"EFFECT OF MATURITY AND STORAGE TEMPERATURE ON SHELF LIFE AND QUALITY OF BANANA (*Musa paradisiaca* L.) CV. GRAND NAIN"

A

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ABSTRACT

"EFFECT OF MATURITY AND STORAGE TEMPERATURE ON SHELF LIFE AND QUALITY OF BANANA (*Musa paradisiaca* L.) CV. GRAND NAIN"

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ABSTRACT

The present experiment entitled "Effect of maturity and storage temperature on shelf life and quality of banana (*Musa paradisiaca* L.) cv. Grand Nain" was carried out during 2008–2009 at Regional Horticultural Research Station and Post Harvest Technology Centre, ASPEE college of Horticulture and Forestry, Navsari Agricultural University, Navsari. The treatments were three different maturity stages *viz.*, M_1-75%, M_2-90%, M_3-100% maturity and four storage temperatures *viz.*, T_1-12^{0}C, T_2-14^{0}C, T_3-16^{0}C and ambient temperature. The experiment was laid out in Complete Randomized Design with factorial concept.

The banana bunches harvested at 100% maturity stage had higher weight of bunch, weight of finger and pulp: peel ratio. Among different storage temperatures the pulp: peel ratio was maximum at ambient condition.

Organoleptic qualities at ripening were observed maximum at 16^{0}C and at 100% maturity stage. The best

colour and texture was found in the fruits harvested at 100% maturity and stored at 16^{0}C (M_3T_3).

Green, yellow and shelf life of fruits were maximum at 75% maturity stage. Among the storage temperatures, at 12^{0}C green and shelf life and at 14^{0}C yellow life of fruits were observed maximum. The maximum green life and shelf life of fruits were observed in fruits harvested at 75% maturity and stored at 12^{0}C (M_1T_1) whereas, yellow life of fruit was found maximum when 75% matured fruits were stored at 14^{0}C (M_1T_2).

The minimum physiological loss in weight and titratable acidity and maximum firmness of fruit were observed at 75% maturity (M_1) and at 12^{0}C (T_1) storage temperature, individually as well as in combination.

The quality in respect total soluble solids, reducing sugar and total sugars of banana fruits was found superior at 100% maturity (M_3). Among the different storage temperatures, the fruits stored at ambient temperature maintained their superiority in respect of above parameters up to 13th day, after which this fruits were subjected to senescence. After 13th day the total soluble solids, reducing sugar and total sugars were increased gradually with the incressing in maturity and storage temperature up to the period of their shelf life which was decreased with the increased maturity and storage temperature.

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CERTIFICATE

This is to certify that the thesis entitled **"EFFECT OF MATURITY AND STORAGE TEMPERATURE ON SHELF LIFE AND QUALITY OF BANANA (*Musa paradisiaca* L.) CV. GRAND NAIN"** submitted by Mr. **GONGE AMOL PRALHAD** in partial fulfillment of the requirement for the award of degree of **MASTER OF SCIENCE (HORTICULTURE) in FRUIT SCIENCE** to Navsari Agricultural University is a record of bonafide research work carried out by him under my guidance and supervision and the thesis has not previously formed on the basis for the award of any degree, diploma or other similar title.

Place : Navsari
Date : 07th July 2009

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DECLARATION

This is to declare that the whole of the research work now submitted in this thesis for the partial fulfillment of the requirement for the degree of **MASTER OF SCIENCE (HORTICULTURE)** in **FRUIT SCIENCE** is the result of investigation done by me under direct guidance and supervision of **Dr. N. L. PATEL, Dean**, Aspee college of Horticulture and Forestry, Navsari Agriculture university, Navsari and that no part of the work has been submitted for any other degree so far.

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ABBREVIATIONS

SR. NO.	ABBREVIATIONS	MEANING
1.	%	=Per cent
2.	@	=At the rate of
3.	^0C	=Degree centigrade
4.	C.D.	=Critical difference
5.	C.V.	=Co-efficient of variance
6.	cv.	=Cultivar
7.	*et al.*	= And others
8.	*etc.*	= et cetera (and so on)
9.	Fig.	=Figure
10.	g	=Gram
11.	ha^{-1}	=Per Hectare (Unit of area)
12.	*i.e.*	= id est (That is)
13.	kg	=kilogram
14.	kg/cm^2	= Kilogram per square centimeter
15.	mg	=Mili gram
16.	mm	=Mili meter
17.	PLW	=physiological loss in weight
18.	RH	=Relative humidity
19.	S.Em.	=Standard error of mean
20.	Sig.	= Significant
21.	TSS	=Total soluble solids
22.	Var.	=Variety
23.	*viz.*,	= Videlicet (Namely)

