) on the basis of biochemical studies reported that good quality Basrai dwarf bananas can be obtained if the harvesting of the bunches was done 80 days after spike emergence.

Madamba et al. (1977) studied the effect of maturity on bio-chemical changes during ripening of banana cv. Lacatan. Fruits picked at maturity stage A (between full and full three quarters) showed parallel trends in biochemical changes with those picked at maturity stage B (between full three quarters and light full three quarters).

Desai and Deshpande (1978) reported that on the basis of their studies on cvs. Pachabale, Rasabale and Rajabole that bananas picked at 90 and 105 days,

stored better and showed better quality than bananas picked at 120 days. They further pointed out that the firmness, total chlorophyll and the ratio of total sugars to acidity were the most promising maturity indices.

Teaotia and Bhan (1966) reported that to obtain high quality Indian pineapples, it should be harvested when the specific gravity lies in the range of 0.98 to 1.02, T.S.S. content 14.8 to 17%, the TSS/acid ratio 20.85 - 27.24 and fruit has a developed a yellowish to brownish yellow colour. Earlier harvesting is possible when T.S.S. is 10 - 12.5% and skin greenish yellow.

Lakshminarayana et al. (1970) observed that the Alphonso mangoes reach the harvest maturity in 16 weeks after fruit set. The weight continued to increase until harvest. The growth of the fruit in term of length, diameter and weight showed a decline between 9 and 14 weeks at the time of the development of the stone.

Studies on indices of maturity of 'chittidar' guava by Tripathi & Gangwar (1971) revealed that specific gravity was a good index for fixing maturity.

Chandha et al. (1972) reported that the pine-apple fruit variety 'Kew' takes 165 days to attain ripening. For canning purpose it can be harvested within 150 - 160 days of maturity.

2. EFFECT OF GROWTH REGULATORS ON MATURITY AND RIPENING

2.1 Maturity

Increase in size and weight of fruits, delayed maturity, earlier ripening as a result of pre-harvest applications of growth regulators were reported by many workers on different crops.

Clark and Kerns (1942) reported that NAA sprays at conc. 0.05% produced increase in size and weight of pineapple fruits. The maturity was delayed by one week at high concentration of N.A.A. The number of fruitlets was not influenced by the spray. Grossmann (1950) also reported that application of NAA several weeks before normal fruit maturity delayed maturity and increased fruit size.

Reduction in fruit weight and earlier maturity followed by 2, 4-D application on mature fruits is an

reported by Evan (1959). Das (1964) recommended NAA application at concentration of 20 and 50 ppm for increased fruit weight and delayed maturity in pineapples. Ali & Talukdar (1965) also got similar effects with Planofix. They reported that Planofix application delayed maturity and significantly increased fruit weight and size in pineapples.

Aziz and Wahab (1970) compared acetylene, coalgas and 2, 4-D for the artificial ripening of bananas and found that bananas treated with 2, 4-D at 100 ppm for 30 records were marketable for longer than those from other treatments. The 2, 4-D treatment was the cheapest.

Tomi et al., 1970 reported that dwarf cavendish bananas were sprayed with 2, 4-D (10 - 40 ppm) and GA (10 - 20 ppm) either seperately or together, at various times between flowering and about a month before harvesting to assess the effects on fruit ripening and storage. Sprayed fruits stored at room temperature attained maximum finger weight after 6 - 9 days, compared with 14 days when cold stored at 55°F, with unsprayed fruits the corresponding time was 12 and 21 days respectively. The pulp percentage and soluble solids

contents at both temperatures increased with storage duration and were highest with fruit sprayed with 2, 4-D at 10 ppm during flowering. Soluble solids contents were enhanced by most treatments, difference between sprayed and unsprayed fruit being most marked during the first few weeks storage.

Wee (1971) reported that spraying the developing fruit of pineapple cv. Singapore Spanish with a solution of Planofix increased fruit weight, diameter and acidity. The best time for treatment was 6 weeks after the appearance of the inflorescence. The treatment also delayed maturity.

Huang (1973) studied the effects of plant growth hormones on the development of pineapple fruit and reported that NAA or sodium salt of NAA sprays one month after flowering increased yield by 11 - 32% and the higher the concentration, the greater the increase. Also, Na NAA @ 100 ppm delayed ripening by 12 - 16 days.

2.2 Growth Regulators on Ripening

Freiberg (1955) reported that the immersion of banana stem in solutions containing sodium 2, 4-D;

2,4, 5-T or CPA accelerated ripening. The effect of ripening was more marked on the pulp than on the skin.

Dedolph and Goto (1960) reported that when the hands of 'Dwarf Cavendish' were cut and dipped in water solutions of 2, 4-D at 100 ppm, ripened more quickly and uniformly than those from other treatments (GA at 20 ppm; 2, 3, 5-trichlobenzoic acid at 25 ppm and IAA 250) Damigella (1962) found that 2, 4, 5-T was more effective than 2, 4-D in promoting early ripening in mandrins. Murata et al. (1965) studied the effects of growth regulators on the ripening of 'Shinzun' bananas and found that the climacteric ascent was hastened by 100 to 1000 ppm 2, 4-D.

Lakshminarayana et al. (1967) reported that in sapota fruit ripening was hastened by 2, 4-D (100 ppm), 2, 4, 5-T (100 ppm) and 2, 4, 5-TP(25 ppm) when sprayed on the trees 10 days before harvest.

In mangoes wherein anthracnose is a problem, ethephon treatment shortened the ripening period, giving no time for the development of anthracnose and

thus producing flavours and appearance (Campbell and Malo, 1969).

Krishnamoorthy and Subramanyam (1970) reported that a 100 ppm concentration of 2, 4, 5-TP delayed ripening of 'pairi' mangoes and had no effect on the skin colour.

Audinay (1970) reported that in pineapple pre-harvest sprays of ethrel 1-8 kg/ha with a plant population 50000/ha 4 weeks before the theoretical picking resulted in earlier and more homogenous ripening and a briefer harvest period proportional to the doses of ethrel applied.

Bondad (1971) dipped 'Lakatan' bananas for 5 minutes in 2500 ppm Ethephon solution and observed that climacteric peak was attained 5 days earlier in treated fruits than in untreated ones.

Saha (1971) reported that ripening of guava could be hastened by 2, 4-D and 2, 4, 5-T. The rate of ripening was doubled in guavas treated with 200 ppm of 2, 4, 5-T.

Deol and Bhullar (1972) reported when mango fruits stored in polythene, were treated with 2,4-D and 2, 4, 5-T,

ripening was normal after 12 days of storage, and wastages due to diseases and physiological disorders were reduced.

Sadasivam and Muthuswamy (1972) studied the effects of 2, 4-D and 2, 4, 5-T on ripening of bananas. Three quarters full hands of Dwarf Cavendish bananas were dipped in solution of 2, 4-D or 2, 4, 5-T at concentrations in the range 25-3000 ppm and held at room temperature (28 - 33°C). At 250 ppm and above both compounds ripened the fruits after 6 days compared with 76% of untreated fruits. Ripening was retarded by some of lower concentrations. Peacock (1972) recommended exposure to ethylene for uniform early ripening of green bananas at short periods. Terai et al. (1973) reported that when the central region of mature green bananas was treated with ethylene at 80 - 100 ppm ripening ie., degreening of the skin and sugar accumulation in the pulp, started in the treated part and gradually progressed to the untreated parts. Parmar (1974) recommended immersion of the bunches in ethrel (ethephon) 50% at 2 ml per litre of water to replace conventional and sealed room method of ripening bananas.

In a trial with ethylene and 2, 4-D the best results by way of accelerated, uniform ripening were obtained with ethylene at 5000 ppm applied for 10 seconds to fruits at 20°C and at high RH for 16 hours (Anon 1976).

Banna (1976) reported that ethephon treatment shortened the time required for the artificial ripening of bananas (Gros Michel) through its effects on colour development, peeling quality, pulp/peel ratio and T.S.S. content. Thus fruit reached maximum ripening in 4, 6 and 14 days respectively, for high (1500 - 1000 ppm), low (100 & 250 ppm) and the control treatments.

Liu (1976) worked out the correlation between banana storage life and minimum treatment time required for ethylene response. Accordingly; a linear regression equation as $Y = 4.59 + 1.25\ X$ was fitted where Y = is the storage life in days in air at 21°C, X = is the minimum time in hours required for ripening in 10 ppm ethylene. The coefficient of correlation between the variables was 0.92.

Uneven ripening of 75% mature Dwarf cavendish bananas was reported by Rizk et al. (1976), when the harvested bunches after holding for 5 days were sprayed with 2, 4-D or 2, 4, 5-T each at 500 or 1000 ppm and covered with polythene for 2 days followed by partial covering for 3 days.

Terai and Ogata (1977) studied the role of glycolysis in the respiration of banana fruits stimulated by ethylene. They found that during ripening the content of reducing sugars increased in banana pulp and peel, and the levels of glycolytic intermediates, corresponded to the respiratory changes in the pulp tissue. The respiration of peel sections decreased and the content of some glycolytic intermediaries increased when ethylene was removed. Singh et al. (1977) also reported accelerated rate of ripening in bananas as a result of ethrel application. Bosrai Dwarf bananas were treated with ethrel (ethephon), calcium carbide or 2, 4-D or were covered with dry banana leaves during September and October at ambient temperature and humidity. Ethrel at 5000 ppm induced ripening in 2 and 2.5 days and at 3000 ppm in 3 and 3.5 days, in September and October respectively. The controls took about 6 and 10 days to ripen respectively. The other

treatments caused slower ripening than ethrel and produced inferior fruits.

Awad et al. (1977) also reported that green fruits immersed for 2 minutes in ethephon at 500 ppm had their climacteric advanced by 5 days whereas fruits treated with GA at 100 ppm had their climacteric delayed by 2 days, compared with the control. Liu (1978) reported that bananas ripened with ethephon in suitable film packages had good eating quality and a longer shelf life than bananas ripened in air.

Morrisliebermen (1979) reported that the ripening is decided by the integrated role of hormones other than ethylene. Auxins accelerate ripening in green bananas as a result of increasing ethylene production. Degreening, pulp softening, respiration and ethylene production are influenced by auxins, gibberellins and cytokinins.

3. CHANGES DURING RIPENING

3.1 Peel/Pulp ratio

Gore (1914), Smith (1932) as quoted by Leonecke (1950) reported that during ripening of the

fruit, the pulp increases in weight due to an increase in water content. This water is obtained from the peel and probably also from the stalk. Because of this, the peel loses weight, and this will cause a change in the pulp to peel ratio as the fruit ripens.

Barnell (1941) Wardlaw, Leornard and Barnell (1939 a, b) also supported the earlier work as they found that there was an increase of pulp/peel ratio from 1.2 - 1.6 in green fruit depending on maturity, to 2.2 - 2.4 at advanced ripening reaching 3 or more in rotting fruits after prolonged storage. Barnell (1943) and Simmonds (1966) reported that the rise in pulp/peel ratio was closely related to change in sugar concentrations in two tissues.

Venkantarayappa et al. (1975) reported marked increase in pulp/skin weight ratio was an indication of eating ripe stage in banana. Such a change occured in Giant Cavendish from 3.16 to 4.25 and in DC from 2.03 to 4.15 on the 11th day. The actual attainment of eating ripe stage was very closely in agreement with pulp/skin weight ratio and it was almost simultaneous in both the varieties.

3.2 Carbohydrates

The most conspicuous change in the maturation of the banana is the conversion of starch to sugars (Loessecke, 1950). Wardlaw and Leonard (1940) have studied the carbohydrate changes taking place during ripening. The predominent carbohydrate of green banana is starch which is very largely replaced by sucrose, glucose and fuctose during ripening. Poland et al. (1938) reports that maltose in traces along with four other sugars of which one is reported to be rhamnose (Lulla & Johar, 1955).

Yang and Ho (1958) reported that the changes in carbohydrate metabolism and respiratory mechanism during the course of ripening indicated the existance of a transition stage between maturation and senescence in which there is a marked and sudden rise of respiration accompanied by physiological and chemical changes. Starch is converted to sucrose and in the post climacteric stage, into glucose and fuctose.

Simmonds (1966) summarised the earlier works by reporting that sugars are present in green fruits only in very small amounts, averaging about 1 - 2 per cent

of fresh pulp, they increased to 15 - 20 per cent at ripeness, the beginning of the increase coinciding with the respiration climacteric. Starch disappears concurrently, dropping from about 20 per cent in the green fruit to about 1 - 2 per cent in the ripe fruit, it being higher in the ripe plantain (about 6%) than in dessert bananas.

Venkatarayappa et al. (1975) found that during ripening of Gros Michel and Dwarf Cavendish bananas, the acidity tended to increase gradually in both the clones with the advancement of ripening. No significant changes in fat content during ripening have been detected (Loesecke, 1950).

3.3 Acidity

Acidity of the pulp roses to a maximum at or soon after the climacteric and then usually shows a slight fall as ripening progresses. The skin of the fruit shows a similar trend but is slightly delayed with respect to the pulp (Gane, 1936, Barnel, 1941a, b 1943).

Loesecke (1950) reported that there is no

significant change in the nitrogen content of the ripening fruit. Protein in the ripe fruit lies between 0.5 and 1.5 per cent. Hulme (1955) found that 17 amino acids, together with abnormally large amount of L. histidine of the free acid.

3.4 Tannins

Barnell and Barnell (1945), using the diastase inactivation method, estimated a tannin fraction that they presumed to be responsible for the astringency of the unripe fruit. They found that this fraction fell in the ripe fruit to about one-fifth of its value in green, preclimacteric fruit. The tannin content was three to five times more abundant in the peel than in the pulp and also fell sharply at ripening. The moisture content of the pulp was found to be increased when the fruit ripens (Stratton & Loesecke, 1930, Gore, 1914).

4. STORAGE

Wax coating mature green bananas was suggested by Blake (1966) as a method for prolonging storage life of fruits. Green bananas cv. Monas Mari dipped in waterbased emulsions containing 2 - 10% paraffin wax

delayed the development of full colour, increased shelf life, reduced weight loss and reduced respiration. The magnitude of each effect was generally related to the concentration of wax in the dipping treatment.

Mahmoudi and Eisawi (1968) stored the Dwarf Cavendishi banana at temperatures of 52°, 55° or 60°F and 80 - 85% RH, unwrapped and wrapped in tissue kraft paper or perforated polythene. They reported that no decay occured to hands of two-third full bananas stored for 3 weeks in polythene at 52°F. At all storage temperatures, the peel/pulp ratio, the pulp moisture percentage and weight loss percentage increased and peel thickness and pulp firmness decreased. The rates of these changes increased with temperature and storage time. Total carbohydrates and starch decreased and total and reducing sugars increased during storage. The changes were least rapid in polythene.

Scott et al. (1968) reported that the storage life of bananas packed in polythene bags can be increased at least by 2 weeks by inclusion of $KMnO_4$ as ethylene absorbent.

Mavin (1969) recommended that centralised packing and use of polythene bags containing a desicant are effective and economic method of minimising losses through bananas aiming at the market in a state of mixed ripeness which is caused by a combination of high temperature and high RH.

Scott et al. (1970) further reported that potassium permanganate reduced the concentration of ethylene and calcium hydroxide reduced concentration of CO_2 in sealed polythene bags containing bananas. When fruits that were not packed in sealed bags were ripe (16 days after the beginning of storage) all the fruits in sealed polythene bags were in firm green condition and there was little difference between treatments in sealed polythene bags. After 29 days some of the fruits in sealed bags had softened, but fruits in bags containing $KMNO_4$ were firmer than fruits receiving other treatments and this effect was more marked after 38 days. About 2 weeks additional storage life was obtained by packing $KMNO_4$ with the fruit. Liu (1970) also reports that inclusion of a ethylene absorbent within sealed polythene bags containing bananas prolong the storage life as the endogenous ethylene produced by the bananas is absorbed by the ethylene absorbant instantaneously.

A comparative study of skin coating and smoking treatment on the ripening and storage behaviour of banana cv. Basrai was conducted by Agnihotri and Ram (1971). The results indicated that skin coated bananas smoked and unsmoked groups could be maintained in good condition respectively for 6 days and 8 days and those receiving smoke treatment alone for 4 days, whereas check samples failed to ripen properly, and mostely turned black after 4 days.

Fuch and Gorodeiski (1971) studied the course of ripening of bananas stored in sealed polythene bags and reported that bananas not sealed in polythene bags (control) became ripe (yellow, soft and dwarth good flavour) after 7 days of storage, while all fruits sealed in bags with or without $KMNO_4$ was still green after 14 days. The amount of ethylene in the atmosphere in bags containing $KMNO_4$ was lower than in those without. Tongue (1972) also reported similar results by storing green bananas in polythene covers containing $KMNO_4$.

Muthuswamy et al. (1972) recommended cold storage as a method for prolonged shelf life for bananas. Whole bunches of dwarf cavendish were successfully stored at

14.4°C and 80 - 90% RH for 25 days as compared with 7 days at room temperature 29°C - 32°C. Detached hands ripened after 18 days in refrigerated storage and within 7 days at room temperature. Two coatings of wax emulsion containing 6 or 12% wax greatly retarded ripening in cold storage and reduced weight-loss.

Kao (1971) reported that gamma-irradiation of green bananas at 20 - 30 Krad delayed soluble solids formation, starch disappearance, and respiratory activity. Storing irradiated bananas at 12 - 20°C or 25 - 30°C delayed ripening by about 7 and 5 days respectively.

Sadasivam et al. (1971) reported that a double coating of 12% wax emulsion (as waxol W-12) prolonged storage life and reduced the weight loss of whole bunches held at 58°F; only 50% of the fruits was ripe after 30 days, compared with 100% of the unwaxed bunches. The wax coating also increased the storage life of detached hands by 5 days at room temperature and by 10 - 12 days at 58°F.

Zica and Brune (1973) reported that banana

cv. Prata ripening was most markedly delayed by unperforated polythene bags with absorbent, but this treatment made the fruit commercially unacceptable. The most suitable commercial treatment was with perforated polythene bags without absorbent, which delayed ripening by about 5 days.

Scott and Gandanegara (1974) studied the effects of temperature on storage life of bananas in sealed polythene bags and found that sealed polythene bags containing $KMNO_4$ kept at 30°C have similar life to that stored conventionally in air at 12.8°C. Patil and Magar (1975) studied the effect of purafil, $Ca(OH)_2$ and a 1 : 1 mixture of purafil and $Ca(OH)_2$ on storage life of bananas stored in sealed polythene bags at 13, 24 or 31°C. They results indicated that purafil reduced ethylene concentration, $Ca(OH)_2$ reduced CO_2 concentration and the mixture reduced concentration of both ethylene and CO_2. Parafil extended the storage life of preclimacteric bananas by 16, 8 and 4 days at 13°C, 24°C and 31°C respectively. Ndubisu (1976) also reported that fruits held in polythene bags with purafil alone remained green and hard for 3 - 4 weeks before ripening started and they were fully ripe after 5 weeks.