INTRODUCTION

I. INTRODUCTION

In the galaxy of fruit crops banana is the most dominating crop. Fruits and their culture have very close association with life of man and the human civilization is linked with development of fruit industry. Role of fruits which are widely called as 'protective foods' in human diet, is well known from the prehistoric era. Banana and plantain (*Musa sp.*) are widely grown in India with great socio-economic significance and is interwoven in the cultural heritage of the nation. Banana is known as 'Apple of the Paradise' and botanically named as *Musa paradisiaca*. Banana is one of the largest photosynthetic units in the plant kingdom. Banana is a source of food, fodder, fibers, beverages, fermentable sugars, medicines, flavorings, cooked foods, silage, fragrance, rope, cordage, garlands, shelter, clothing, smoking material, wrapping/parcelization, making house roofs and wall linings and has numerous religious as well as industrial uses like in making resin/gum/glue/latex, dye and tanning. Owing to these multifaceted uses it is referred as 'Kalpatharu'.

In India, banana is fourth important food crops in terms of gross value and is exceeded only by paddy, wheat and milk products. It is also a dessert fruit for millions, apart from a staple food owing to its rich and easily digestible carbohydrates with a calorific value of 67-137/100 g per fruit, it is a good source of vitamin A (190 IU per 100 g of edible portion) and vitamin-C (100 mg/ 100g) and fair source of vitamin B and B2. Fruits are also rich source of minerals like magnesium, sodium, potassium, phosphorus and a fair source

of calcium and iron. It makes healthy and salt free balanced diet than many fruits. One hectare of banana yields 37.5 million calories of energy as compared to 2.5 million calories from wheat and multifarious uses. About 24 bananas each weighing around 100 g would provide the energy requirement (2400 calories per day) of a man (Singh, 2002).

India is the largest banana consumer and producer country in the world followed by Brazil, contributing about 15 per cent of the total world production. Among the fruits, banana holds first position in production and productivity in India. It ranks second in area after mango. In India, annual production of banana is 23.20 million tones from an area of 6.47 lakh hectares spread all over the country and productivity is 35.9 tones ha-1 (Anon., 2008). Banana covers 11 per cent of the total area under fruits, contributing nearly one third of total fruit production in the country. In India, Tamil Nadu, Maharashtra, Karnataka, Kerala, Assam and Gujarat are the leading banana producing states. The highest productivity is 62 tones ha-1 in Maharashtra followed by Gujarat (54.8 t ha-1) in the year 2007-2008., Anon (2008).state wise area, production and productivity of banana fruit crop in the year 2007-2008 is given in appendix-I.

In India, banana contributes 36.5 per cent of fruit production. There are three important banana producing zones in India are South India, Western India and Eastern India. Among the banana growing states of India, Gujarat, covers an area of 57,668 hectares with production of 31,57,738 metric tones. The largest area is covered under Bharuch district with an area of 13,493 hectares with the highest production of

8, 55,138 metric tones. Navsari district covers an area of 400 hectares with a production of 20,800 metric tones annually (Anon., 2008). Banana is cultivated in the districts of Bharuch, Surat, Anand, Narmada, Junagadh, Vadodara, Navsari and Valsad because of favorable agro-climatic conditions and abundant supply of well and canal irrigation water. Banana is grown successfully from 80 N to 28^0 N latitudes with temperature and rainfall of 15^0-35^0C and 500-2000mm per annum, respectively. District wise area and production of banana fruit crop in the year 2007-08 is given in appendix-II.

Medicinally banana act as preventive for heart ailments. Use of pseudostem core has been well recognized as medicine in dissolving kidney stones. Stalks are mashed and used as poultice for sprains or broken bones, root sap from certain varieties is used as a medicine to thrush a child's mouth irritation and to treat skin warts, recently pounded banana peels have been found to contain antibiotic properties.

Since the last 50 years, a considerable research work has been done in the country on various aspects such as varieties, irrigation, weed management, spacing, post harvest technology etc. for increasing yield and quality of banana fruits. India, though being the largest producer of banana in the world, does not figure in the world scene like the banana republics in Latin America does. The export demand has remained untapped because of the indifference of the government and the associations concerned, poor quality and sheer lack of proper marketing infrastructure. Indian bananas though equally tasty have skins which are either spotted or with black strips owing to improper post-harvest handling and

storage which has made Indian bananas unsuitable for exports.

In India the demand of banana fruit increase from the month of August to end of December because there are many religious festival celebrated during this period like "shravan month" for god Shiva, "Dashera" "Diwali" and "Eid" and in that period many of the people take banana as staple food during fasting .Now a day by the use of biotechnology the duration of crop is minimized as compare to crop propagation by sucker. In south Gujarat most of harvesting is done in the month of August and September. Ultimately because of short storage life of banana (10-12 days) at room temperature there is some shortage of banana fruit in the month of October and November ("Dashera" and "Diwali"). Because of high demand in these months the price increases. By the use of storage facility the shelf life of the fruit increase upto 30-40 days and farmer gets more economically benefit from the same crop Patil and Magar (1976) and Narayana and Mustaffa, (2007).

The post-harvest losses of fresh banana fruits go up to 30-40 per cent due to improper handling and storage (Patil and Hulmani, 1998). Maturity of banana is very important from the marketing point of view as the harvest maturity depend on destination market. The most common method of measuring the maturity is based on the number of days after shooting, (Stover and Simmonds, 1987 and Thompson and Burden, 1995.) Measuring the diameter shape and angularity of individual finger are the other methods to estimate the maturity which are destructive and practically difficult to use in the field.

A few main challenges faced by fruit industry are the enormous post-harvest losses, lack of information on handling, packaging system and post-harvest treatments. Attempts have been made to retard ripening and delay the senescence of fresh fruits by means of post-harvest storage at different temperature and with different maturity. Though large numbers of varieties are grown in India, "Grand Nain" is the leading and popular cultivar choice by the grower of Gujarat for domestic and foreign market. Hence, it becomes necessary to find out some suitable post-harvest treatments to extend the shelf-life of this cultivar with reduction in loss. Information on these aspects are meagre, to generate data base information on effect of maturity and storage temperature on shelf life and quality of banana this experiment was conducted with the following objective.

1. To study the effect of different maturity stages of fruit and storage temperature on the shelf life and quality of banana.
2. To study the interaction effect of different maturity stages of fruit and storage temperature on shelf life and quality of banana.

REVIEW

OF

LITERATURE

II. REVIEW OF LITERATURE

Banana being a delicate and highly perishable fruit, the local production is subjected to serious post harvest losses, mainly due to harvesting at improper maturity stage, poor handling and storage practices.

Bananas are harvested at different degree of maturity depending on the distance of haulage and time of consumption. The stage of maturity at harvest has profound influences on its physical appearance, biochemical constituent, the quality of the fruits and its shelf life, Waskar and Roy (1992). To the market and consumption point of view the fruits harvested at proper maturity stages is very important and the most common method in advanced countries to judge the maturity is based on the number of weeks or days after anthesis (Narayana and Mustaffa, 2007).

Banana is one of the climacteric fruits which start fast ripening process after harvesting and there is no any effect of harvesting time or different maturity stages on the shelf life of fruits when stored at room temperature. Storage of banana at room temperature favours decay, softening and off flavour development (Deka *et al.* 2006). The control on ripening temperature is important to obtain better quality fruits within specific marketable life so the temperature influences the ripening changes in banana. The fast ripening process of banana is minimum under cold storage temperature due to lower rate of respiration, which helps to increased shelf life and quality of fruits. The rate of respiration was slow in the fruit at cold room as compared to ambient condition Gane (1936).

Therefore, experimental results relating to comparison of effect of maturity and storage temperature on physical as well as chemical observation on the banana are reviewed under the following heads.

A. Physical observation

2.1 Weight of bunch

Singh *et al.* (1967) found that the maximum (27 kg) weight of bunch at full maturity of plant under Maharashtra condition in banana cv. Basrai and Harichal.

Singh *et al.* (1976) reported that the maximum weight of bunch varied from 15 to 25.5 kg when fruit was harvested in duration between 80 to 98 days from spike emergence to maturity of bunch in banana cv. Basrai.

2.2 Number of fingers per bunch

Singh *et al.* (1976) observed that maximum number of finger per bunch in the range of 120 to 205 in banana cv. Basrai.

2.3 Weight of fingers

Lodh *et al.* (1971) concluded that with increasing in maturity the weight fingers of banana was increased. Maximum weight of finger was observed from 100 days to 130 days in the range of 97.25 to 144 g in banana cv. Dwarf Cavendish.

In banana cv. Basrai at 80 to 98 days of harvesting period the weight of fingers was observed in the range of 67 to 98.5 g (Singh *et al.*, 1976).

Muastaffa *et al.* (1998) reported that Suitable harvesting stage was found to be between 12-15 weeks after

flowering emergence. The size, weight and volume of fruits increased significantly for fruit from all position (hands within bunch and fingers with in a hand) of the bunch until the end of the maturity stage.

2.4 Green, yellow and shelf life of fruit (days)

2.4.1 Effect of maturity

Inaba *et al.* (1984) studied on Cavendish bananas, they harvested the fruits from 65 to 105 days after flowering and fruits ripened at 25^0 C after transport to Japan. After the onset of the climacteric little difference were found among fruit harvested at different maturities.

Fruit harvested at 75% maturity recorded the maximum green life in banana cv. Poovan and Karpuravalli. Poovan fruit at 75% maturity had a green life of 10 days, yellow life 4 days and shelf life 14 days whereas cv. Karpuravalli had green life 8 days, yellow life 4 days and shelf life 12 days. Full matured (100%, maturity) Poovan fruit had 6 days of green life while Karpuravalli had 5 days when fruit were stored at ambient temperature (Narayana and Mustaffa, 2007).