Salunkhe and Wu (1975) recommended sub-atmospheric storage of bananas for prolonging shelf life of mature green bananas.

5. EFFECT OF FUNGICIDAL TREATMENTS ON CONTROL OF POST HARVEST DISEASES OF BANANA

Damodaran and Ramakrishnan (1963) during their studies on anthracnose disease of banana some 26 isolates of Gleosporium musarum were tested on 31 banana cultivars. They found that all the varieties were susceptible, the susceptibility varied with the age of fruit, cultivars and the incubation period.

The fungi associated with the crown rot of boxed banana were isolated and identified by Geena & Goos (1963). The inoculation of banana crown with pure cultures of Thielaviopsis paradoxa, Botryodiploidia theobromae Pat. Gleosporium musarum cooke and Massee caused severe rotting, Deightoniella torulosum Syd. M.B. Ellis produced a moderate rot, while Fusarium roseum (Link) Snyd & Hans Gobbosum, Verticillium theobromae (Turc) Mason & Hughes and Fusarium moniliformae sheldom were only weakly active in individual trials, but were found to be more severe in combination. Roth and Loest (1966) reported that fungi

such as Gleosporium musarum, Theilaviopsis paradoxa, Geotrichum Candidus Nigrospora Sphaerica, Fusarium semitectum, Fusarium moniliformae, Fusarium oxysporum (Var. F.Sp) cubens Botryo diplodia theobromae Verticillium candelobrum, Verticillium theobromae and several actinomycetes bacteria and yeast were associated with the collar rot of banana fruits. Ramakamanantoae (1966) reported that Isoamyl butyrate and isoamyl isovalerianate could completely inhibit the growth of Gleosporium musarum during a 5 day test, the former resulted delayed colour change, while the later hastened the changes in skin colour without affecting degree of ripeness of the pulp.

Greene and Morales (1967) reported that tannins from green banana fruit latex inhibited the activity of B-amylase produced by Gleosporium musarum resulting no spread of the fungus.

Out of the 5 chemicals tested for the control of black end and anthracnose of bananas both caused by Gleosporium musarum, Burden (1969) reported that best control was achieved by benlate followed by thiabendasole and 2 aminobutane. The prophylactic measures suggested include good cultural and sanitation practises, careful

handling of fruit after harvest, clean packing sheds, washing and dipping in thiabendazole or Benlate.

Shillingford (1970) reported that fungal rots were induced principally by Gleosporium musarum and Fusarium roseum which were responsible for much deterioration in the quality of jamaican banana. He had reported that thiabendazole and benomyl at 200 and 300 ppm respectively gave good control when used for post harvest dips. Moderate control was obtained with Dithane M-45 (Maneb) at 200 ppm.

Prossard (1971) reported that banana rots induced by artificial inoculation of the stem end and skin with collectotrichum musae were effectively controlled by one minute dip in 400 ppm thiabendazole or 100 ppm benomyl, 5 hours after inoculation. Meredith (1971) reported that benomyl and to a lesser extent thiabendazole were effective against established latent infection in banana. Rippon (1972) claimed that the best control of Gleosporium musarum on inoculated banana hands was rendered by post harvest application of benomyl (100 ppm).

Prossard and Laville (1973) reported that

carbendazin (as Bavistine) at 200 - 300 ppm (according to season) is effective as post harvest dips for one minute for controlling anthracnose disease of banana. Griffee and pipegar (1975) used benomyl and thiabendazole as standards against banana crown rot. In *in vivo* studies thiophenate methyl and benzimidazole derrivatives (Bavistin and DAM 18654) at 250/ug/ml a.i gave similar degree of control as benomyl at the same dosage as TBZ at 400 mg/ml.

Materials and Methods

MATERIALS AND METHODS

The investigations were carried out at the College of Horticulture, Vellanikkara during the period 1978-1980 to study the effect of various pre and post-harvest treatments on storage and quality of banana cv. Nendran.

'Nendran' grown from uniform suckers under uniform agro-climatic conditions and management practices under rainfed conditions were utilised for the studies. The experiment was conducted at the Instructional Farm of College of Horticulture.

Sampling and Layout

Bunches with same date of shooting were marked for the purpose of study. Uniform fingers collected from the second hand of different bunches were sampled seperately at 10 days interval, starting from shooting and were utilised for maturation studies. The physical and chemical characters of the fruits were studied as detailed below.

1. PHYSICAL CHARACTERS

1.1 Length

1.2 Girth

1.3 Volume

1.4 Weight of whole fruit

1.5 Pulp/Peel ratio

2. CHEMICAL CHARACTERS

2.1 Starch

2.2 Sugars (reducing and non-reducing)

2.3 Titrable acidity

2.4 Ascorbic acid content

2.5 Tannin

2.6 Dry matter content

2.7 Moisture content

1. PHYSICAL CHARACTERS

Sampling was done from 10 bunches taking 3 fingers each from the inner row of the second hand and average worked out.

1.1 Length of fingers

Length was taken from the base of the finger

along the outer curvature upto and including apex using a non-elastic twine and measuring with a centimetre scale.

1.2 Girth of fingers

The girth was measured at the point of maximum thickness adopting the same method as that of the length measurement.

1.3 Volume of fingers

The volume was measured by water displacement method.

1.4 Weight of whole fruit

Weight of fingers was measured using a top loading automatic electric balance and expressed in gms.

1.5 Pulp/Peel ratio (by weight)

Peel was seperated with a sharp stainless steel knife and weight of the peel and pulp were recorded seperately. The ratio was calculated by dividing the pulp weight of a finger with the weight of the peel.

2. CHEMICAL CHARACTERS

2.1 Starch

Starch was estimated by the standard procedure as stated in A.O.A.C.(1960).

2.2 Sugars

2.2.1 Reducing sugars

The reducing sugars of the sample were determined as per the method described in A.O.A.C.(1960).

To a known quantity of macerated pulp, distilled water was added. After thorough mixing the solution was clarified with neutral lead acetate and deleaded with sodium oxalate and made up to known volume. The solution was then filtered and an aliquot of this solution was titrated against a mixture of Fehling's A and B solutions, using methylene blue as indicator. The reducing sugar was expressed as percentage.

2.2.2 Total sugars

The total sugars were estimated as per the method described by A.O.A.C. (1960). Five ml of concentrated hydrochloric acid was added to a known

volume of clarified solution prepared as stated earlier and the same was kept overnight. The solution was then neutralised by adding sodium hydroxide and titrated against a mixture of Fehling's A and B solutions. The total sugar was expressed as percentage.

2.2.3 Non-reducing sugars

The difference between total sugars and reducing sugars was worked out and expressed as non-reducing sugars.

2.2.4 T.S.S.

Total soluble solids were found out by a pocket refractometer.

2.3 Titrable acidity

The method described by A.O.A.C. (1960) was adopted. Ten gram of the macerated sample was digested with boiling water and made upto a known volume. An aliquot of the filtered solution was titrated against 0.1 N NaOH using phenolphthalein as indicator. The acidity was expressed as percentage of citric acid.

2.4 Ascorbic acid

The method described by A.O.A.C. (1960) was used. A known quantity of the pooled sample of the fruit was macerated in a mortar by adding small quantities of two per cent metaphorphoric acid and then filtered and made upto a known volume. An aliquot of the extract was taken to which an equal volume of two per cent metaphorphoric acid was added. The content was titrated against a standardised solution of 2, 6, dichlorophenol indophenol dye. The ascorbic acid content of the juice was then calculated and expressed as mg/100 g of pulp.

2.5 Tannin

Colorimetric method of tannin estimation as described by Renganna (1977) was made use of and the value was expressed as percentage.

2.6 Dry matter content

A weighed quantity of the pulp was chopped into small pieces and were dried in hot air oven at 70°C for about 72 hours till two consecutive weights agreed. Dry matter content was then worked out by

dividing the weight of oven dried sample with fresh weight of the sample and expressed as percentage.

2.7 Moisture content

A weighed quantity of the pulp was chopped into small pieces and dried in a hot air oven at 70°C till there is no further reduction in weight. The moisture content was then worked out from the weight lost during drying and expressed as percentage of fresh pulp weight.

EFFECT OF PRE-HARVEST SPRAYS OF PLANT GROWTH REGULATORS IN QUALITY OF THE FRUIT

In order to study the effect of growth regulators on quality, bunches of almost the same chronological age (± 2 days on either side) were sprayed with different levels of growth regulators on 60th day after shooting. The growth regulators and the different levels tried were as given below:

Growth regulators	Concentrations tried		
1. Ethrel	100 ppm	200 ppm	400 ppm
2. 2, 4-D	2 ppm	4 ppm	10 ppm
3. NAA	25 ppm	50 ppm	100 ppm

shooting

The treated bunches were harvested on 70th day, 80th day and 90th day after shooting. Physical characters such as length, girth, weight of fingers, peel weight, pulp weight, pulp/peel ratio and chemical characters such as T.S.S., sugars (reducing and non-reducing), titrable acidity and brix/acid ratio were studied.

PREPARATION AND APPLICATION OF GROWTH REGULATORS

Measured quantities of growth regulators were taken and dissolved in 5 ml of absolute alcohol. The stock solutions were diluted with distilled water so as to give the required concentrations. In the case of Ethrel, the proprietory product was pipetted out and dissolved in water directly to give the required concentration.

The solutions were applied on selected bunches of uniform age covering the entire bunch using an atomizer.

STORAGE CUM FUNGICIDAL STUDIES

Storage cum fungicidal studies were conducted on uniformly mature banana bunches. The following

treatments were employed in the fungicidal studies.

1. Control (no spray, no dip)
2. Spray alone (on 60th day after shooting)
3. Dip alone (soon after harvest)
4. Spray and dip (spray on 60th day + dip at harvest)

For the spray and dip 3 fungicides each at 2 levels were used as mentioned below.

Fungicides	Concentrations
1. Anthracol	0.05%, 0.01%
2. Bavistin	500 ppm, 1000 ppm
3. Thiride	0.1%, 0.2%

All the above treatments were subjected to the following methods of storage.

1. Polythene bag (200 guage of size 45 cm x 30 cm)
2. Polythene bag + $KMnO_4$
3. Open storage
4. Smoke house ripening and storing in open

The intensity of anthracnose disease caused by Gloeosporium musarum on the fruits were scored on alternate days upto complete rotting stage. A score card with points from 0 - 9 was used for scoring the

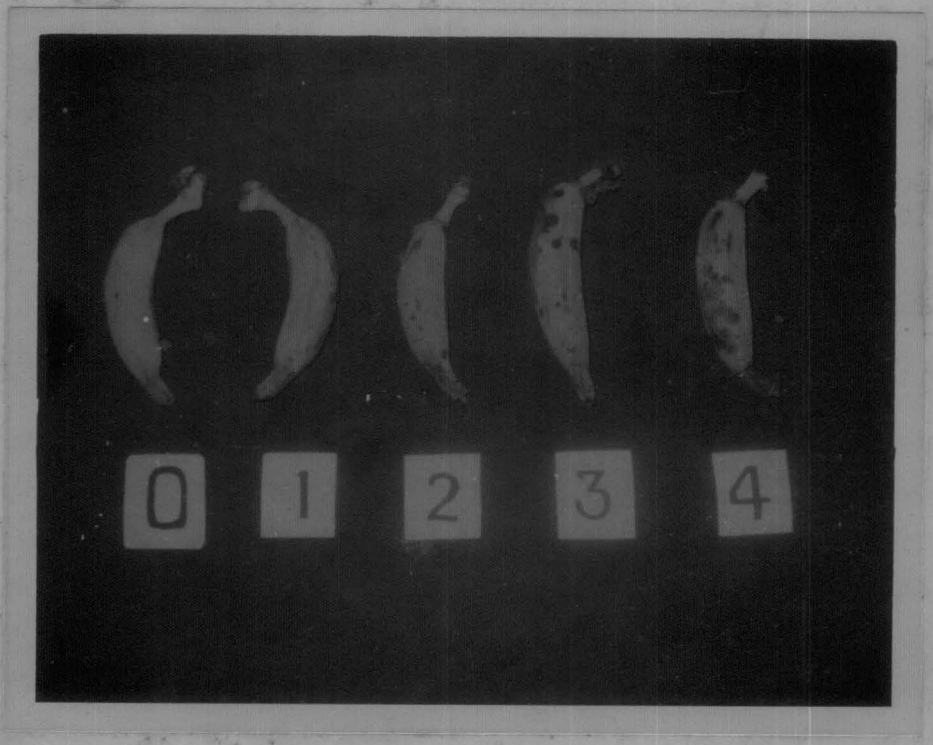
intensity of infestation on different treatments.

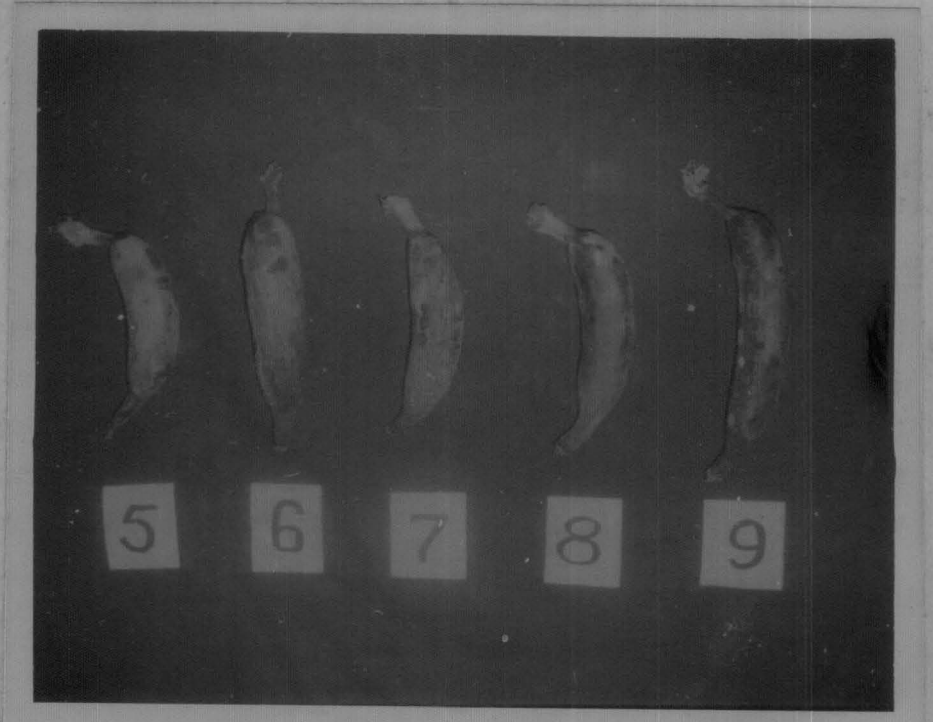
The description of the scores used is given below.

Score	Description
0	Black spots Nil to 10% of the area of the fruit
1	Black spots 10% to 20% of area of the fruit
2	Black spots 20% to 30% of area of the fruit
3	Black spots 30% to 40% of area of the fruit
4	Black spots 40% to 50% of area of the fruit
5	Black spots 50% to 60% of area of the fruit
6	Black spots 60% to 70% of area of the fruit
7	Black spots 70% to 80% of area of the fruit
8	Black spots 80% to 90% of area of the fruit
9	Black spots 90% to 100% of area of the fruit

To judge the ripening rates under different storage conditions, another method of scoring on alternate days was adopted as detailed below:

Score	Description
0	Green
1	Green to greenish yellow
2	Greenish yellow to yellowish green
3	Yellow
4	Yellow with black spots
5	Over ripe stage with rotting/blackening


0
1
2
3
4


5
6
7
8
9

Five fingers each were sampled out at 2 days interval from all the 4 storage treatments for conducting quality analysis and the following characters such as T.S.S., sugars (both reducing and non-reducing), titrable acidity and ascorbic acid content were studied.

Six fingers selected at random from each bunch constituted one treatment of a replication. In order to prepare the required concentrations of fungicidal solutions, measured quantities of fungicides were dissolved in water. Pre-harvest sprays were conducted using an atomiser.

1. Polythene bag (200 guage)

The fingers soon after separation from bunches were kept in polythene bags and sealed.

2. Polythene cover + $KMnO_4$

About 125 gm of well dried sawdust taken in cloth bags were soaked in saturated potassium permanganate solution for half an hour and the excess solution was drained off before keeping in the polythene bags, containing green fingers and the bags were then sealed.

3. Open storage

The harvested bunches were kept under open conditions at room temperature for ripening.

4. Smoke house ripening and storing in open

The bunches kept in smoke houses for 24 hours were taken out, fingers seperated and kept under open conditions for further ripening.

STATISTICAL ANALYSIS

The data on different aspects studied were subjected to statistical analysis, following the methods of Snedecor and Cochran (1967). The mean values were worked out for different parameters. All the characters of different treatments were analysed by the analysis of variance technique. Critical differences were calculated for the comparison of treatments.

Results

RESULTS

The results of the different studies conducted are presented in the following sections.

1. Growth and development studies with a view to fix up optimum maturity.
2. Effect of pre-harvest sprays of growth regulators on the quality of fruits.
3. Comparative study of different storage methods.
4. Effect of different fungicidal treatments on controlling anthracnose disease of banana.

1. GROWTH AND DEVELOPMENT OF THE FRUIT

The growth and development of the fruits, as represented by length, girth, weight, volume and specific gravity of the fingers from shooting to 90th day were collected at an interval of 10 days and these are presented in tables 1 & 2 and figures 1, 2, 3 & 4.

1. PHYSICAL CHARACTERS

1.1 Length of fingers

The data showed that at the time of shooting, the mean length of fingers was 17.52 cm and at full maturity (90 days after shooting) it was 24.32 cm showing

an increase of 6.8 cm in length during a period of 90 days. The increase in length was 61.91 per cent during the first 30 days and 31.18 per cent during next 30 days. The last 30 days (from 60 to 90 days) accounted for only 6.91 per cent of the total increase (Table 1).

1.2 Girth of fingers

The mean maximum girth of the fruits at shooting was 8.79 cm and at full maturity 13.31 cm. Out of this increase of 4.52 cm in girth, 67.70 per cent had taken place within 30 days of shooting, 24.34 per cent during next 30 days and only 7.96% during last 30 days(Table 1).

1.3 Volume

The data showed that the increase in volume was rapid during the first two months of growth period resulting an increase from 68 cc at shooting to, 164.4 cc on 60th day. Thereafter the increase continued and at full maturity the fruits had a volume of 172.00 cc. The specific gravity of the fruits also increased from 0.76 at shooting to 1.00 on 60th day. The specific gravity was 1.02 at 80th day, thereafter showing a reduction to 1.01 at full maturity.

1.4 Weight of fingers

The fingers weighed 51.82 g on an average at shooting, which increased to 173.23 g at harvesting maturity, thus showing an increase of 121.41 g during 90 days' growth. The increase in weight of fruits were at a rapid rate during first 30 days, accounting for 65.32 per cent of total increase in weight. The increase was 27.05 per cent during next 30 days and 7.63 per cent during last 30 days.

The above results clearly indicated that about 2/3 of the total growth took place during the first 30 days after shooting and it was less than 10 per cent after 60 days (Table 1 and Fig.1).

1.5 Pulp/peel ratio

Pulp to peel ratio was more or less constant (0.32 - 0.33) upto 30 days after shooting and it increased thereafter to 1.24 by 60 days. The increasing trend continued and the ratio was 1.84 at full maturity (Table 1).

2. CHEMICAL CHARACTERS

2.1 Starch

Accumulation of starch in the pulp of fruits

Fig. 1 - PERCENTAGE INCREASE IN LENGTH, GIRTH AND WEIGHT OF BANANA FINGERS [CV NENDRAN] AT DIFFERENT STAGES OF GROWTH.

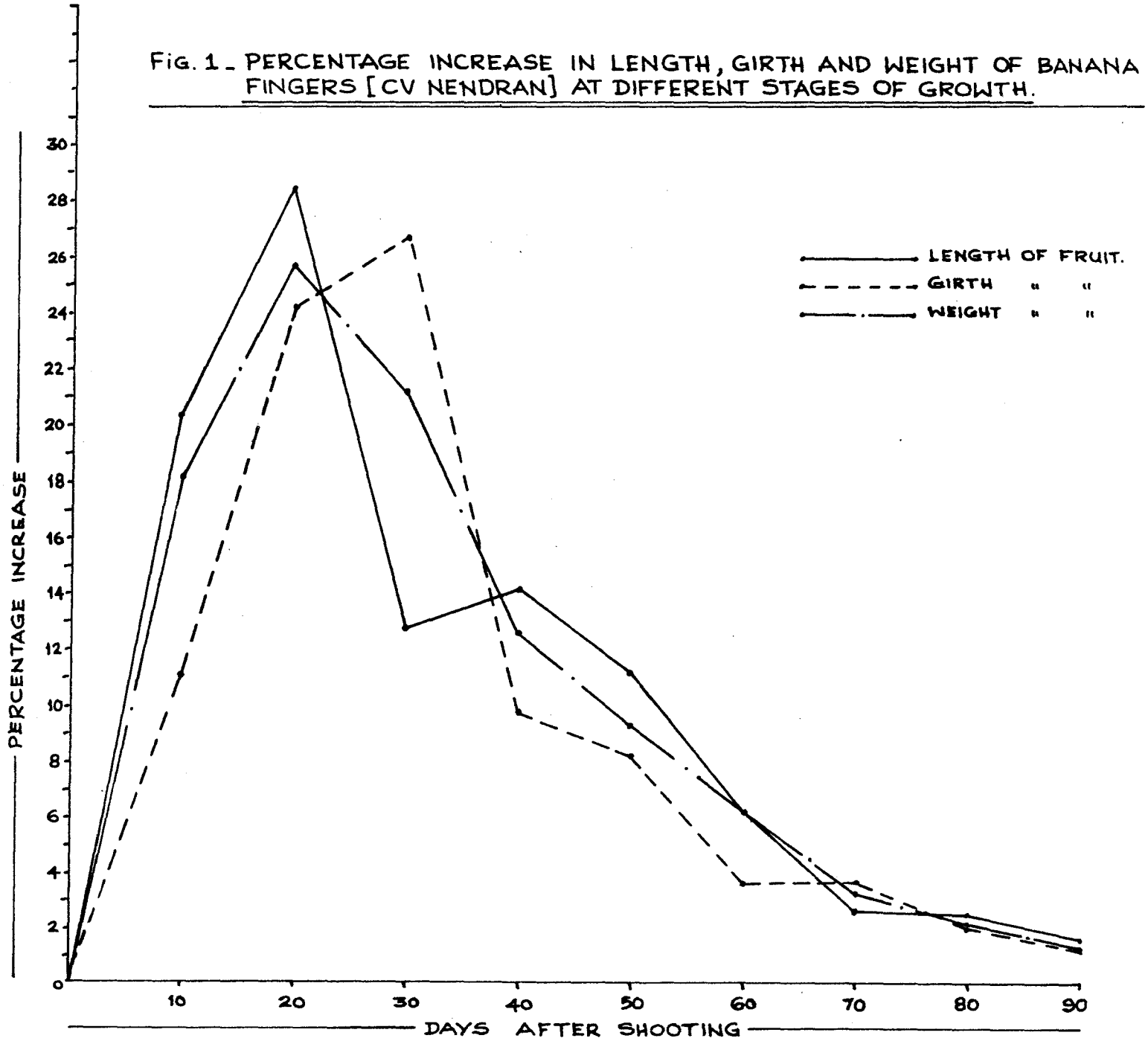


FIG. 2 - PERCENTAGE OF DRYMATTER AND STARCH CONTENT OF BANANA FINGERS [CV NENDRAN] AT DIFFERENT STAGES OF DEVELOPMENT.

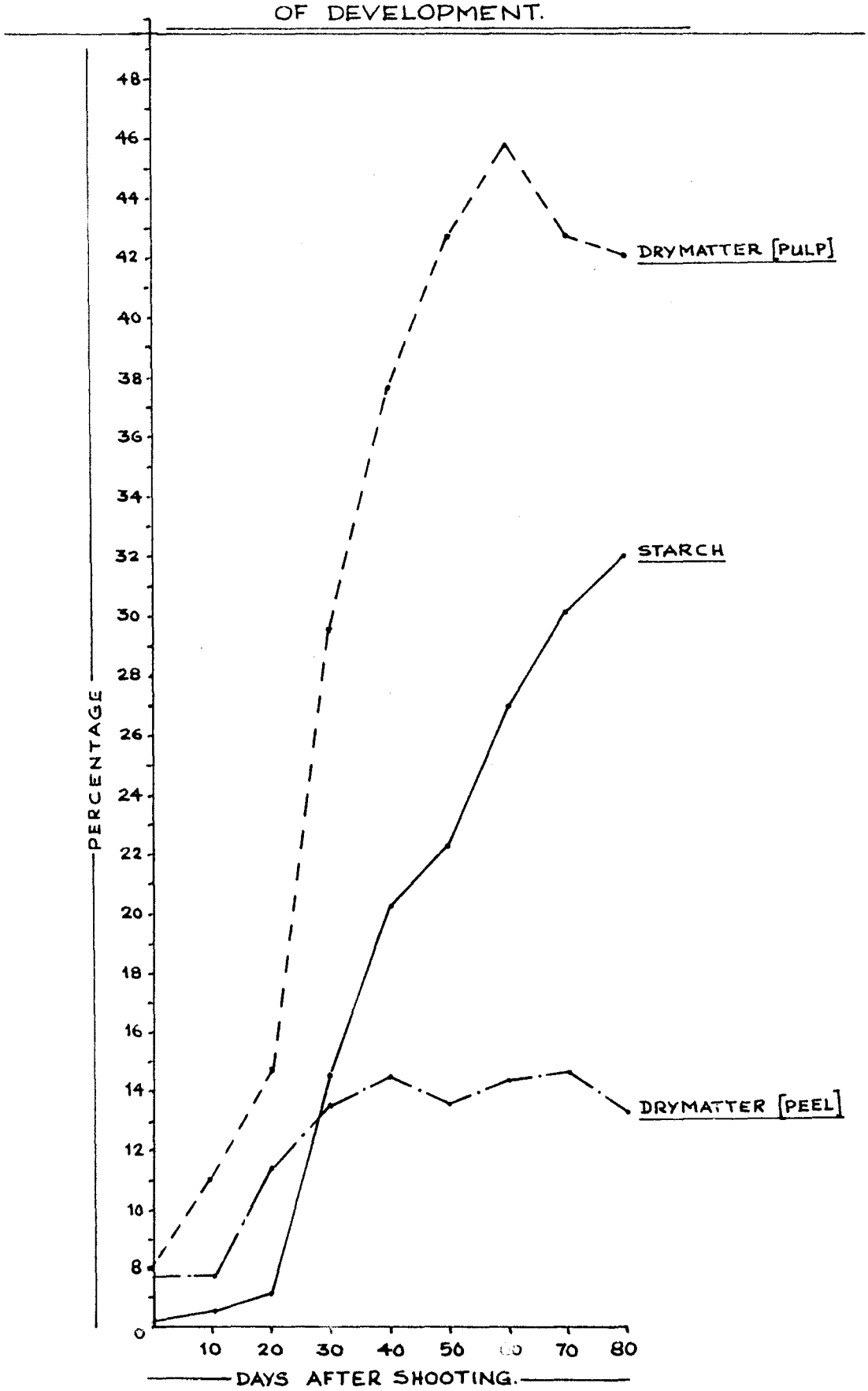


Table 2. Variation in dry matter, starch, sugars, ascorbic acid, acidity and tannin content of banana fingers (cv. Nendran) during development

Days after shooting	Starch Content %	Starch Content % increase of the total	Total sugars % of fresh pulp	Ascorbic acid (mg/100g)	Acidity (% of fresh pulp)	Tannin (% in the peel)	Dry matter % Pulp	Dry matter % Peel	Moisture content % Pulp	Moisture content % Peel
10th day	1.395	-	0.50	1.18	0.04	40.48	8.24	7.92	91.86	92.55
20th day	3.012	5.28	0.51	3.68	0.048	32.65	11.05	7.65	88.10	92.42
30th day	6.86	12.57	0.625	8.48	0.056	20.22	14.76	14.45	85.24	88.55
40th day	14.64	25.41	0.66	10.64	0.064	12.07	29.58	13.57	70.42	86.43
50th day	20.41	18.85	0.85	12.50	0.068	10.38	37.66	14.60	62.34	85.40
60th day	22.23	5.94	0.93	11.11	0.088	16.25	42.82	13.63	57.18	86.37
70th day	27.40	15.71	1.00	14.62	0.08	15.17	45.90	14.40	54.10	85.60
80th day	30.05	9.83	1.20	16.24	0.08	6.77	42.75	14.83	57.25	85.17
90th day	32.01	6.40	1.29	18.00	0.096	7.72	42.05	13.60	57.95	86.40

continued until full maturity. The increase in starch accumulation was only 17.85 per cent during the first 30 days, while it was 50.20 per cent during next 30 days. The percentage increase was reduced to 31.95 thereafter (Table 2).

2.2 Sugars

The data on the total sugar content of developing fingers showed that the total sugar content of the pulp increased from 0.5% at 10 days after shooting to 1.29 per cent at full maturity. The total sugar was less than one per cent during the first 70 days of its growth and increased thereafter to 1.29% at 90th day after shooting (Table 2).

2.3 Titrable acidity

The data showed that the titrable acidity of the pulp continued to increase till full maturity. The acidity rose from 0.04 per cent of fresh pulp at 10 days after shooting to 0.096 per cent at full maturity (Table 2).

2.4 Ascorbic acid

The vitamin C content of the fruits increased

FIG.3_ WEIGHT OF BANANA FINGERS [CV NENDRAN] AT DIFFERENT STAGES OF DEVELOPMENT.

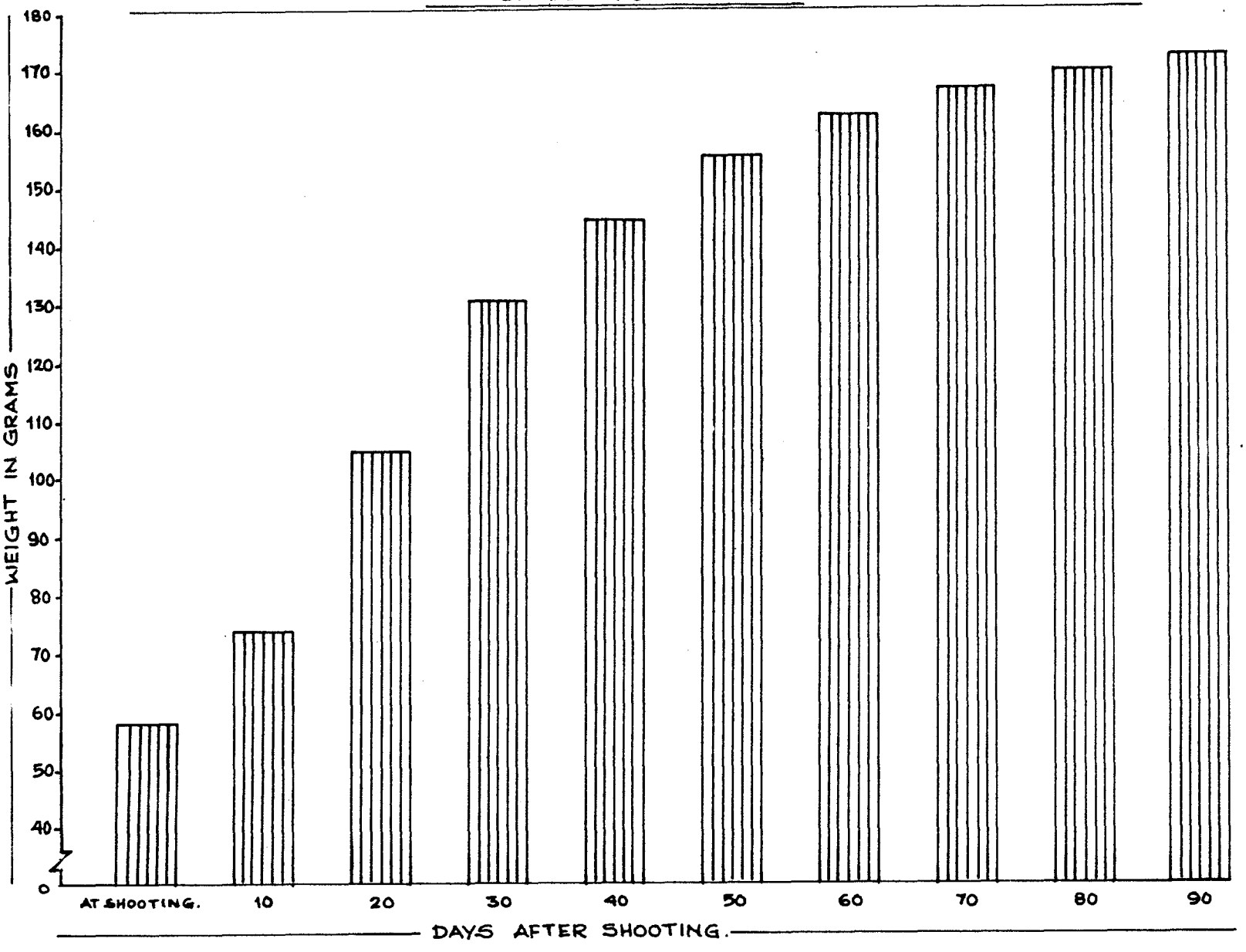
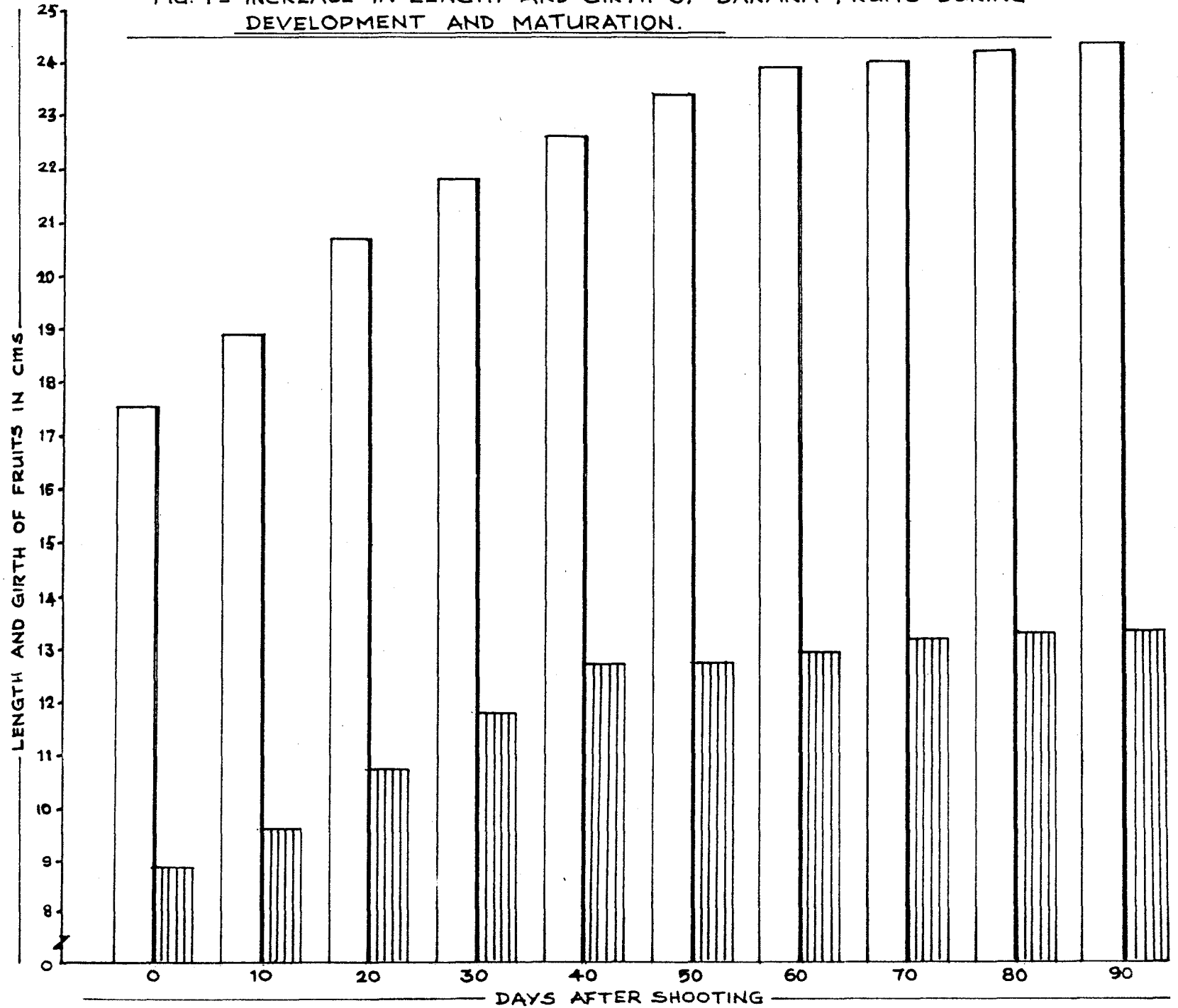


FIG. 4- INCREASE IN LENGTH AND GIRTH OF BANANA FRUITS DURING DEVELOPMENT AND MATURATION.



as the fruit attained maturity. The data showed that the ascorbic acid content rose from 1.18 mg/100 g of pulp ten days after shooting to 18 mg/100 g at harvest maturity. The increase was not continuous as the fruit at 60th day showed a reduction from 12.5 mg on 50th day to 11.11 mg, the further increase being in a regular pattern (Table 2).