2.4.2 Effect of storage temperature

Muthuswamy *et al.* (1971) concluded that banana bunches could be held in refrigerated storage at 14.4^0C for about 25 days, compaired with 2-7 days at room temperature ,($29-32^0$C). Detached hands ripened within 7 days at room temperature and riched the fully ripe stage after 18 days at 14.4^0C. In cold storage the rind colour changed from green to yellow in 7-14 days while at room temperature colour changed at 4-7 days.

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Desai and Deshpande (1975) observed the content of total yellow pigments (xanthophylls plus carotene) remained more or less constant during ripening of variety Pachabale, Rasabale and Rajabale at 20^{0}C of fruit storage in banana.

Marriott and New (1975) observed the physiological changes during storage of fruits of tetraploid banana clones and cv. Valery were similar. The preclimacteric period of fruits of tetraploid clones stored at 14^{0}C was 18-21 days compared with 26 days for Valery.

Rippon and Trochoulias (1976) found that fruit was adversely affected when ripened at 15 or 17^{0}C and subsequently removed to temperatures 10^{0}C or more above the ripening temperature. Ripening at 17^{0}C proved best, combining relatively rapid turnover of fruit with subsequent moderate shelf life.

Patil and Magar (1976) studied on physicochemical changes of different varieties of banana. Cultivars Basrai, Harichal, Lalkel, Rajeli and Safed Velchi were studied for various stage of ripening. The banana fruit take about 32 days for full ripening at 13^{0}C except Safed Velchi. The climacteric occurred on 24th day after harvest when stored at 13^{0}C.

Bananas, cvs. Poovan and Robusta, were harvested at 75% maturity and the bunches were cut into hands which were either kept at room temperature (23-28^{0}C, controls) or covered with moist sand (20-26^{0}C) for up to 30 days. Control fruits of Poovan and Robusta ripened in 10-13 and 13-15 days, respectively, compaired with 20-21 and 22-30 days for those kept in sand, respectively.[Neelakantan and Sadasivam, 1977]

Peacock (1980) stated that in bananas, cv. Giant Cavendish, Shelf-life was found to be decreased exponentially with increasing temperature when fruit was stored at eight temperatures from 13.9 to 32.5^{0}C for various periods.

Hussein *et al.* (1985) stated that banana cv. Hindi and Paradica fruits kept in open plastic boxes in stimulated market condition for up to 12 days.

Ngalani (1986) found that banana fruits cv. French Sombre began to turn yellow 3 days after harvest when held at 25-30^{0}C. Fruits held at 8-10^{0}C showed no deterioration in organoleptic quality after 21 days.

Chang *et al.* (1990) studied the fruit of 100% maturity exhibited colour change (chlorophyll breakdown) faster than fruit of lower maturity and also higher tannin content in fruit was forms in lower maturity of banana.

Collin and Dalnic (1991) stated that fruits of plantain cv. Orishele imported to France from the Cote d Ivoire could be kept at 22^{0}C for up to 21 days.

Deka *et al.* (2006) observed that in cold storage with 12^{0}C the maximum shelf life was 38.05 days as against 12.96 and 11.13 days in evaporate cool storage and ambient condition, respectively in banana cv. Barjahaji (AAA group).

2.5 Physiological loss in weight (%)

2.5.1 Effect of maturity

El- Tomi *et al.* (1963) observed greatest weight loss in banana picked at "full" stage compared to banana harvested at the "half full" and "three quarter" stage.

Raman *et al.* (1971) recorded that fruit of Dwarf Cavendish registered more weight loss (7.5%) than those of

Robusta (4.6%) at the end of three week of storage when fruit harvested at 'Three quarter full' and stored at 14.2^{0}C with 80-90% relative humidity

Narayana and Mustaffa (2007) stated that the physiological loss in weight was maximum in 75% maturity and it was least in 100% maturity in banana cv. Poovan. While in cv. Karpuravalli it was minimum in 75% maturity and maximum in 100% maturity.

2.5.2 Effect of storage temperature

El- Mahmoudi and Eisawi (1968) reported that at storage temperature of 11.1, 12.7 and 15.6^{0}C (80-85% relative humidity), the weight loss percentage of fruit increased during storage and the rate of loss increased with temperature and storage period.

Wasker (1989) recorded the highest physiological loss in weight of Basrai banana fruit when stored at room temperature (15.0 to 24.6^{0}C and 26-90% RH) moderate in cool storage (12.8 to 15.0^{0}C and 65 to 70 RH) and lowest in cool chamber (14.0 to 18.1^{0}C and 90 to 95% RH).

Weight loss percentage was greater (13.1%) in bananas stored at higher temperature (18^{0}C) than those stored at lower temperature (16^{0}C). [Saeed Ahmad *et al.* 2006]

Deka *et al.* (2006) reported in banana cv. Barjahaji (AAA group) that the average physiological loss in weight was only 1.04% in cold room as against 6.94 and 4.46 per cent in ambient conditions and evaporative cool storage, respectively on 8th day of storage. The PLW of banana was even less than

10 per cent on 30th days of storage in cold room. Similar result observed by Hardenburg *et al.* (1990).