2.5 Tannin

The tannin content in the peel decreased as the fruit matured, the content being 40.48 per cent at 10 days and 7.72% at full maturity. On 60th day, it was 16.25 per cent and thereafter it reduced to 7.72 per cent at full maturity. However an increase in the percentage of tannin content was noticed between 50th and 60th day (Table 2).

2.6 Dry matter content

Accumulation of dry matter in the pulp and the peel continued till full maturity. The dry matter content rose from 8.24 per cent at 10 days after shooting to 42.05 per cent at full maturity in case of pulp while it was 7.92 and 13.6 per cent respectively in case of peel (Table 2, Fig. 2).

2.7 Moisture content

Moisture content in the pulp and the peel reduced gradually as the fruit matured, the reduction being at a rapid rate in the case of pulp (91.69% to 57.95%). In the case of peel, the reduction was from 92.55 to 86.4 per cent.

2. EFFECT OF PRE-HARVEST SPRAYS OF GROWTH REGULATORS ON THE QUALITY OF FRUITS

The effect of pre-harvest application (60th day of shooting) of growth regulators on the post harvest qualities of the fruits were studied. The data are presented in Tables 3 to 12.

2.1 PHYSICAL CHARACTERS

2.1.1 Length of fruits

All the growth regulators tried contributed significantly towards growth of the fruit irrespective of stage of harvest or concentration of chemical tried. The fruits harvested 10 days after growth regulator application showed that all the treatments resulted in a significant (at 0.05% level) increase in the length of the fruits as compared to the control. The treatment T_5 (Ethrel 400 ppm) resulted in maximum

Table 3. Effect of growth regulators on the length of fruits

Treatments		Stage of harvest (days after shooting)			Overall mean
		70th day (cm)	80th day (cm)	90th day (cm)	
T_1	Ethrel 100 ppm	22.9	23.46	24.33	23.56
T_2	Ethrel 200 ppm	23.84	25.43	26.89	25.39
T_3	Ethrel 400 ppm	24.53	24.53	24.89	24.65
T_4	2, 4-D 2 ppm	23.21	24.81	25.40	24.47
T_5	2, 4-D 4 ppm	24.01	26.07	27.27	25.78
T_6	2, 4-D 10 ppm	23.23	24.80	24.68	24.23
T_7	NAA 50 ppm	23.23	24.38	24.61	24.07
T_8	NAA 100 ppm	23.03	24.59	26.19	24.60
T_9	NAA 200 ppm	21.30	24.00	24.75	23.35
T_{10}	Control	20.13	22.59	22.99	21.90
	Mean	22.94	24.47	25.2	

	F value	Critical difference
Treatment	8.78**	1.02
Stages of harvest	32.40**	0.55
Treatment × stages	7.14**	1.78

** Significant at 1 per cent level

increase with 24.53 cm as against the control T_{10} (20.13 cm). The treatments T_5 (24.01 cm), T_2 (23.84 cm), T_6 (23.23 cm), T_7 (23.23 cm), T_4 (23.21 cm) and T_8 (23.03) were on par with the T_3 .

The fruits harvested after 80th day of shooting (20 days after application of growth regulators) also showed that there was significant increase in length of fruits by the treatments. The treatment 2, 4-D 4 ppm resulted the maximum increase in length of fruits (26.07 cm) as compared to the control (22.59 cm). The harvest at full maturity also showed that T_5 (27.27 cm) is superior to all other treatments, where the treatments T_2 (26.89 cm) and T_8 (26.19 cm) were on par with T_5 as compared to the control T_{10} (22.99 cm).

The overall effect of the treatments showed that the increase in length of fruits was significant at 5% level due to all treatments. The maximum average length of 25.78 cm was noticed in case of 2, 4-D at 4 ppm (T_5). The effect of T_2 (25.39 cm) was on par with T_5. The average length of fruits in the case of control was only 21.9 cm.

2.1.2 Girth of fruits

With regard to the girth of fruits, the

Table 4. Effect of growth regulators on the girth of the fruits

	Treatments	Stages of harvest (days after shooting)			Overall mean
		70th days (cm)	80th days (cm)	90th days (cm)	
T_1	Ethrel 100 ppm	12.69	13.21	12.82	12.91
T_2	Ethrel 200 ppm	12.45	12.75	13.35	12.85
T_3	Ethrel 400 ppm	12.46	12.97	12.61	12.68
T_4	2, 4-D 2 ppm	12.74	13.40	13.45	13.20
T_5	2, 4-D 4 ppm	13.75	13.13	13.37	13.41
T_6	2, 4-D 10 ppm	12.93	13.63	13.68	13.41
T_7	NAA 50 ppm	12.37	12.88	13.13	12.79
T_8	NAA 100 ppm	13.26	12.13	13.67	12.85
T_9	NAA 200 ppm	12.23	12.41	13.03	12.56
T_{10}	Control	12.51	12.01	12.50	12.34
	Mean	13.34	12.85	13.11	

	F value
Treatment	0.47^{NS}
Stages	0.342^{NS}
Treatment x Stages	0.89^{NS}

NS = Non Significant

effects of treatments were not significantly different from that of control.

2.1.3 Weight of fruits

The effect of treatments on the weight of fruits was significant. Weight of fruits showed significant difference between different stages of harvest also (Table 5). The fruits harvested at full maturity (90 days) had significantly higher mean weight (176.69 g) as compared to that of 80th day harvest (167.67 g) and 70th day harvests (154.69 g). The effect of treatments were similar under all stages of harvest. The maximum mean weight of the fruits 191.8 g/fruit was obtained in the treatment T_6 (2, 4-D 10 ppm) followed by T_5 (2, 4-D 4 ppm) with 191.19 g as against the control (132.75 g). The effects of T_2 (177.22 g), and T_4 (176.219 M) were on par with T_6. All other treatment effects were also significantly superior to the control.

2.1.4 Pulp/peel ratio

The various treatments have got significant influence on the pulp/peel ratio of the fruits (Table 6). The pulp to peel ratio varied significantly between stages of harvest also. The mean pulp to peel ratio of ripened fruits was highest (3.42) at full

Table 5. Effect of growth regulators on weight of fruits

	Treatments	Stages of harvest (days after shooting) 70th day (g)	80th day (g)	90th day (g)	Overall mean
T_1	Ethrel 100 ppm	143.77	159.60	169.37	157.58
T_2	Ethrel 200 ppm	161.39	182.35	187.94	177.22
T_3	Ethrel 400 ppm	160.34	179.85	186.08	175.42
T_4	2, 4-D 2 ppm	163.35	181.99	183.29	176.21
T_5	2, 4-D 4 ppm	181.33	181.00	209.23	191.19
T_6	2, 4-D 10 ppm	166.89	205.28	203.28	191.80
T_7	NAA 50 ppm	157.26	163.11	166.62	162.33
T_8	NAA 100 ppm	162.55	147.99	167.91	159.48
T_9	NAA 200 ppm	130.23	139.73	148.57	139.51
T_{10}	Control	117.79	135.85	144.63	132.75
	Mean	154.69	167.67	176.69	

	F value	CD
Treatments	11.63**	16.15
Stages of harvest	12.01**	8.84
Treatments x Stages	0.607^{NS}	27.97

** = Significant at 1 per cent level

NS = Non Significant

Table 6. Effect of growth regulators on pulp/peel ratio of fruits at different stages of harvest

Treatments		Stages of harvest (days after shooting)			Overall mean
		70th day	80th day	90th day	
T_1	Ethrel 100 ppm	3.02	2.60	3.31	2.98
T_2	Ethrel 200 ppm	2.84	2.80	3.11	2.92
T_3	Ethrel 400 ppm	2.94	2.95	3.43	3.11
T_4	2, 4-D 2 ppm	3.17	3.04	3.27	3.16
T_5	2, 4-D 4 ppm	3.00	3.17	3.21	3.13
T_6	2, 4-D 10 ppm	3.19	3.31	3.50	3.33
T_7	NAA 50 ppm	3.01	3.57	3.44	3.34
T_8	NAA 100 ppm	3.34	4.00	3.99	3.78*
T_9	NAA 200 ppm	3.24	3.49	3.68	3.47
T_{10}	Control	3.19	3.60	3.29	3.36
	Mean	3.09	3.25	3.42	

	F value	CD
Treatment	11.33*	0.20
Stages of harvest	15.88**	0.13
Treatment x stages	2.21	0.37

** = Significant at 1 per cent level

* = Significant at 5 per cent level

maturity as against 3.25 on 80th day harvest and 3.09 g 70th day harvest. The overall effect of treatments summed over the stages of harvest show that the pulp to peel ratio was significantly higher for the treatment T_8 (NAA 100 ppm) which was 3.78 as against 3.36 in the case of control. The effects of T_9 (3.47), T_7 (3.34) and T_6 (3.33) were on par with the control. All other treatments resulted in a reduction of pulp/peel ratio than the control.

2.2 CHEMICAL CHARACTERS

2.2.1 Total Soluble Solids

There was significant difference among the treatments in the T.S.S. content of the fruits. The ripened fruits of 70th day harvest (10 days after growth regulator application) showed that all the treatments significantly increased the TSS content of fruits. The maximum TSS content of 33.27 per cent was recorded by T_3 (Ethrel 400 ppm) followed by T_8 (33.2 per cent), T_9 (32.75%), T_2 (31.47%), T_6 (31.07%) and T_5 (30.87%) as compared to the control of 25.6 per cent (Table 7). The ripened fruits of 80th day and 90th day harvests also showed that the effects of treatments T_3, T_2 and T_9

were significantly superior than all other treatments in respect of TSS content (Table 7). The effect due to different stages of harvest on TSS content was not significant thereby showing an improvement in quality of earlier harvests. The overall effect of treatments showed that T_5 had significantly superior mean TSS content of 33.8 per cent as against 29.31 per cent of the control. The effects of NAA 200 ppm (T_9-32.71%) and Ethrel 200 ppm (30.62%) were on par with the treatment T_5. The treatments T_6 (30.62%), T_7 (29.8%), T_8 (29.8%), T_1 (29.56%) & T_4 (29.36%) recorded higher TSS than the control (Table 7).

2.2.2 Sugars

2.2.2.1 Total sugar

The total sugar content of the fruits increased significantly due to the treatments (Table 8). The ripened fruits of 70th day harvest showed higher total sugar content on an average of 19.08 per cent as compared to 80th day (15.96%) and 90th day (15.03%) harvests. All the treatments significantly increased the total sugar content of fruits of 70th day harvest. The NAA at 100 ppm (T_8) had maximum total sugar content

Table 7. Effect of growth regulators on the T.S.S. content of fruits

	Treatments	Stages of harvest (days after shooting)			Overall mean
		70th day (%)	80th day (%)	90th day (%)	
T_1	Ethrel 100 ppm	22.93	28.27	30.47	29.56
T_2	Ethrel 200 ppm	31.47	33.67	29.73	31.62
T_3	Ethrel 400 ppm	33.27	33.87	34.27	33.80
T_4	2, 4-D 2 ppm	30.40	28.47	29.20	29.36
T_5	2, 4-D 4 ppm	30.87	28.60	28.07	29.18
T_6	2, 4-D 10 ppm	31.17	30.53	30.27	30.62
T_7	NAA 50 ppm	30.13	28.87	30.40	29.80
T_8	NAA 100 ppm	33.20	28.33	27.87	29.80
T_9	NAA 200 ppm	32.73	31.53	33.87	32.71
T_{10}	Control	25.60	30.67	31.67	29.31
	Mean	30.87	30.28	30.58	

	F value	CD
Treatment	9.45**	1.45
Stages of harvest	1.04^{NS}	0.80
Treatment x Stage	3.94*	2.51

** = Significant at 1 per cent level

* = Significant at 5 per cent level

NS = Non Significant

Table 8. Effect of growth regulators on total sugar content of banana fruits

Treatments		Stages of harvest (days after shooting) 70th day (%)	80th day (%)	90th day (%)	Overall mean
T_1	Ethrel 100 ppm	20.96	17.55	15.40	17.97
T_2	Ethrel 200 ppm	19.28	15.99	15.42	16.89
T_3	Ethrel 400 ppm	17.88	15.83	15.29	16.33
T_4	2, 4-D 2 ppm	18.45	16.81	14.49	16.58
T_5	2, 4-D 4 ppm	20.11	18.14	15.25	17.83
T_6	2, 4-D 10 ppm	18.85	16.37	15.10	16.78
T_7	NAA 50 ppm	17.96	18.50	15.08	17.18
T_8	NAA 100 ppm	21.81	17.98	15.63	18.47
T_9	NAA 200 ppm	19.52	16.49	14.68	16.89
T_{10}	Control	15.97	15.94	13.96	15.29
	Mean	19.08	15.96	15.03	

	F value	CD
Treatments	12.86**	0.71
Stages of harvest	212.73**	0.39
Treatment x stages of harvest	4.06**	1.22

** = Significant at 1 per cent level

* = Significant at 5 per cent level

of 21.81% followed by T_1 (20.96%), T_5 (20.11%), T_9 (19.52%), T_2 (19.28%) as against the control (15.91%). A subsequent reduction in the total sugar content as days pass by was noticed for fruits of 80th day and 90th day harvests as compared to 70th day harvested fruits. The fruits harvested 20 days after growth regulator application showed that treatments T_7 (18.5%), T_5 (18.14%), T_8 (18.98%) and T_1 (17.55%) had significantly superior total sugar content than T_{10} (15.94%), the effects being on par with each other. In the case of 90th day harvest, all treatments showed significantly higher total sugar content than control, the maximum being for T_8 (15.63%) followed by T_2 (15.42%) as against the control (13.96%).

2.2.2.2 Reducing sugar

All the treatments tried had significant effects on the reducing sugar content of fruits. The significantly higher reducing sugar content were recorded by the fruits of 70th day harvest (mean 17.94%) as compared to 80th day (16.24%) and 90th day (13.85%) harvested fruits as shown in the Table 9 .

Among the fruits harvested 10 days after growth

Table 9. Effect of growth regulator treatments on the reducing sugar content of fruits

Treatments		Stages of harvest (days after shooting)			Overall mean
		70th day (%)	80th day (%)	90th day (%)	
T_1	Ethrel 100 ppm	20.52	15.03	13.78	16.44
T_2	Ethrel 200 ppm	18.85	15.63	14.70	16.39
T_3	Ethrel 400 ppm	16.58	15.17	14.56	15.44
T_4	2, 4-D 2 ppm	16.89	16.26	13.16	15.44
T_5	2, 4-D 4 ppm	19.76	17.80	13.42	16.99
T_6	2, 4-D 10 ppm	17.78	15.62	14.29	15.90
T_7	NAA 50 ppm	15.83	18.27	13.83	15.98
T_8	NAA 100 ppm	21.96	17.79	14.31	17.88
T_9	NAA 200 ppm	17.49	16.16	13.26	15.64
T_{10}	Control	14.17	14.67	13.22	14.02
	Mean	17.94	16.24	13.85	

	F value	CD
Treatment	11.24**	0.86
Stages of harvest	148.62**	0.47
Treatment x stages of harvest	6.81**	1.47

** = Significant at 1 per cent level

regulator application the highest reducing sugar content was recorded by T_8 (21.56%) followed by T_1 (20.52%) as compared to the control (14.17%). All the other treatments except T_7 were significantly higher in reducing sugar content. In the case of 80th day harvest T_7 had maximum reducing sugar content of 18.27 per cent which was on par with T_5(17.8%) and T_8(17.79%) as compared to control with 14.67 per cent. The 90th day harvest also showed that all the treatments except T_4 had significantly higher reducing sugar content, the highest being 14.7% recorded by T_2. The effects of T_3 (14.56%), T_8 (14.31%), T_6 (14.29%) T_7 (13.83%), T_1 (13.78%), T_5 (13.42%) and T_9 (13.26%) were on par with T_2.

2.2.2.3 Non-reducing sugar

The non-reducing sugar content of treated fruits at varying stages of harvest showed significant difference (Table 10). Among the 70th day harvested treated fruits, the T_7 had maximum (2.13%) non reducing sugar as compared to the lowest 0.33% recorded by T_5. The fruits of 80th day harvest showed that the treatment T_1 resulted in high non-reducing

Table 10. Effect of growth regulators on non-reducing sugar content of ripe fruits

Treatments		Stages of harvest (days after shooting)			Overall mean
		70th day (%)	80th day (%)	90th day (%)	
T_1	Ethrel 100 ppm	0.302	2.55	1.66	1.50
T_2	Ethrel 200 ppm	0.39	0.47	1.59	0.82
T_3	Ethrel 400 ppm	1.24	0.644	0.74	0.88
T_4	2, 4-D 2 ppm	1.58	0.538	1.29	1.14
T_5	2, 4-D 4 ppm	0.33	0.360	1.83	0.84
T_6	2, 4-D 10 ppm	1.07	0.739	0.80	0.87
T_7	NAA 50 ppm	2.13	0.23	1.25	1.20
T_8	NAA 100 ppm	0.306	0.19	1.38	0.63
T_9	NAA 200 ppm	2.06	0.34	1.42	1.27
T_{10}	Control	1.79	1.24	0.74	1.26
	Mean	1.12	1.29	1.27	

	F value	CD
Treatment	1.68^{NS}	NS
Stages of harvest	5.91**	0.33
Treatment x stages of harvest	3.77**	1.02

** = Significant at 1 per cent level

NS = Non Significant

sugar of 2.55 per cent as against 0.19 per cent recorded by T_8, being the lowest. The 90th day harvest showed that T_1 contained more non reducing sugar of 1.66% as compared to 0.74 per cent of control.

2.2.3 Acidity

The acidity of the treated fruits were highest for those fruits harvested at full maturity with mean acidity 0.313% followed by 80th day (0.296%) and 70th day harvested fruits (0.242%) (Table 11).

The overall effect of treatments showed that T_9 (NAA 200 ppm) increased acidity of fruits to 0.315 per cent as compared to 0.287% in the case of control. The treatment T_2, T_5, T_6, T_1, T_4, T_8 and T_7 were on par in their effects with T_{10}, the acid content being 0.289%, 0.285%, 0.282%, 0.280%, 0.280%, 0.276%, 0.274% and 0.287% respectively.