2.6 Firmness of fruit

Firmness of fruit was increased after harvesting of banana when the flesh softening occurred, and creating a alcoholic compound in fruit (Huet, 1956).

2.6.1 Effect of maturity

Desai and Despande (1978) reported that the fruit harvested at early mature stage (90 and 105 days) were more firm than those harvested at fully mature stage (120 days).

Wills *et al.* (1984) noted a decrease in firmness of 'Cavendish' banana from 12.2 kg per cm^2 at unripe stage to 0.8 kg per cm^2 in firm ripe stage.

2.6.2 Effect of storage temperature

The decrease in firmness during storage of fruit was due to changes in nature of pectin substances cementing the cell wall and hydrolysis of starch, hemicelluloses and cellulose during ripening of fruit (Leopold, 1964).

Desai and Deshpande (1975) reported that the fruit of three bananas cvs. Pachabale, Rasabale and Rajabale during storage at 20^0C, the firmness decreased progressively (from 3.95 to 0.36 kg per cm^2) with marked variations between the 14th and 21st days of storage.

Rippon and Trochoulias (1976) reported that the banana ripened at higher temperature (19^0C) tended to have a firmer pulp than fruit ripened at lower temperature (15^0C).

Peacock (1980) observed that pulp firmness was affected by temperature in bananas, cv. Giant Cavendish,

stored at eight temperatures from 13.9 to 32.5^{0}C for various periods and noted that lower ripening temperatures produced firmer fruit.

Wasker (1989) reported that the fruit of Basrai banana stored in cool chamber and cold storeage had maximum firmness at the shelf life of 20.5 days irrespective of ripening methods.

Sen and Chaudhuri (1976) recorded that when bananas fruit kept at 5^{0}C (RH 60 - 65%) or at room temperature of 28^0 - 30^{0}C (RH 80 - 85%) for 4 and 12 days, respectively, hardness declined much more rapidly at room temperature.

2.7 Pulp: Peel ratio at ripening

2.7.1 Effect of maturity

The average pulp weight of fruit increased with the concomitant decreased of peel weight during storage of banana. The maximum pulp to peel ratio was observed at full maturity at 130 days after the emergence of spike in banana cv. Dwarf Cavendish (Lodh *et al.* 1971).

Desai and Deshpande (1978) reported that full mature (120 days) fruit of Rajabale and Rasabale recorded higher pulp to peel ratio on ripening compared to fruit harvested at an early mature (90 days) or mature (105 days) stage.

Sanchez *et al.* (1980) observed that for processing frozen green banana of high quality, it is recommended that the fruit to be harvested at a pulp: peel ratio of about 1.5. In green hand peeled banana shear press force value decreased linearly with an increased in pulp to peel ratio. Fruit with a

pulp to peel ratio ranging 1.3-1.5 was of acceptable. Fruit with higher pulp to peel ratio had less of flavour than less developed fruit probably due to the higher tannin of the latter.

The banana fruit of four cvs. Bhos, Basrai Dwarf, Dudhia Mal Bhog and Barsain were harvested at 3 quarters full maturity stage. The pulp to peel ratio was maximum (1.318) in Basrai Dwarf followed by Dudhia Mal Bhog (1.288) as compared to minimum (1.27) in Bhos followed by Barsain (1.14) at mature stage of fruit. The pulp to peel ratio increased several folds at ripe stage in all varieties and ranged from 1.97 to 3.39 (Tripathi *et al.*1981).

2.7.2 Effect of storage temperature

El-Mahmoudi and Eisawi (1968) reported an in pulp to peel ratio with increase temperature as well as storage period.

Raman *et al.* (1971) concluded that the pulp to peel ratio (1.8) remained constant upto three week in Robusta and a sudden rise was noticed during the fourth week. In Dwarf Cavendish, the ratio increased gradually from 1.8 to 3.0 in four weeks when fruit harvested at three quarter full and stored at 14.2^{0}C with 80-90% relative humidify.

The ratio of pulp to peel was related to accumulation of moisture in the pulp which was derived from carbohydrates breakdown and the osmotic transfer of water from skin to pulp, (Palmer, 1971 and Charles and Tung, 1973).

Desai and Deshpande (1975) the ratio of pulp to skin of banana fruits of cultivars Pachabale, Rasabale and Rajabale increased (1.77 to 2.91) considerably during ripening at 20^{0}C.

Patil and Magar (1976) reported that the pulp to skin ratio found to be increased with progressive ripening of banana at 13^{0}C with the cvs. Basrai, Harichal, Lalkel, Rajeli and Safed Velchi.

Chitarra and Lajolo (1985) observed that at 20^{0}C a slight rise in the pulp peel ratio occurred after the climacteric stage which was gave the indication of ripening of bananas (ABB group).

Saeed Ahmad *et al.* (2006) reported that bananas ripening at 18^{0}C were with higher pulp/peel ratio (1.78) than those ripening at 16^{0}C.

B. Chemical observation

2.8 Total soluble solids (TSS)

2.8.1 Effect of maturity

Singh *et al.* (1976) reported that the total soluble solids increased with advanced maturity and at different harvesting period.

Fruits that grew and developed between March and August were superior as compare to fruits harvested in between September and February. Samples in both seasons were collected at 10 day intervals for 150 days from Opening of the 3rd hand. T.S.S were found 2.4% at 70 and 80 days and 2.8% at 90 and 100 days after opening of the 3rd hand just after harvesting between March and August (Dhua *et al.*, 1988).

Munasque and Mendoza (1990) reported that Senorita banana fruits were tagged at the time of shooting (emergences of the floral apex at the crown) and observation on fruit recorded 6 to 7 week after removal of male

inflorescence. They noted that pulp soluble solids content increased gradually during fruit development.

Ahmad *et al.* (2001) stated that an increased in the level of total soluble solids proportionate to the different maturity level.

Deca and Harmine (1997) recorded bio-chemical changes at different stages of fruit development at 25, 50, 75,100 and 125 days after emergence of finger (DAEF) in banana cultivar Borjahaji (AAA). Considerable variations in bio -chemical constituent were observed during development. Total soluble solids increased from 4.8 -11.5%.

The total soluble solids were significantly higher in fully mature (100%) fruit in cv. Poovan and Karpuravalli *i.e.* 24.65 and 30.92, respectively as compared to 75% (21.73 and 16.65) and 90% maturity (24.47 and 19.71) at ambient temperature (Narayana and Mustaffa, 2007).

2.8.2 Effect of storage temperature

Raman *et al.* (1971) reported an increase in total soluble solids value in Robusta and Dwarf Cavendish during third week (14.8 and 17.8) and fourth week, (17.2 and 18.0), respectively, when fruits were harvested at three quarter full and stored at 14.2^{0}C with 80-90 % relative humidity.

The mature fruit of Basrai Dwarf had the highest T.S.S (15^0) followed by Barsain (13^0) as against minimum T.S.S at 10^0 in Bhos followed by Dudhia Mal Bhog (11^0) at 3 quarters full maturity stage of harvesting. The T.S.S content approximately doubled after ripening in Bhos (20^0) and Dudhia Mal Bhog (24^0) varieties as compared to the value in mature ones. However, Basrai Dwarf (19^0) and Barsain (17^0) did not

show appreciable increases in T.S.S during ripening. (Tripathi *et al.*, 1981).

Shivashankar (2003) studied the total soluble solids fluctuation of banana fruit cv. Neypoovan and cv. Burrocemsa stored at 10^0C and 15^0C. In cv. Neypoovan T.S.S was higher at 10^0C (33.67) and at 15^0C it was 30.33 after 15 days of storage while at room temperature it was 32.17. In Burrocemsa T.S.S was higher at 10^0C (22.33) and at 15^0C it was 22.7 after 15 days of storage while at room temperature it was 21.87.

Deka *et al.* (2006) reported that in banana cv. Barjahaji (AAA group) at shelf life termination stage, in the cold storage at 12^0C with out any post harvest treatment the total soluble solids were found higher (17^0 Brix) and at evaporative cool storage at 12^0C and at ambient condition it was found 16^0 Brix.

Saeed Ahmad *et al.* (2006) stated that the total soluble solids were higher (22.8%) in bananas ripening at 18^0C than those at 16^0C.

2.9 Titrable acidity

2.9.1 Effect of titrable acidity

Wyman and Palmer (1963) reported that titrable acidity was increased with advancement of maturity.

Lodh *et al.* (1971) observed that the titrable acidity increased upto the age of 40 days. At 44 days to 55 days it showed a slightly decreasing tendency and after 55 days of fruit growth, titrable acidity increased till 130 day of growth.

Tripathi *et al.* (1981) reported at 3 quarters full maturity stage of harvesting, the banana fruits of four cvs.

Bhos, Basrai Dwarf, Dudhia Mal Bhog and Barsain recorded acidity in the range of 0.16% to 0.25%. All the varieties showed an appreciable change in acidity ranging from 0.34 to 0.38% after ripening.

Dhua *et al.* (1988) observed fruits, that grew and developed between March and August was superior as compared to fruit harvested in between September and February. Samples in both seasons were collected at 10-days intervals for 150 days from opening of the 3rd hand. Titrable acidity was found 0.14, 0.16, 0.19 and 0.19 at 70, 80, 90, 100 days after opening of the 3rd hand respectively just after harvesting between March and August.