2.2.4 Brix/acid ratio

The brix/acid ratio of the treated fruits harvested at various stages of maturity varied significantly. The fruits harvested 10 days after growth

Table 11. Effect of growth regulators on acidity of the fruits

Treatments		Stages of harvest (days after shooting)			Overall mean
		70th day (%)	80th day (%)	90th day (%)	
T_1	Ethrel 100 ppm	0.267	0.263	0.310	0.280
T_2	Ethrel 200 ppm	0.256	0.262	0.352	0.289
T_3	Ethrel 400 ppm	0.238	0.246	0.319	0.267
T_4	2, 4-D 2 ppm	0.256	0.287	0.298	0.280
T_5	2, 4-D 4 ppm	0.239	0.309	0.308	0.285
T_6	2, 4-D 10 ppm	0.245	0.301	0.299	0.282
T_7	NAA 50 ppm	0.227	0.288	0.305	0.274
T_8	NAA 100 ppm	0.221	0.328	0.280	00276
T_9	NAA 200 ppm	0.216	0.355	0.375	0.315
T_{10}	Control	0.254	0.324	0.282	0.287
	Mean	0.242	0.296	0.313	

	F value	CD	
Treatment	13.60**	0.00876	0.01151
Stages of harvest	373.9**	0.00619	0.00814
Treatment x stages of harvest	24.88**	0.01641	0.02156

** = Significant at 1 per cent level

Table 12. Effect of growth regulators on brix/acid ratio of fruits

Treatments		Stages of harvest (days after shooting)			Overall mean
		70th day	80th day	90th day	
T_1	Ethrel 100 ppm	113.289	115.313	102.852	110.485
T_2	Ethrel 200 ppm	123.470	128.699	84.524	112.230
T_3	Ethrel 400 ppm	139.621	137.286	107.318	128.075
T_4	2, 4-D 2 ppm	119.152	99.426	98.178	105.585
T_5	2, 4-D 4 ppm	129.373	92.638	91.092	104.368
T_6	2, 4-D 10 ppm	127.590	101.747	101.100	110.146
T_7	NAA 50 ppm	132.759	100.374	99.908	111.013
T_8	NAA 100 ppm	151.323	86.873	99.722	112.639
T_9	NAA 200 ppm	151.082	89.052	90.70	110.278
T_{10}	Control	99.923	94.218	112.324	102.155
Mean		128.758	104.56	98.77	

	F value	CD
Treatment	10.30**	6.09
Stages	174.60**	3.34
Treatment within stages	16.19**	10.55

** = Significant at 1 per cent level

regulator application had on an average highest Brix/acid ratio (128.76) while it decreased to 104.56 at 80th day harvest and 98.77 for 90th day harvested fruits. The stages of maturity versus treatment interaction were also significant. Among the fruits harvested on 70th day T_9 (151.08) and T_8 (151.32) had significantly superior Brix/acid ratio than all other treatments. The treatments T_7 (139.76), T_3 (132.62), T_5 (129.32), T_6 (127.59), T_2 (123.47), T_4 (119.15) and T_1 (113.29) were also superior than the control 99.22. The fruits harvested 20 days after growth regulator application showed that T_3 had 137.29 Brix/acid ratio, and T_2 128.7, both being significantly higher than T_{10} (94.22). Among the fruits harvested at 90th day, all the fruits receiving growth regulator treatment showed a significant reduction in Brix/acid ratio as compared to the control (112.33).

The overall effect of treatments showed that the highest brix/acid ratio was produced by the treatment T_3 (Ethrel 400 ppm) with the ratio 128.075 as against 102.16 of the control.

3. COMPARATIVE STUDY OF DIFFERENT STORAGE METHODS

The fruits remain hard green for long under T_1 (Polythene cover + $KMnO_4$) and it took 17 days to

attain the yellow ripe stage with desirable eating qualities, as compared to 9 - 11 days under T_2 (sealed polythene cover), 5 - 7 days under T_3 (open storage) and 3 days under T_4 (smoke house ripening)(Table 13, Fig.5).

The ripened fruits maintained the eatable qualities for 5 days under treatment T_3 and T_4 while it was only 3 days and 2 days under T_1 and T_2 respectively (Table 13).

The post climacteric degradation of the fruits was quick under treatment T_1 and T_2 where it took only 2 days from previous stage for complete rotting of the fruits. Blackening of the skin without any rotting was noticed for fruits under T_3 and T_4 within 2 days after ripening. The total number of days taken from harvest to rotting was 21 days under T_1, 15 days under T_2, 13 days and 9 days under T_3 and T_4 respectively.

The changes in chemical constituents during ripening of the fruits kept in various storage conditions were studied and the results are presented in table 14 to 18.

3.1 Total Soluble Solids

The effects of treatments on TSS content

Table 13. Effect of storage treatments on ripening of mature fruits in banana cv. Nendran

Storage Treatments	Number of days taken to reach following stages of ripening				
	Green to greenish yellow	Greenish yellow to yellowish green	Yellow	Yellow with black spots	Rotting/ Darkening
Polythene cover + $KMnO_4$	11	13	17	19	21
Polythene cover	5	7 - 9	9 - 11	15	15
Open storage	3	4 - 5	5 - 7	9 - 11	13
Smoke house ripening & open storage	1 - 1.5	2	3	7	9

of the fruits were significant. At the eatable ripe stage, indicated by the yellow colour of fruits, the fruits stored in open (Treatment 3) contained highest amount of brix (31.6%) followed by Treatment 2 (31.2%), and Treatment 1 (29.60%). The lowest value for TSS was shown by Treatment 4 (smoke house ripening and storing in open) with 29.00%.

The post climacteric deterioration of fruits, as evidenced by the reduction in TSS content at yellow spot stage was significant at 0.5% level under treatments T_1 and T_2, TSS content being 21 and 24.8% respectively. The fruits under treatment T_3 showed a slight reduction in TSS content at this stage (30.4%) while the fruits under T_4 actually showed a meagre increase in TSS content to 31.2%. Thereafter at rotting stage, both T_3 and T_4 fruits also showed the rapid reduction in TSS content.

3.2 Carbohydrate

Differential changes in carbohydrate content of fruits were noticed during ripening of fruits under different methods of storage (Tables 15 & 16).

3.2.1 Starch

The effect of treatments on starch hydrolysis

Table 14. T.S.S. of banana fruits (cv. Nendran) at varying stages of ripening under different storage treatments

	Storage Treatments	Stages of ripening				
		Green to greenish yellow	Greenish yellow to yellowish green	Yellow	Yellow with black spots	Over ripe with retting/blackening
T_1	Polythene cover + $KMnO_4$	24.20	27.60	29.60	21.0	24.20
T_2	Polythene cover	23.80	26.20	31.20	24.80	17.60
T_3	Open storage	22.80	28.40	31.60	30.40	28.80
T_4	Smoke house ripening & open storage	24.80	27.40	29.00	31.20	21.00
	F value	0.924^{NS}	2.04^{NS}	7.24*	12.71**	16.12**
	CD	NS	NS	1.39*	4.06	3.56

* = Significant at 5 per cent level

** = Significant at 1 per cent level

NS = Non Significant

FIG.5_T.S.S CONTENT OF RIPENING BANANAS [CV NENDRAN] UNDER DIFFERENT STORAGE TREATMENTS.

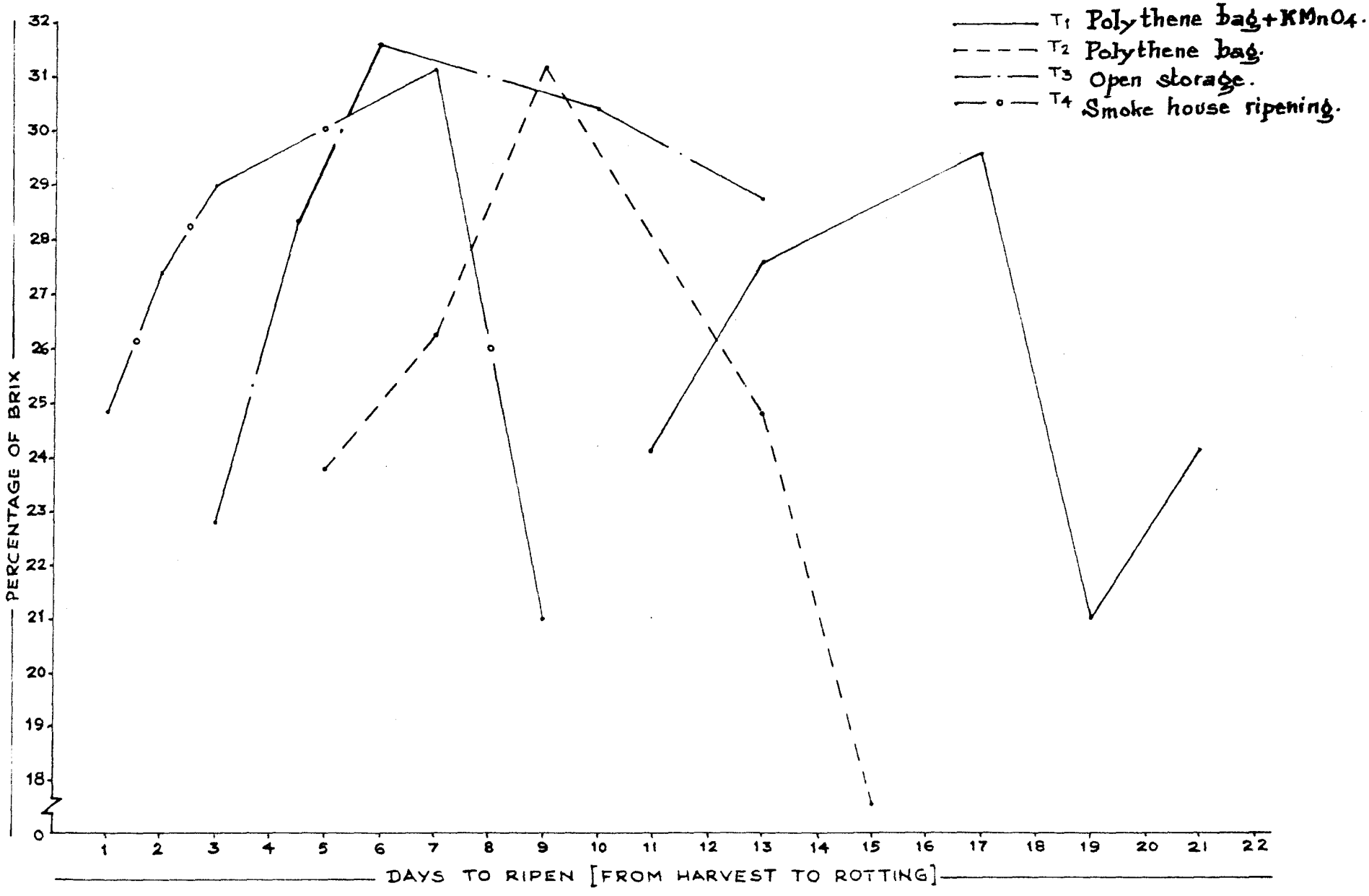


Table 15. Starch content of fruits at varying stages of ripening under different storage treatment

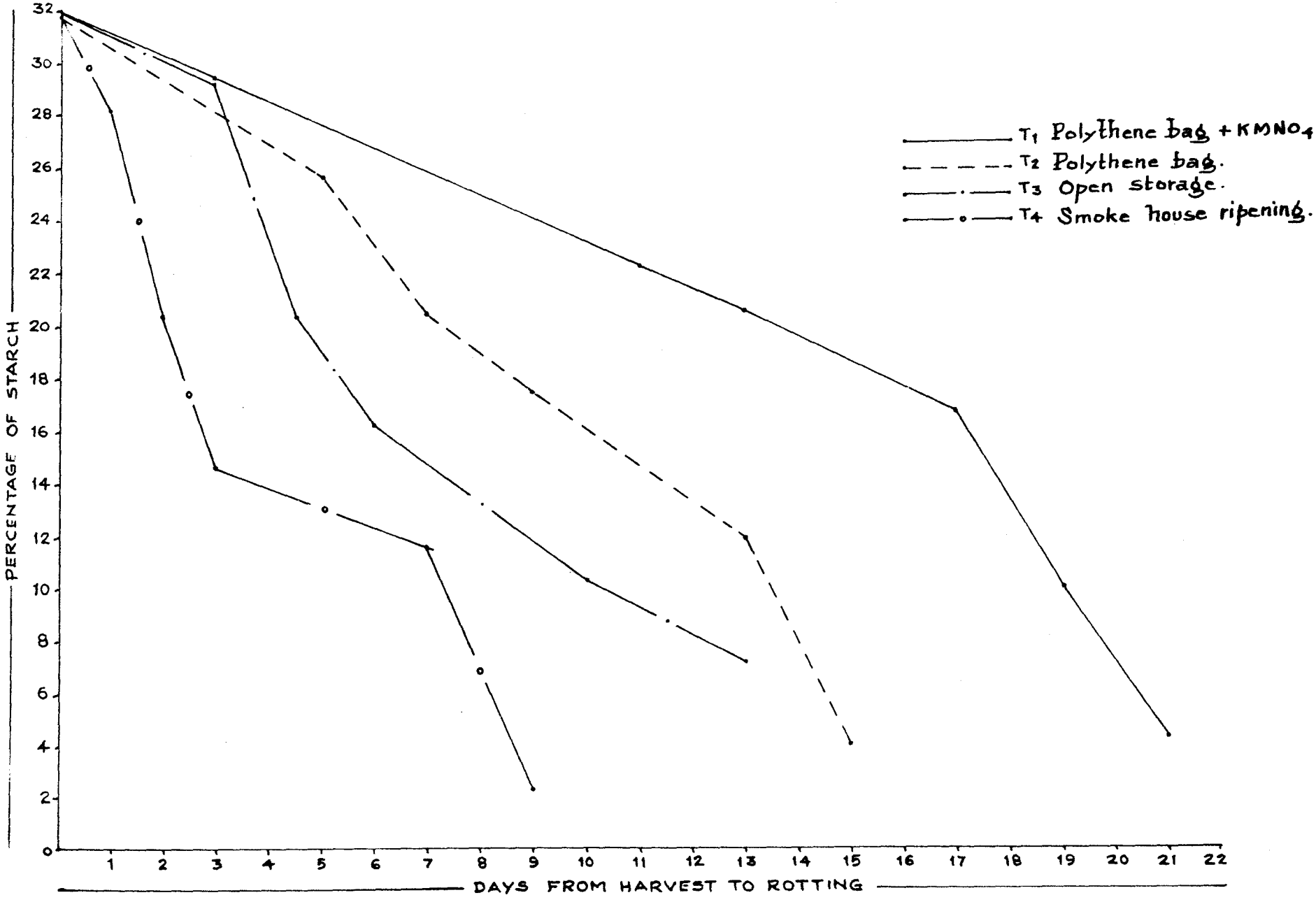
	Storage Treatments	Stages of ripening				
		Green to yellow	Greenish yellow to yellowish green	Yellow	Yellow with black spots	Over ripe with rotting/blacening
T_1	Polythene cover + $KMnO_4$	22.49	20.73	16.89	10.05	4.36
T_2	Polythene cover	25.95	20.53	16.12	12.00	4.10
T_3	Open storage	29.15	20.51	11.02	10.22	7.23
T_4	Smoke house ripening & open storage	28.16	20.57	14.76	11.90	2.38
	F value	28.23**	0.07	26.66**	0.61	57.94*
	CD		NS			

*= Significant at 5 per cent level

**= Significant at 1 per cent level

NS= Non Significant

FIG. 6 - STARCH CONTENT OF FRUITS AT VARYING STAGES OF RIPENING UNDER DIFFERENT STORAGE TREATMENTS.



was significant (Table 15). Hydrolysis of starch into simpler sugars was rapid on ripening of fruits under the treatments T_3 and T_4. The hydrolysis was delayed under T_1 and T_2 conditions, resulting in slow rate of ripening of the fruits.

3.2.2 Total sugars

The total sugar content of ripe fruits under different storage treatments differed significantly. A rapid increase in total sugar content was noticed in T_3 and T_4, but the increase was at a slow rate only under T_1 and T_2. At yellow ripe to yellow with black spot stage, when the fruits were having optimum eatable qualities, the total sugar content ranged from 18.44 to 18.84 per cent under T_3. The change was from 14.73 to 18.49 per cent in T_4, but under T_1 and T_2 a reduction from 11.45 to 9.95 and 13.26 to 12.02 was noticed. The total sugar content further increased to 19.1% under T_4 when the fruits had lost their appearance due to shrinking and blackening of skin, while T_1 showed a reduction to 7.77%, T_2 to 12.22% and T_3 to 15.53 per cent respectively.

3.2.3 Reducing sugars

The effect of treatments on the reducing

sugar content was significant. The reducing sugar content was maximum for fruits at yellow with black spot stage for all treatments except for T_1. The reducing sugar content was maximum for T_3 (18.76) followed by T_4 (15.77%) and T_2 (11.19%) at this stage, while it was only 9.73% for T_1 at this stage as compared to 11.32% at yellow ripe stage. On advancement of ripening beyond yellow with black spot stage the fruits under all treatments except T_4 showed a reduction in reducing sugar content whereas T_4 fruits showed an increase from 15.77% to 18.75%.

3.2.4 Non-reducing sugars

At eatable ripe stage the non-reducing sugar content of fruits under different storage conditions varied significantly. The non-reducing sugar content was highest for T_2 (3.53%), followed by T_3 (1.87%), T_4 (0.54%) and T_1 (0.37%) respectively.

3.3 Acidity

Changes in acid content of the fruits followed a similar trend under different storage conditions. Acidity increased (Table 17) as the ripening progressed and reached a peak at the eatable ripe stage.

Fig.7- VARIATION IN TOTAL SUGAR CONTENT OF RIPENING BANANA FRUITS UNDER DIFFERENT STORAGE TREATMENTS.