Senorita banana fruits were tagged at the time of shooting (emergences of the floral apex at the crown) and observation of fruit recorded 6 to 7 week after removal of male inflorescence. Titrable acidity increased with advancing maturity. Titrable acidity increased until colour index 3 (more green than yellow) and declined as the fruit turned yellow in colour. (Munasque and Mendoza, 1990)

Deca and Harmine (1997) recorded bio-chemical changes at a different stage of fruit development at 25, 50, 75,100 and 125 days after emergence of finger (DAEF) in banana cultivar Borjahaji (AAA). Titrable acidity increased from 0.19-0.4%.

Narayana and Mustaffa (2007) reported that the titrable acidity was more (0.364%) in 100% mature fruit than that in 75 and 90% mature fruit.

2.9.2 Effect of storage temperature

Desai and Deshpande (1975) reported the fruit of 3 banana cvs. Pachabale, Rasabale and Rajabale during storage at 20^0C, increased in titrable acidity (2.35 to 6.14 meq/l00g pulp) with marked variations between the 14^{th} and 21^{st} day of storage.

Shivashankar (2003) studied the acidity of banana fruit cv. Neypoovan and Burrocemsa stored at 10^0C and 15^0C. In cv. Neypoovan acidity was higher at 15^0C (0.49) and at 10^0C it was 0.41 after 15 days of storage while at room temperature it was 0.48. In cv. Burrocemsa acidity was higher at room temperature (0.45) while at 15^0C and 10^0C it was 0.44 and 0.43 after 15 days of storage respectively.

Deka *et al.* (2006) reported that in banana cv. Barjahaji (AAA group) in the cold storage at 12^0C at shelf life termination stage, with out any post harvest treatment acidity was 0.38 and it was found higher in the evaporative cool storage 0.62 and 0.60 at ambient condition.

2.10 Reducing sugar

2.10.1 Effect of maturity

Lodh *et al.* (1971) stated that among the different stages from the emergence of anthesis to harvesting at 130 days the fruit ripened under ambient temperature showed maximum reducing sugar (6 per cent) at fully ripening stage.

Chang *et al.* (1990) reported increased level of reducing sugar by higher activity of amylase and phosphoryalse enzyme coupled with minimum level of starch.

In unripe banana fruit, 20-25% starch on fresh weight basis was recorded which was rapidly degraded into sugar during ripening (Reneta *et al.*, 2002).

Narayana and Mustaffa (2007) stated that reducing sugar was found significantly higher at 100% maturity (20.82% and 20.11% for Poovan and Karpuravalli, respectively,) as compared to 75% and 90% maturity fruit.

2.10.2 Effect of storage temperature

Raman *et al.* (1971) stated that at the end of four week of storage the percentage reducing sugar in Dwarf Cavendish was 7.1 as against 4.0 in the case of Robusta, when fruit harvested at three quarter full and stored at 14.2^{0}C with 80-90 % relative humidity.

Desai and Deshpande (1975) reported that in the fruits of 3 banana cvs. Pachabale, Rasabale and Rajabale during storage at 20^{0}C, increased in reducing sugar (0.18 to 14.22% on fresh weight of pulp) with marked variations between the 14th and 21st day of storage.

Kim and Lee (1988) reported banana ripened rapidly at 25^{0}C. Reducing sugar contents increased as the fruits ripened.

Banana fruits of cv. Neypoovan and Burrocemsa stored at 10^{0}C and 15^{0}C were studied for reducing sugar. In cv. Neypoovan, reducing sugar was higher at room temperature (17.71) while at 15^{0}C and 10^{0}C it was 12.91 and 13.10 after 15 days of storage, respectively. In cv. Burrocemsa reducing sugar was higher at 10^{0}C (19.30) and at 15^{0}C it was 14.60 after 15 days of storage while at room temperature it was 17.00 (Shivashankar, 2003).

2.11 Total sugars

The most striking chemical changes which were occurred during the postharvest ripening of banana like the hydrolysis of starch and accumulation of sugar (Loesecke, 1950)

2.11.1 Effect of maturity

Lodh *et al.* (1971) found that total sugars remained more or less constant from 40 to 100 days of fruit development and after 100 days increased considerably in banana cv. Dwarf Cavendish.

Tripathi *et al.* (1981) reported that at three quarters full maturity stage of harvesting, the banana fruits of four cvs. Bhos, Basrai Dwarf, Dudhia Mal Bhog and Barsain recorded total sugars from the range of 1.17 to 1.67. All the varieties showed increases in total sugars ranging from 12.23 to 19.2 after ripening.

Dhua *et al.* (1988) observed fruits that grew and developed between March and August were superior as compared to fruit harvested in between September and February. Samples in both seasons were collected at 10 day intervals for 150 days from Opening of the 3rd hand. Total sugars were found 0.48, 0.71, 0.98 and 1.01 (% fresh weight) for 70, 80, 90,100 days after opening of the 3rd hand respectively, just after harvesting between March and August.