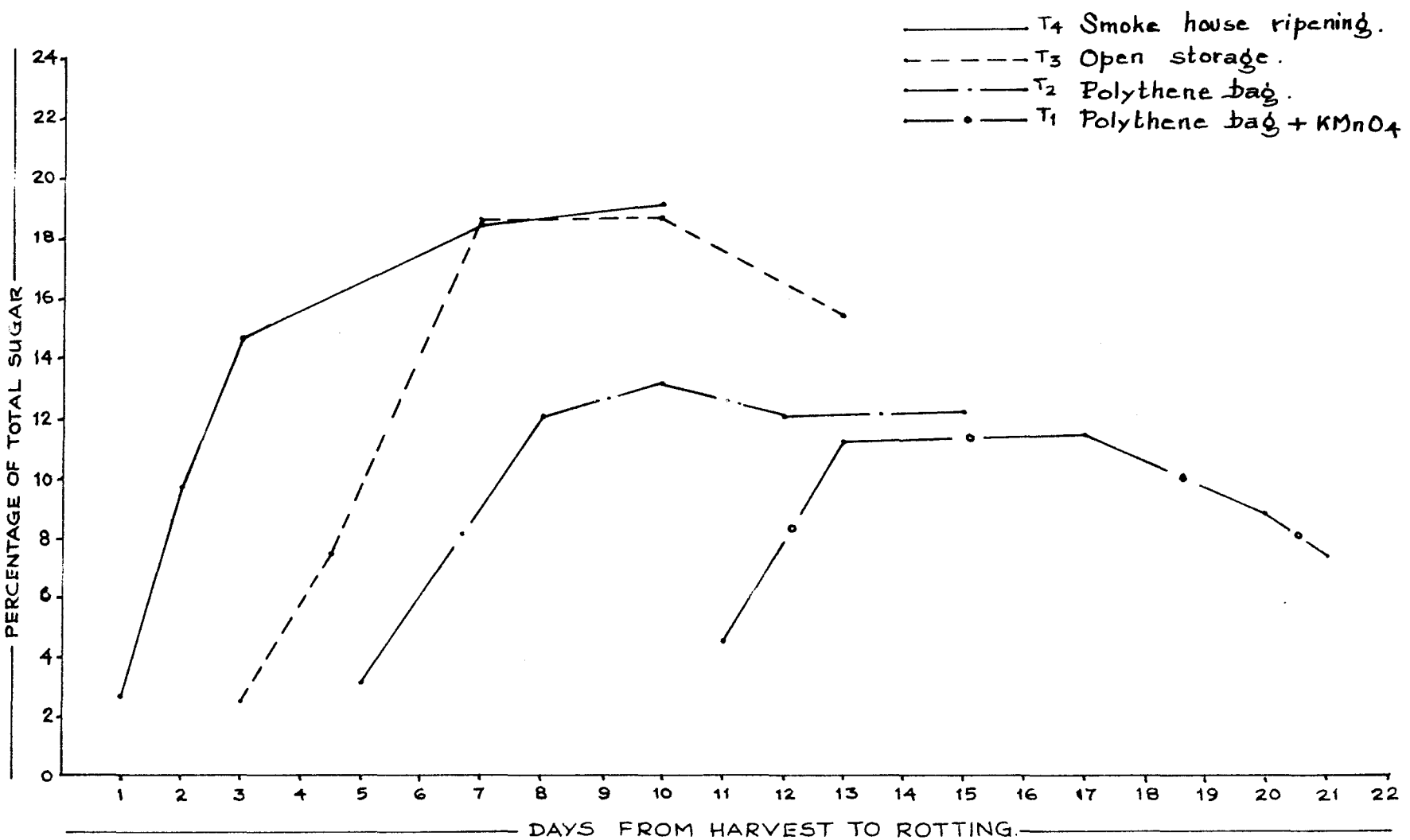


FIG. 8- VARIATION IN REDUCING SUGAR CONTENT OF RIPENING BANANAS [CV NENDRAN] UNDER DIFFERENT STORAGE TREATMENTS

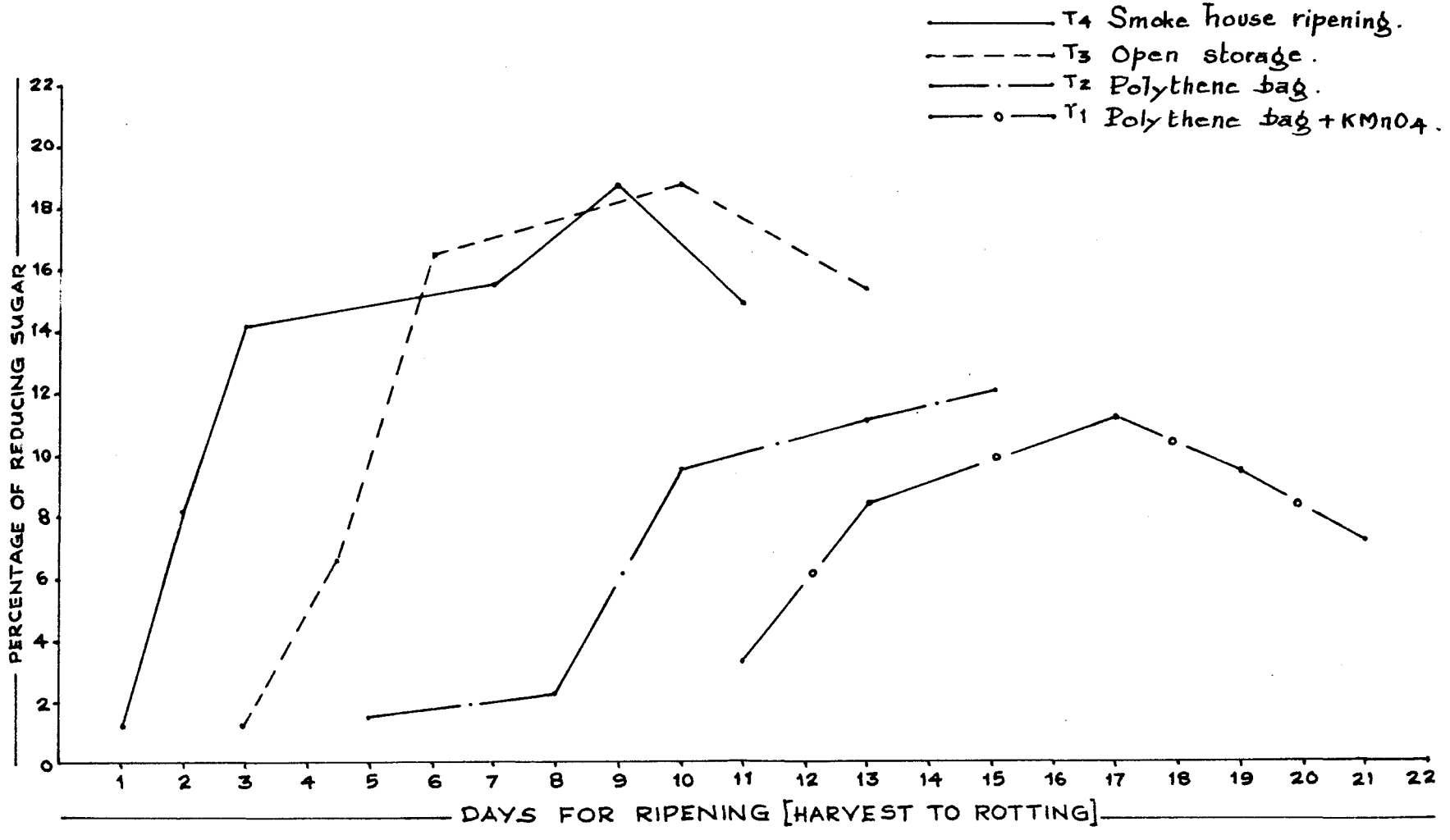


FIG. 9_ NON REDUCING SUGAR CONTENT OF RIPENING FRUITS OF BANANA [CV NENDRAN] UNDER DIFFERENT STORAGE TREATMENTS.

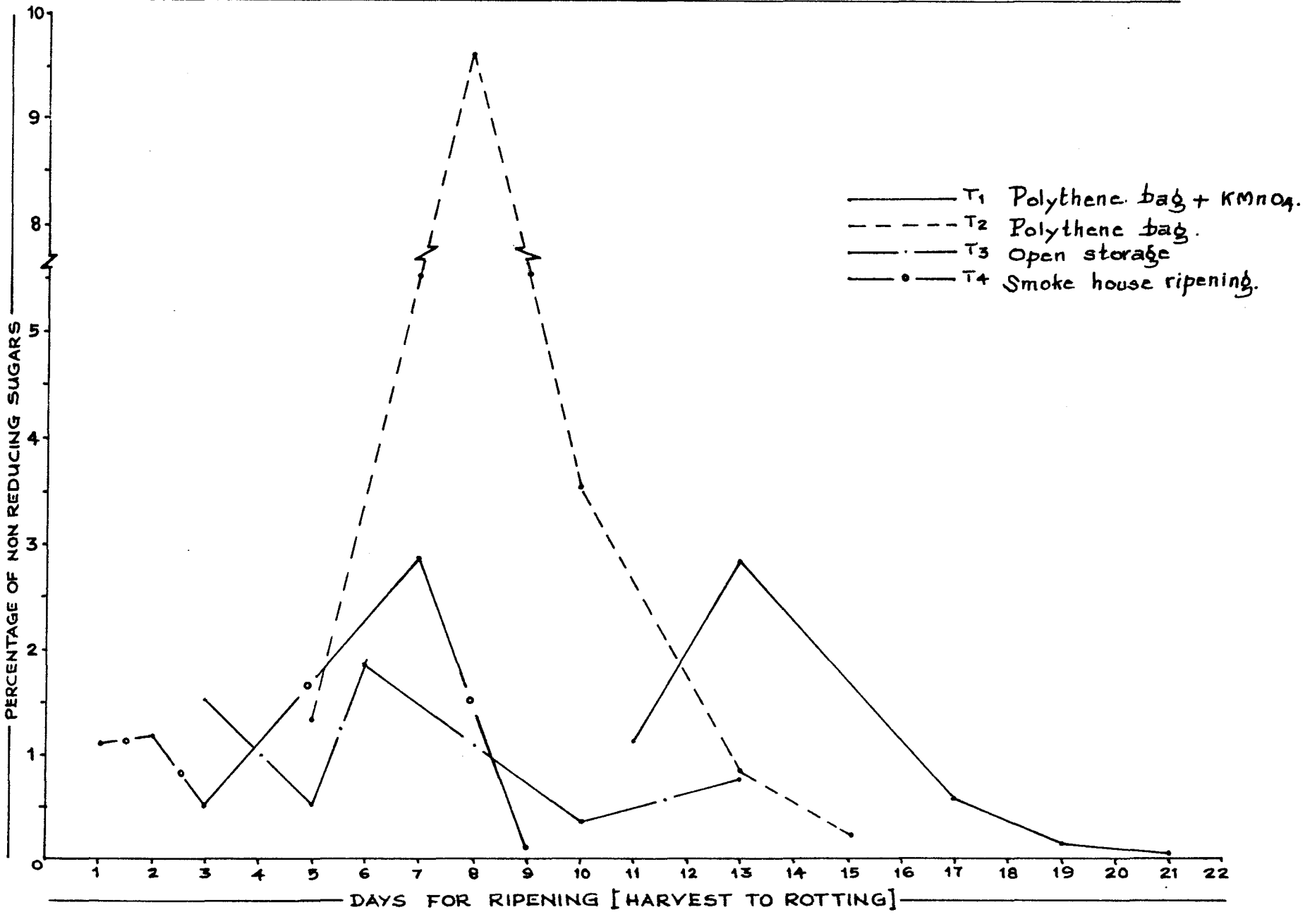


Table 17. Acid content in percentage of fruits at varying stages of ripening under different storage treatments

	Storage Treatments	Stages of ripening				
		Green to greenish yellow	Greenish yellow to yellowish green	Yellow	Yellow with black spots	Over ripe with rotting blackening
T_1	Polythene cover + $KMnO_4$	0.078	0.316	0.542	0.315	0
T_2	Polythene cover	0.094	0.309	0.538	0.366	0.310
T_3	Open storage	0.080	0.305	0.489	0.30	0.216
T_4	Smoke house ripening & open storage	0.086	0.327	0.424	0.361	0.268
	F value	2.75	12.7*	23.18**	1.42	41.54*
	CD	0.0124	0.0317	0.0318	0.832	0.0064

* = Significant at 5 per cent level
** = Significant at 1 per cent level

At the eatable ripe stage the acidity was maximum of 0.542% under T_1 followed by 0.538, 0.489 and 0.424% under T_2, T_3 and T_4 respectively. On further ripening the acidity decreased and at rotting stage acidity was zero under treatment T_1 as compared to 0.31%, 0.216% and 0.268% for T_2, T_3 and T_4 respectively.

3.4 Vitamin C content

Vitamin C content of the fruits showed a slight increase during early stages of ripening and decreased thereafter as ripening progressed. At eatable ripe stage ascorbic acid content was maximum of 15.5 mg/100 g under T_3 followed by 14.04 mg under T_2, 13.09 mg/100 g under T_1 and 7.74 mg under T_4. The oxidation of ascorbic acid was slow under polythene cover (T_2) and smoke house ripening (T_4) treatments, and was stable under over ripe stages (Table 18).

4. EFFECT OF FUNGICIDAL TREATMENTS ON CONTROLLING ANTHRACNOSE DISEASE OF BANANAS

The results of the fungicidal studies for controlling anthracnose disease of banana showed that all the treatments resulted in significant reduction in the disease incidence as compared to the control. The disease intensity as evidenced by the spread of black spots on the skin of

Table 18. Ascorbic acid content (mg/100 g) of fruits at different stages of ripening under different storage conditions

	Storage Treatments	Stages of ripening				
		Green to greenish yellow (mg/100g)	Greenish yellow to yellowish green (mg/100g)	Yellow (mg/100g)	Yellow with black spots (mg/100g)	Over ripe with rotting blackening (mg/100 g)
T_1	Polythene cover + $KMnO_4$	19.78	20.07	13.09	5.01	0.75
T_2	Polythene cover	18.67	20.71	14.04	7.25	8.13
T_3	Open storage	19.56	20.11	15.59	11.01	00
T_4	Smoke house ripening & open storage	18.67	13.69	7.74	7.25	8.87
	F value	1.24	24.27**	21.55**	19.82*	58.55**
	CD	NS	2.018	2.20	1.797	1.846

* = Significant at 5 per cent level

** = Significant at 1 per cent level

NS = Non Significant

FIG. 10_ ACID CONTENT OF RIPENING FRUITS OF BANANA [CV NENDRAN] UNDER_ DIFFERENT STORAGE TREATMENTS

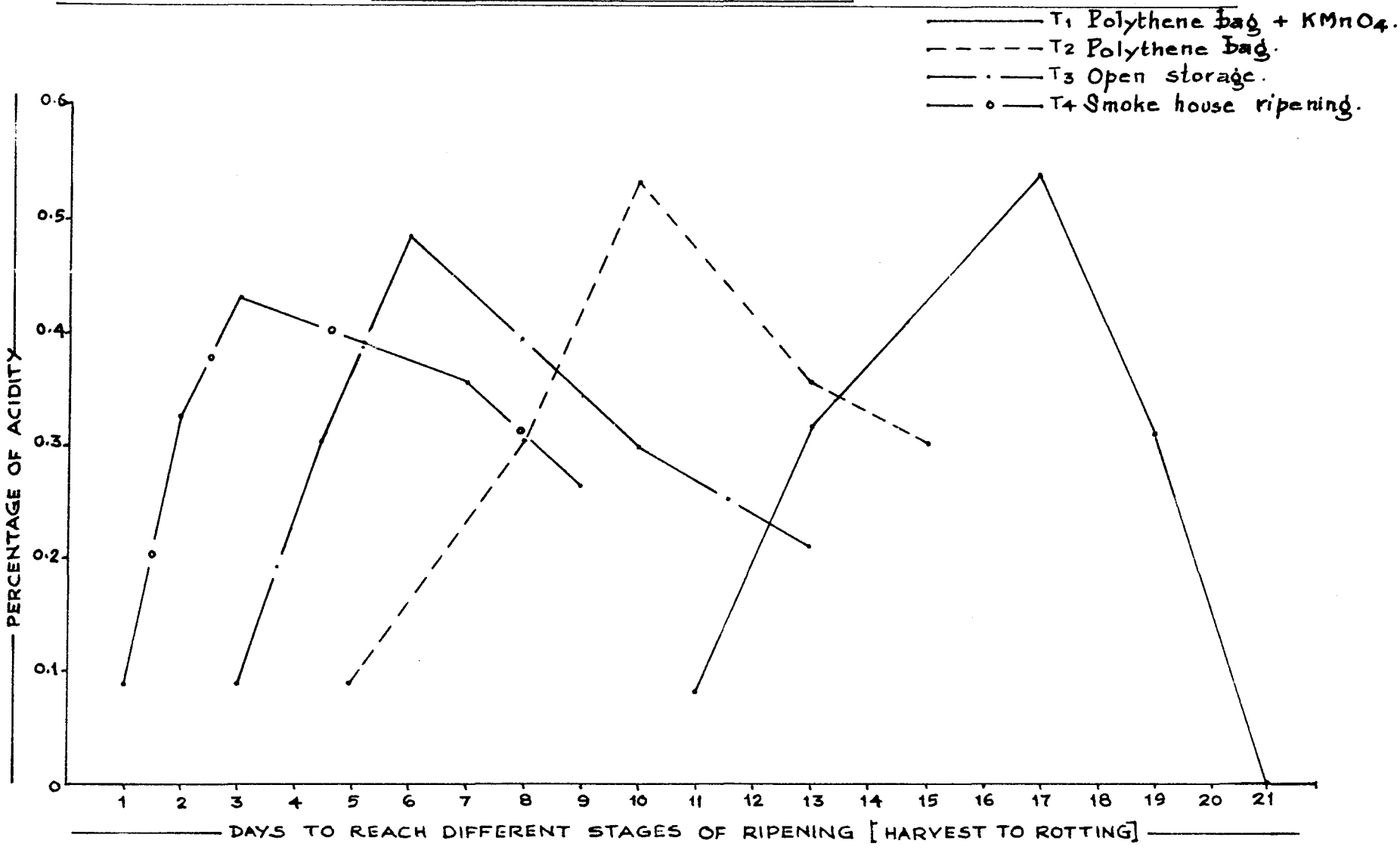
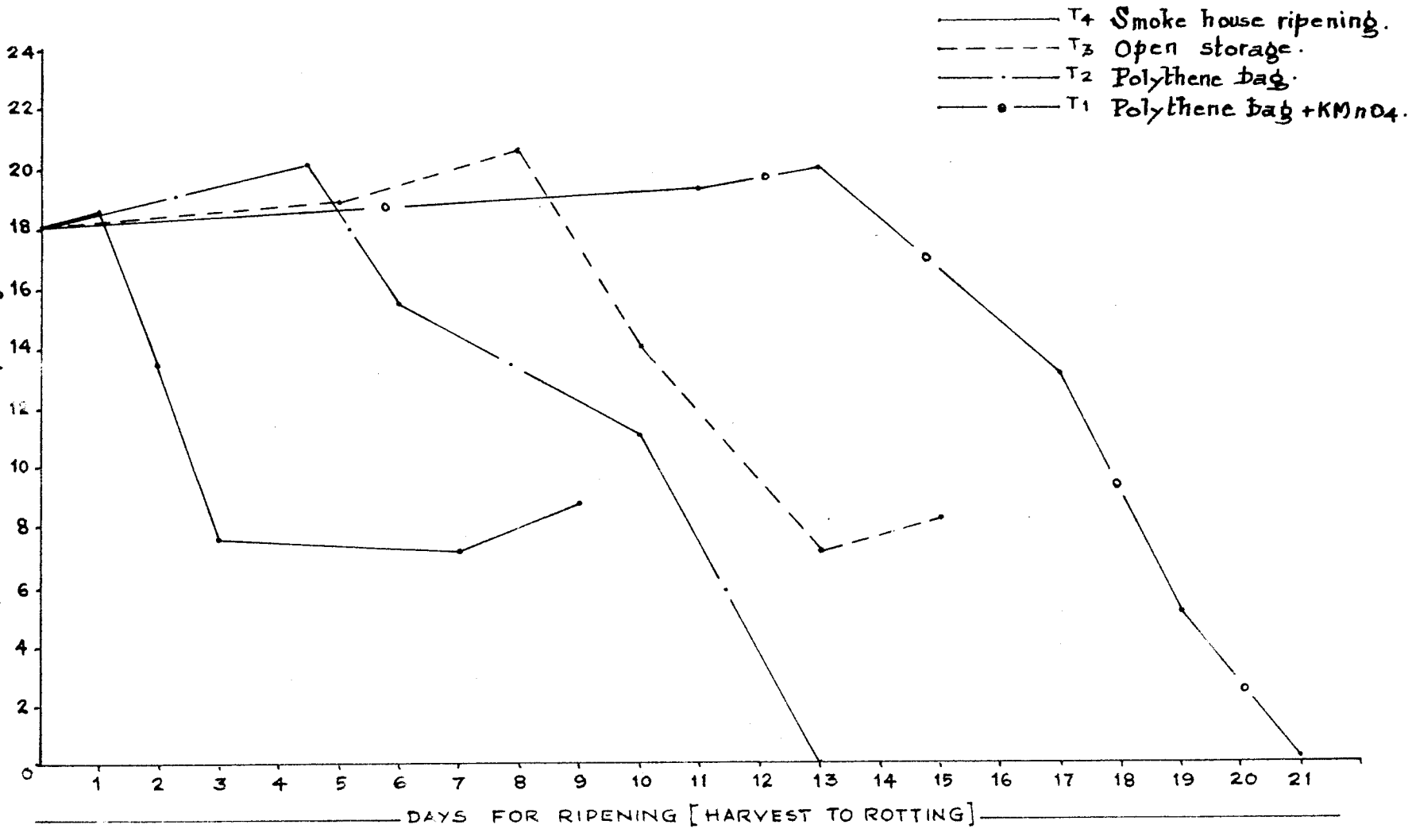


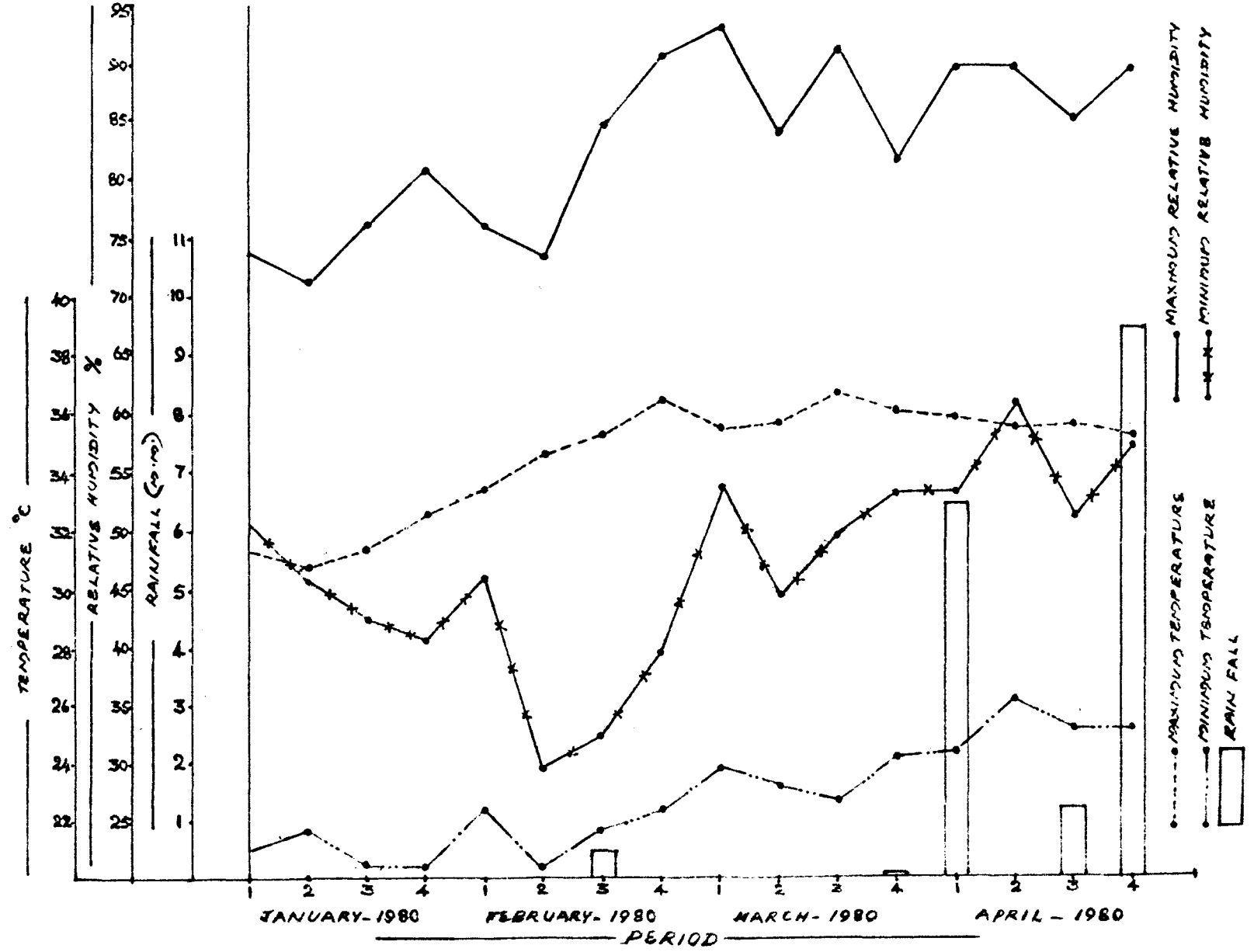
FIG. 11 – ASCORBIC ACID CONTENT OF RIPENING FRUITS OF BANANA [CV NENDRAN] UNDER DIFFERENT STORAGE TREATMENTS



fruits was significantly influenced by the storage treatments. The anthracnose disease was least in the polythene bag + $KMnO_4$ storage method followed by polythene bag alone. The fruits receiving smoke treatment had the maximum infection while the incidence was more than the former and lesser than the latter in case of open storage (Table 19). On 8th day after storage, the fruits under smoke treatment developed 50 - 60% area of the fruit with black spots while fruits under polythene bag + $KMnO_4$ showed only 10 - 20%. At eatable ripe stage the fruits under polythene cover + $KMnO_4$, infection extended upto 30 - 40% of the area as compared to 50 - 60% in the smoke treatment; 40 - 50% in open storage and 30 - 40% in polythene bags. But on advancement of ripening, the fruits receiving smoke treatment and open stored one showed rapid development of the spots and within another 3 to 4 days more than 90% of the area was infected. The results also showed that there is no significant difference in the disease infection due to various methods of fungicidal treatment thereby showing equal effectiveness with all the chemicals tried and different methods of application. This indicates that any one of the chemicals (anthracol at 0.05% or 0.1%; Bavistin 500 ppm or 1000 ppm; Thiride 0.1% or

0.2% in the only one method of application (spraying or dipping) can be effectively used to reduce the incidence of the infection without impairing the quality and appearance. Among the fungicides itself, Bavistin at 1000 ppm given as pre-harvest spray and post harvest dip together gave maximum control, followed by Thiride at 0.1 per cent.

FIG.12. WEEKLY AVERAGES OF WEATHER DATA FOR THE PERIOD FROM JANUARY 1980 TO APRIL 1980



Discussion

DISCUSSION

The results of the study on the growth and development of the fingers, the effect of growth regulators on the quality of fruits, comparative study of different storage treatments and the study of different fungicidal treatments for controlling anthracnose disease of banana cv. Nendran grown under rainfed conditions are discussed below.

1. STUDIES ON GROWTH AND DEVELOPMENT OF FRUIT

The studies on the development of banana fingers cv. Nendran from shooting to maturity have shown that the growth of fruits by way of increased length, girth, weight and volume of fruits continued till the fruit attained full maturity on the 90th day (vide Fig. 1 & Fig. 2). The maximum increase in these parameters was during the first 30 days which accounted for about 31.9 per cent increase in the case of length, 67.7 per cent increase in the case of girth, 65.32 per cent in the case of weight and 69.23 per cent in the case of volume. The second month (from 30 - 60 days) accounted for an increase of 31.18 per cent in the case of length, 24.34 per cent in the case of girth, 27.05

per cent in the case of weight and 25.46 per cent in the case of volume. The increase in growth was less than 10 per cent in the case of last one month.

The specific gravity of the fruit was 0.76 at shooting which gradually increased as the fruit matured and reached a value of one at 60th day or after 60 days, then remained more or less constant thereafter showing a similar rate of increase in weight and volume of the fingers. At full maturity the specific gravity reduced to 1.01.

Similar studies have been conducted by several workers (Baily 1912; Barnell and Barnell 1945; Gore 1914; Loesecke 1950; Lulla and Johar 1957; Lodh et al., 1971) and the results of the present study is also in confirmity with earlier works, that the growth of banana fingers continues from shooting to full maturity. The results of the present study revealed that in the case of rainfed "Nendran" planted during April last week, the bunch emergence took place in late November during which period there was no rain in this part of Kerala. The normal fruit growth takes place during early days making use of the available moisture in the soil. The low rate of increase in growth after

60 days may be due to the low moisture status in the soil or due to the natural growth phenomena. The higher growth rate during the first 60 days indicate that the water and nutrient supply should be optimum during this period failing which the growth of the fruit is likely to be affected.

Pulp to peel ratio was more or less constant (0.32 - 0.33) upto 30 days after shooting and increased thereafter to 1.24 by 60 days and 1.84 at full maturity. The present study was in agreement with that of Loesecke (1950); Barnell (1941 a); Barnell (1943). This is natural because of the fact that during the first month after shooting the growth of peel and pulp was more or less uniform, but thereafter, the carbohydrate accumulation of the pulp continued at a rapid rate resulting in a change in pulp to peel ratio from 0.32 to 1.84 at full maturity. The change in specific gravity of the fruit from 0.76 at shooting to 1.02 at eighty days also confirms the deposition of dry matter within fruit without affecting the volume much. The change in pulp to peel ratio can be attributed to differential rates of dry matter accumulation in the pulp and the peel. The dry matter content of the pulp rose from 8.24 per cent

10 days after shooting to 42.05 per cent at full maturity as compared to the change from 7.92 to 13.6 per cent only in the case of peel.

The starch accumulation in the pulp of the fruits continued until full maturity as it changed from 1.39 per cent at shooting to 32.01 per cent at full maturity. The total sugar content was 0.5 per cent 10th day after shooting and it increased to 1.29 per cent at full maturity. The results of the present work is in conformity with that of several others (Leonard and Barnell 1939; Belevel 1932; Barnell 1940; Barnell 1941; 1943; Wally et al., 1969; Lodh et al., 1971; Singh et al., 1976; and Singh et al., 1980).

The ascorbic acid content of developing fruits increased from 1.18 mg/100 g of fresh pulp at shooting to 18 mg/100 g at full maturity. The results of the present work is in agreement with the irregular pattern of ascorbic acid increase in the developing banana fruits reported by Lodh et al. (1971). The acidity of the fruits continued to increase as it rose from 0.04 per cent ten days after shooting to 0.096 per cent at full maturity. The similar result was earlier reported by Lodh et al. (1971).

The tannin content in the peel reduced from 40.48 per cent to 7.72 per cent at maturity. This is in agreement with the works of Barnell and Barnell (1945) and Chakravarthy (1957).

The results on growth and development studies also indicate that Nendran can be harvested 70 days after shooting and can be ripened without loss in quality; but, there is a reduction in weight at the rate of 5 g per fruit if harvested on 70th day and 2 g if harvested on 80th day. The stage of harvest at full maturity is 90 days. Early harvest is helpful for staggering the harvest in case of glut in the market so that the cultivators will have a better bargaining power.

2. EFFECT OF GROWTH REGULATORS ON QUALITY OF FRUITS

All the growth regulators tried contributed significantly towards growth of the fruits irrespective of stage of harvest or concentration of chemical tried. The increase in length of fruits was significant at 5 per cent level in all the treatments. The maximum average length of 25.78 cm was recorded in the case of 2, 4-D at 4 ppm; the effect of Ethrel at 200 ppm

(25.39 cm) was on par with 2, 4-D at 4 ppm. The average length of fruits in the case of control was only 21.9 cm. The effects of treatments were not significantly different in case of girth. All the treatments also resulted in an increased weight of fruits. The fruits harvested at full maturity had significantly higher mean weight (176.69 g) as compared to that of 80th day (167.67 g) and 70th day harvests (154.69 g). The effect of treatments was similar under different stages of harvest, the maximum mean weight of fruits of 191.8 g was brought about by the treatment of 2, 4-D at 10 ppm followed by 2, 4-D at 4 ppm with 191.19 g as against the control with 132.75 g. Similar results of increased fruit size and weight as a result of growth regulator application have been reported by several workers (Clark and Kerns, 1942; Evans, 1959; Das 1964; Tomi et al., 1970; Wee, 1971 and Huang, 1973).

The increase in length of fruits due to growth regulator application may be attributed to the effect of auxins in cell elongation (Sircar, 1971). The increase in weight is due to more accumulation of dry matter in the fruits as it serves as a sink with more auxin level. Being a vegetative parthonocarpic fruit,

the external application of auxins will help to increase the auxin level of the fruits, ultimately resulting in more flow of water and accumulation of dry matter. The result showed that the net yield can be increased at full maturity stage on an average by 44.48 per cent by the application of 2, 4-D at 10 ppm one month in advance of maturity. In effect the application has resulted in an increased weight of 1.77 kg per bunch of 35 fingers. The increased yield per hectare having a plant population of 2250 by the application of 2, 4-D will be 3.98 tonnes which accounts an increased income of around Rs.5,800/- at the additional expenditure of only Rs.400/- per hectare.

The various growth regulators tried have got significant influence on the pulp/peel ratio of the fruits. The pulp to peel ratio varied significantly between stages of harvest also. The mean pulp to peel ratio of ripened fruits was highest (3.42) at full maturity as against 3.25 and 3.09 in the case of harvests at ten and twenty days for full maturity. Thus, the increase in pulp to peel ratio as the fruit advances in maturity may be due to more accumulation of dry matter in the pulp than in the peel resulting in

more weight of pulp as compared to the peel. The effect of treatments was significantly higher in pulp/peel ratio in case of NAA application at 100 ppm (3.78); while control fruits had only 3.36 pulp/peel ratio. Except for different levels of NAA, all the other treatments resulted in a reduction of pulp to peel ratio as compared to the control. The changes in pulp/peel ratio was subjected to detailed studies by Barnell (1943), Simmonds (1966), Loessecke (1950) and Stratton & Loessecke (1931). Simmonds (1966) reported that the rise in pulp/peel ratio was closely related to change in sugar concentration in the tissues. He observed that the osmotic pressure of all parts of the unripe banana bunch was sensibly constant and that ripening was accompanied by the establishment of an osmotic gradient tending to cause the movement of water from skin to pulp. The reduction in the skin weight in the present study and consequent changes in the pulp/peel ratio may be due to the above reasons.

The growth regulator treatment could significantly influence the total soluble solids of the fruits. The ripened fruits of 70th day harvest (10 days after growth regulator application) showed that all the treatments significantly increased the T.S.S. content

of the fruits. The maximum T.S.S. content of 33.27 per cent was recorded by Ethrel 400 ppm followed by NAA 50 ppm (33.2%); NAA 100 ppm (32.75%); Ethrel 200 ppm (31.47%); 2, 4-D 10 ppm (31.07%) and 2, 4-D 4 ppm (30.8%) as compared to the control of 25.6 per cent. The T.S.S. content of treated fruits at different stages of harvest did not show any significant variation; but the control showed an increase from 25.6% at 70th day harvest to 29.31 per cent at 90th day harvest. Thus the quality of the fruits harvested on 70th day can be improved by pre-harvest application of growth regulators. Similar results have also been reported by Aziz and Tomsky (1975); Sadasivam and Muthuswamy (1972; 1973) and Freiberg (1955). The total and reducing sugar content of the fruits increased significantly due to growth regulator application. The effect was more marked in fruits of 70th day harvest which showed an average of 19.08 per cent total sugars and 17.94 per cent reducing sugars as compared to 15.96 per cent and 16.24 per cent for 80th day harvest and 15.03 per cent and 13.85 per cent for 90th day harvests respectively. The increase in total and reducing sugar contents during 70th day harvest (10 days after growth regulator application) as compared to 80th day harvest (20 days after

growth regulator application) and at full maturity (30 days after growth regulator application) may be due to the biochemical changes that were brought about by the plant growth regulators. The conversion of starch to sugars was rapid during the initial days of application and the same was reduced gradually (Vide Table 8 & 9).

The acidity of the fruits was less for 70th day harvest (0.242%) as compared to 80th day (0.29%) and 90th day (0.313%) harvested fruits. Among the treatments NAA at 200 ppm increased the acidity of fruits to 0.315 per cent as compared to 0.287% of the control. In other cases except for Ethrel 200 ppm, the acidity was lower than the control. But it was not statistically significant. Such reduction in acidity due to growth regulator treatments was also noticed by Veera and Das (1971) and Shant (1975).

The brix/acid ratio of the treated fruits harvested at various stages of maturity varied significantly. The fruits harvested 10 days after growth regulator application had on an average highest brix/acid ratio (128.76) while it reduced to 104.76 for 80th day and 98.77 for 90th day harvests. This reduction was

not due to increased brix content of 70th day harvested fruits, but it was due to high acid content shown by the 90th day harvested fruits. All the fruits harvested at full maturity showed a reduction in brix/acid ratio as compared to the control. This can be due to an increased acid content of fruits resulted by growth regulator treatment in fruits of full maturity as compared to the control fruits. The overall effect of treatments showed that the highest brix/acid ratio was resulted by fruits receiving Ethrel 400 ppm (128.07) as against 102.16 in control. The result is in agreement with the works of Freiberg (1955); Blake and Stevenson (1956); Dedolph and Goto (1960); Sadasivam and Muthuswamy (1972) and Asis and Tanaky (1975).

3. COMPARATIVE STUDY OF DIFFERENT STORAGE TREATMENTS

In the study conducted to compare different storage methods of banana, it was found that the fruits stored in polythene bag with potassium permanganate took 17 days to reach full ripening stage while only 9 - 11 and 5 - 7 days were required in the case of polythene bags and open storage respectively. The period for ripening after harvest was only 3 days in the case of the common smoke house method.

The use of sealed polythene covers for extending storage life of bananas was recommended by Mahmoudi and Eisawi (1968); Scott et al. (1971), Thompson et al. (1972), Scott (1975) and Nakamura and Ito (1979). Agnihotri and Ram (1971) compared the skin coating with wax and smoking treatment for the shelf life of banana cultivars and found that the smoking was less efficient. Scott et al. (1968); Scott (1975) recommended transport of banana in ambient temperatures using polythene bags. He reported that after a period of 8 - 18 days the fruits remained in a hard green stage whereas the non packed fruits had ripened which was in agreement with the results of present study. To obtain a further delay in ripening of banana fruits Chiang (1970), Scott et al. (1970), Patil and Magar (1975) recommended inclusion of ethylene absorbent in the polythene bags to delay ripening of bananas during storage. Chiang (1970) reported that brominated activated carbon and $KMnO_4$ on a carrier of either vermiculite or activated alumina doubled the storage life of bananas in sealed polythene bags. The long shelf life in case of polythene bag containing $KMnO_4$ was due to the reduction in ethylene concentration as suggested by Scott et al. (1971).

The ripened fruits maintained eatable qualities

for 5 days under smoke house treatment and open storage while it was only 3 - 5 days in case of polythene bags with or without $KMnO_4$. However, when once the fruits were ripened fully, rotting takes place rapidly in 2 days in case of fruits stored in polythene bags with or without $KMnO_4$. The ripening was not uniform in the open storage and the fruits blackened in 4 days reducing the good appearance. The smoked fruits also developed blackening of the skin in 3 days. The quick rotting in polythene bags may be due to high CO_2 concentration as suggested by Patel & Magar (1975). The smoke house ripening and storing in open can be adopted for obtaining edible fruits for immediate use within 3 days of harvest. The unsaturated hydrocarbons present in the smoke induce the fruit to ripen quickly by accelerating bio-chemical changes resulting in ripening.

There was significant difference in quality between treatments. The brix content was highest under open storage (31.6%) followed by polythene bag storage (31.2%), polythene bag + $KMnO_4$ (29.6%) and smoking (23 per cent). The T.S.S. content reduced rapidly in case of polythene bag with or without $KMnO_4$ and sudden rotting started, while in the case of open

storage and smoking the TSS showed a narrow increase and the fruits blackened and shrinkled. This increase in T.S.S. content of post-climacteric fruits can be attributed to the loss of water from the fruits resulting change in the concentration of T.S.S. content. Agnihotri and Ram (1971) also found that after 8 days of storage period the loss in weight was maximum (31.25%) in samples receiving smoke treatment followed by open storage (23.9%) and that this loss in weight was due to loss of moisture through transpiration. The high relative humidity maintained within polythene bags, along with high concentration of CO_2 resulted in rapid deterioration of the fruits by way of softening of tissues, and hydrolysis of cellular materials resulting in more production of water which may be the reason for rapid reduction in T.S.S. content of post climacteric fruits in case of polythene bag storage treatments.

Differential changes in carbohydrate content of fruits were noticed during ripening of fruits under different methods of storage. The starch hydrolysis into sugars was much rapid on ripening of fruits under open and smoking treatments resulting in a sudden increase in the total and reducing sugar content of fruits. The

delayed pre climacteric phase of bananas stored under polythene bags may be due to the slow hydralysis of starch. The accelerated rate of ripening induced by unsaturated hydrocarbons in the smoke resulting in increased activity of enzymes such as carboxylase and aldalase may be the reason for rapid hydralysis of starch into simple sugars. In the case of open storage the change was comparable to that of a normal fruit undergoing ripening process. Tager and Biale (1957) have reported the appearance of enzyme carboxylase and aldolase in the pulp of climacteric banana fruit; both the enzymes being very active for several days after the climacteric peak has been reached.

At optimum ripe stage the non-reducing sugar content of fruits under different storage conditions varied significantly, the non-reducing sugar being highest for fruits in polythene covers (3.53%) followed by open (1.87%), smoking (0.54%) and polythene bag + $KMnO_4$ (0.37%) respectively. At yellowish green stage the fruits under polythene cover were showing high non-reducing sugar content of 9.81 per cent as compared to 2.25% of reducing sugar. But at yellow ripe stage, the reducing sugar content rose to 9.75 per cent and

the non-reducing sugar reduced to 3.53 per cent indicating rapid change of non-reducing sugar into reducing sugars. This may be due to the fact that during the hydrolysis of starch, non-reducing sugars formed are not converted into reducing sugars due to lack of enzyme activity as the fruits are exposed to higher concentrations of ethylene and carbondioxide under polythene bags. Barker and Salomonas (1962) found an increase of four to five fold in CO_2 and twenty times in the fructose diphosphate content during ripening. Theyalso reported that the increase in the respiration rate during the climacteric was due to an increase in the concentration of fructose diphosphate and that ethylene could induce similar changes. Carthy and Palmer (1962) have reported that approximately 20 volatile compounds in addition to CO_2 and ethylene were produced by ripening banana fruits. Scott (1975) reported that the ethylene and other volatile compounds produced by ripening bananas will get accumulated in polythene bags resulting 'green' ripening of bananas. The higher concentration of ethylene due to accumulation within polythene bags induces fructose diphosphate accumulation resulting high non-reducing sugars during pre-climacteric, which would get changed to reducing sugars due to specific enzyme action.

The acidity of fruits increased at ripening and it was at the peak during eatable ripe stage, thereafter showing a reduction in acid content. Jane (1936); Barnell (1941); Wyman and Palmer (1963); Shimokawa et al. (1972); Srivastava et al. (1972) also have reported similar changes in acid content of ripening bananas.

An increase in Vitamin 'C' content during early stages of ripening and a decrease thereafter was reported by Harris and Poland (1939) as quoted by Von Loesecke (1950). The results of the present study also showed that there was a slight increase in ascorbic acid content of fruits during early stages of ripening under all stages of treatments and reduced thereafter. The retention in ascorbic acid was more in smoke treatment as compared to other treatments. This is in agreement with the findings of Agnihotri and Ram (1971).

4. EFFECT OF DIFFERENT FUNGICIDES ON CONTROLLING ANTHRACNOSE DISEASE OF BANANA

The fungicidal studies showed that all the fungicides viz. Anthracol at 0.05% and 0.1%, Bavistin at 500 ppm and 1000 ppm, Thiride at 0.1% and 0.2% reduced incidence of anthracnose on the ripened fruits.

There was no significant difference with respect to the effectiveness of these fungicides at the levels tried and by different methods of application viz. pre-harvest spray, post harvest dip and pre-harvest spray & post harvest dip together. However, Bavistin at 1000 ppm applied as pre-harvest spray & post harvest dip together resulted maximum reduction in anthracnose disease, followed by Thiride at 0.1 per cent applied in the same way. The results of the present study is an agreement with the works of Frossard and Lavillee (1973) and Griffee and Pinegar (1975), who reported that Bavistin at 200 - 300 ppm is effective as post harvest dips of one minute for controlling anthracnose disease of banana. As there was no significant difference with respect to effectiveness of fungicides by different method of application, it can be suggested that any one of the chemicals in only one method of application (spraying or dipping) can be effectively used for reducing the anthracnose disease of banana.

Summary

SUMMARY

The present investigations were carried out in the Department of Pomology, College of Horticulture during the period 1979 April to 1980 April with the following objectives.

To study (1) the growth and development pattern of banana fruits cv. Nendran and thereby to fix up optimum maturity indices for harvest, (2) the effect of pre-harvest application growth regulators on the post harvest quality of fruits, (3) to compare the efficiency of different methods of storage, and (4) to study the effect of different fungicidal treatments on controlling anthracnose disease of banana.

The following conclusions were made based on the present investigations.

1. The growth of banana fingers by way of increase in size, length, girth, weight and volume is a continuous process from shooting to full maturity and that in rainfed Nendran banana more than 90 per cent increase of these parameters takes place within 60 days of shooting.

2. The dry matter and starch accumulation in the pulp and peel takes place at a rapid rate during the first two months after shooting.

3. The specific gravity which was less than one during the first 2 months of fruit growth assumes value greater than one after 60 days of shooting, indicating differential rates of dry matter accumulation in the pulp and peel.

4. The tannin content of the peel reduces as the fruit attains maturity.

5. The rainfed Nendran banana can be harvested any day after 70 days of its growth without much loss in quality depending upon requirements. The specific gravity more than one, pulp to peel ratio of more than 1.50 along with number of days from shooting can be used for assessing the stage of harvest. Full maturity will be attained by 90 days when the specific gravity will be more than one and pulp/peel ratio 1.84.

6. The pre-harvest growth regulator application on the 60th day after shooting on bunches increases the length and weight of the fingers. 2, 4-D at 10 ppm can increase the yield upto 44.48 per cent.

7. The quality (TSS, total and reducing sugars, brix - acid ratio) of all the fruits receiving growth regulator treatment were improved. Ethrel at 400 ppm resulted maximum TSS content of the fruits followed by NAA at 50 ppm, 100 ppm and 2, 4-D at 10 ppm.

8. Harvest of banana (cv. Nendran) can be preponed by 20 days with better quality if plant growth regulators are sprayed.

9. The storage studies revealed that the storage life of fruits can be prolonged by 10 days storing under polythene + $KMnO_4$ at ordinary room temperature and in polythene bags 6 days longer shelf life can be attained.

10. The ripe fruits for immediate use can be obtained within 3 days of harvest by smoke treatment for 24 hours and then storing in open.

11. The quality of the fruits were better under smoke treatment and open stored fruits as compared to fruits in polythene bags with or without $KMnO_4$, but the appearance of the ripened fruits was best under polythene bag treatments.

12. The fungicidal studies reveal that the

anthracol, at 0.05% and 0.1%, Bavistin 500 ppm and 1000 ppm, Thiride at 0.1% and 0.2% are equally effective in reducing anthracnose incidence of banana fruits stored in polythene bags, and in open, the maximum reduction being resulted by Bavistin at 1000 ppm.

13. Pre-harvest spray and post-harvest dipping were equally effective to control the black spot (Anthracnose) disease caused by Gleosporium musarum.

14. Among the storage treatments, polythene bag + $KMnO_4$ reduced the incidence of anthracnose and the infection was maximum in case of smoke treatment.

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* Originals not seen

APPENDIX - I

Weather data for the period from May 1979 to April 1980

Month	Temperature °C		Relative humidity (per cent)		Total rain-fall (mm)	Number of rainy days
	Maxi-mum	Mini-mum	Maximum	Minimum		
May 1979	35.7	21.8	97	52	155.1	10
June	35.1	22.0	97	53	722.7	22
July	31.1	21.0	98	68	729.8	28
August	31.4	21.6	97	65	462.6	19
September	32.8	22.6	98	67	208.7	18
October	33.4	22.0	95	45	127.3	16
November	32.9	22.2	96	61	317.4	18
December	32.2	19.4	95	45	Nil	Nil
January 1980	33.5	20.5	80	42	Nil	Nil
February	36.0	22.0	90	30	0.5	1
March	35.0	24.0	95	45	0.1	1
April	35.0	25.0	90	53	18.0	6

APPENDIX - II

Analysis of variance for the effect of pre-harvest sprays of growth regulators on quality of the fruits

Source	df	Mean sum of squares				
		Length	Girth	Weight	Pulp/Peel ratio	T.S.S
Total	449					
Stages of harvest	2	198.87**	8.97^{NS}	18347.53**	4.06*	12.91^{NS}
Treatments	9	53.86**	12.32^{NS}	17759.88**	2.90**	116.69**
Stages x Treatments	18	5.193*	23.33^{NS}	927.88^{NS}	0.57*	48.77*
Between Bunches	60	6.14*	26.18*	1527.87	0.26^{NS}	12.38*
Between fingers within bunch	360	8.59	24.31	123.47	0.05	4.06

** = Significant at 1 per cent level
* = Significant at 5 per cent level
NS = Non Significant

APPENDIX - III

Analysis of variance for the effect of pre-harvest sprays of growth regulators on quality of the fruits

Source	df	Mean sum of squares				
		Total sugar	Reducing sugar	Non-reducing sugar	Acidity	Brix/acid
Total	149					
Stages of harvest	2	615.46**	622.20**	11.73**	0.206**	37953.65**
Treatment	9	37.20**	47.90**	3.33^{NS}	0.008**	2239.50**
Stages x Treatment	18	11.74**	29.02**	7.48*	0.014**	3518.71**
Between Bunch	60	2.89	4.26*	1.99**	0.0006*	217.37**
Between fingers within bunch	360	0.56	0.72	0.832	0.00009	28.96

* = Significant at 5 per cent level

** = Significant at 1 per cent level

NS = Non Significant

APPENDIX - IV

Analysis of variance for comparative study of different storage treatments (Green to greenish yellow stage)

Source	df	Mean sum of squares						
		TSS	Starch	Total sugars	Reducing sugars	Non-reducing sugars	Acity	Vitamin C
Total	19							
Treatment	3	3.53^{NS}	22.27*	3.08*	4.6*	0.21^{NS}	0.00023^{NS}	1.15^{NS}
Error	16	3.83	0.79	0.0325	0.107	0.1125	0.000086	0.92

* = Significant at 5 per cent level

NS = Non Significant

APPENDIX - V

Analysis of variance for comparative study of different storage methods (Greenish yellow to yellowish green stage)

Source	df	Mean sum of squares						
		TSS	Starch	Total sugars	Reducing sugars	Non-reducing sugars	Acidity	Vit. C
Total	19							
Treatment	3	4.13^{NS}	0.0519	21.77*	41.21*	86.36**	0.007*	55.02*
Error	16	2.02	0.7387	1.06	1.72	0.49	0.00056	2.27

* = Significant at 5 per cent level
** = Significant at 1 per cent level
NS = Non Significant

APPENDIX - VI

Analysis of variance for comparative study of different storage methods (yellow ripe stage)

Source	df	Mean sum of squares						
		TSS	Starch	Total sugars	Reducing sugars	Non-reducing sugars	Acidity	Vit.C
Total	19							
Treatment	3	7.78*	33.93*	43.94*	45.85*	10.73*	0.015*	58.16*
Error	16	1.08	1.27	1.46	1.23	1.63	0.0006	2.69

* = Significant at 5 per cent level

APPENDIX - VII

Analysis of variance for comparative study of different storage methods (Yellow with black spot stage)

Source	df	Mean sum of squares						
		T.S.S	Starch	Total sugar	Reducing sugars	Non-reducing sugars	Acidity	Vit.C
Total	19							
Treatment	3	116.58*	5.52^{NS}	102.82*	86.32*	8.43*	0.0054^{NS}	35.61*
Error	16	9.175	8.99	4.68	5.57	1.13	0.004	1.8

* = Significant at 5 per cent level

NS = Non Significant

APPENDIX - VIII

Analysis of variance for comparative study of different storage methods (over ripe with rotting/blackening stage)

Sources	df	Mean sum of squares						
		TSS	Starch	Total sugars	Reducing sugars	Non-reducing sugars	Acidity	Vit.C.
Total	19							
Treatment	3	113.67*	20.18*	116.51*	122.49*	0.733*	0.951*	111.04*
Error	16	7.05	0.348	1.12	0.812	0.121	0.002	1.89

* = Significant at 5 per cent level

APPENDIX - IX

Analysis of variance of comparative study of different fungicidal treatments in the controlling of anthracnose disease of banana

Source	df	5th day in the storage	8th day in the storage	10th day in the storage	12th day in the storage	14th day in the storage	16th day in the storage
Total	379						
Treatments	75	0.24	4.78*	6.52*	10.13*	13.02*	13.30*
Storage	3	1.61	39.81*	40.65*	79.13*	91.26*	104.37*
Fungicides	5	0.08	0.94	3.07	5.34	11.63	10.58
Storage x Treatment	15	0.03	1.74	2.19	3.90	3.37	1.91
Method of Application	2	0.03	1.56	1.02	1.85	4.84	5.50
Method x Storage	6	0.04	0.79	0.95	1.68	2.13	2.80
Fungicide x Method	10	0.023	1.15	1.09	1.04	3.56	4.44
Fungicide x Storage x Method	30	0.022	0.67	0.58	4.07	1.75	2.57
Control vs treatments	1	10.54*	121.73*	218.37*	340.67*	455.44*	424.76*
Among control	3	0.42	14.84	21.29	13.43	9.44	9.67
Error	304	0.368	4.00	5.46	9.16	12.93	15.00

* = Significant at 5 per cent level

EFFECT OF PRE AND POST-HARVEST TREATMENTS ON STORAGE AND QUALITY OF BANANA cv. NENDRAN

BY

ARAVINDAKSHAN, K.

ABSTRACT OF A THESIS

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Department of Horticulture (Pomology & Floriculture and Landscaping)

COLLEGE OF HORTICULTURE

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ABSTRACT

The present investigations were carried out in the College of Horticulture, during the year 1978-1980. The objectives were to study (i) the growth and development of banana fingers cv. Nendran and to fix optimum time for harvest (ii) the effect of pre-harvest sprays of growth regulators on post harvest quality of the fruits (iii) the effect of different storage methods on prolonging the shelf life and (iv) to assess the efficacy of different fungicidal treatments on controlling anthracnose disease of ripened fruits.

Fruit growth in rainfed 'Nendran' was found to be a continuous process till it reaches maximum maturity at 90 days after shooting. The length, girth, volume and weight of fingers continued to increase rapidly during early stages of growth, accounting for 90 per cent of growth by 60 days after shooting.

The accumulation of dry matter and the starch took place at increasing rates during the first two month of fruit growth resulting an increase in specific gravity from 0.36 at shooting to more than one after 70 days of shooting and pulp to peel ratio from 0.32 to

1.50 on 70th day. The study showed that rainfed 'Nendran' can be harvested from 70 days after shooting without impairing the quality but with light reduction in quantity.

The growth regulators if applied as pre-harvest sprays on 60th day after shooting increases size, weight and quality of the fruits; the maximum increase in size and weight was resulted by the application of 2, 4-D at 10 ppm. The quality was improved by way of increased TSS, total and reducing sugars by treatments of Ethrel 400 ppm, NAA 50 ppm, 100 ppm and 2, 4-D at 4 ppm and 10 ppm.

Improvement in quality followed by growth regulator application was more evident in case of 70th day harvest than the harvest at full maturity.

The comparative study of different storage methods have revealed that, the polythene bag with potassium permanganate increases the storage life by 10 days, polythene bag alone by 6 days as compared to smoke treatment and open storage. Eventhough the fruits in polythene bag with and without $KMnO_4$ showed a reduction on TSS, total and reducing sugar content, the appearance of the fruits were much better than that of smoked fruits

and open stored fruits and the eating quality were also good.

The study on the incidence of anthracnose disease in the storage showed that all the fungicides used at both concentration viz. anthracol at 0.05% & 0.1%; Bavistin 500 ppm and 1000 ppm; Thiride 0.1% and 0.2%; were equally effective in reducing the black spot development on ripened fruits. Though few spots were present in spite of the treatments, the quality and colour were not affected. Among the storage conditions, Polythene bag + $KMnO_4$ showed least incidence of the spots while it was maximum in case of smoke treatment.