Senorita banana fruits were tagged at the time of shooting (emergences of the floral apex at the crown) and observation of fruit recorded 6 to 7 week after removal of male inflorescence. Total sugars which remained low during

and at 15^0C it was 21.37%, after 15 days of storage while at room temperature they were 20.77% (Shivashankar, 2003).

2.12 Effect of storage temperature on physical and bio-chemical observation

Nakamura *et al.* (1979) reported that under slow banana ripening conditions caused by CO^2 treatment or low temperature, a rapid softening of the pulp, a sudden increase of the sugar content and a temporary increase in the titrable acidity were accompanied by a yellowing of the peel. The physical and chemical changes in the pulp associated with ripening started before the yellowing of the peel.

Broughton *et al.* (1979) noted that physiological changes during the ripening and storage of Pisang Emas banana. Temperature of 20^0C prolonged storage life while temperature below 11^0C caused chilling injuries. High humidity and removal of carbon dioxide enhanced ripening while low humidity adversely affected fruit quality.

Smith and Thompson (1987) observed that in banana, the ripening was associated with loss of pulp firmness, changes in peel colour, and increase in the total soluble solids content of the pulp.

Collin and Dalnic (1991) reported that the colour change during ripening was accompanied by decrease in fruit firmness and starch content, and increase in acidity and total sugars when fruit was stored at 22^0 C.

2.13 Combine effect of maturity and storage temperature on shelf life and quality of banana fruit

Aziz *et al.* (1976) studied on banana cv. Hindi, harvested at the mature green stage and stored at 20-25^{0}C. Titrable acidity rose to a peak and then fell during storage. There was no peak in titrable acidity, but only a slight rise throughout storage, when the fruit were held at 0 or 5^{0}C for 20 days, and under these conditions the fruit failed to ripen. TSS content also rose rapidly during storage at 20-25^{0}C but altered little at 0 and 5^{0}C. Sugar levels were affected by storage temperature; sucrose, the main component, rose throughout storage at all temperatures but particularly at the higher ones.

Madamba (1977) observed the starch, total sugars, titrable acidity and total soluble solids of Lacatan bananas picked at 2 different stages of maturity and ripened at 23.3^{0}C. 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). However, stage A fruits ripened sooner than stage B fruits. The former required 13 days to ripen, whereas the latter took more than twice as long (29 days). Titrable acids increased, accompanied by a rapid decrease in starch, before the eating- ripe stage was reached. Total sugars and total soluble solids remained low until the final stages of ripening, when a rapid increase in these constituents was observed.

Firmen (1991) harvested Afoto plantain at a mature green stage and stored at 20-22^0 C and 50-60% RH. At each stage of ripening (very green, yellow-green, yellow, ripe and very ripe) samples were taken for physiological parameters and chemical analysis. Sugars level increased during ripening from 1.38% at mature green to 75.5% at the very ripe stage with a corresponding decrease in starch level from 77.5% to 2.09%. Total acidity of the pulp increased from 2.55 to 4.40 mEq malic acid / 100g wet weight during ripening.

Nagaraju and Reddy (1995) observed that cool chamber (CC) storage significantly slowed down the rate of increase in physiological weight loss and decreases in firmness of banana cv. Dwarf Cavendish fruit compared with rapid changes in fruit stored in ambient condition (AC). The rate of increase in titrable acidity and total sugars and decrease in starch were slow in fruit stored in CC compared with those stored in AC. Cool chamber storage extended the storage life of under – mature [three quarters mature] and fully- mature fruits by 8 and 3days, respectively, over that of fruit in AC, with out deterioration in sensory or edible quality.

Marin *et al.* (1996) studied that mature green Grand Nain banana (Musa AAA) harvested 13 weeks after flowering in June and September 1993 and February and March 1994 and transported through air freight to Releigh. Fruit were stored under storage condition for 36 days at 14^{0}C and 80-90% RH. Fruit harvested in February and March had a longer green life than those harvested in June and September.

MATERIALS

AND

METHODS

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III. MATERIALS AND METHODS

Post-harvest handling of banana fruits has been an important practice for local as well as export point of view. Out of large number of varieties Basrai was the most popular cultivar among growers for last few decades. But the new variety 'Grand Nain' has gained rapid popularity among the growers of Gujarat, particularly in South Gujarat due to its high yield and other characters.

3.1 Experimental site

The present investigation on "Effect of maturity and storage temperature on shelf life and quality of banana (*Musa paradisiacal* L.) cv. Grand Nain" was carried out during 2008 – 2009 at Regional Horticultural Research Station and Post Harvest Technology Centre, ASPEE college of Horticulture and Forestry, Navsari Agricultural University, Navsari.

3.2 Soil characteristics

As per the seventh approximation, the soil of Navsari has been placed under the great group of vertic ustochrepts, Sub order chrepts and order inceptisols with Jalalpore series, which include deep, moderately drained clayey soil, which was classified earlier as "deep black soil".

The soil of experimental site is black, deep, and rich in organic matter and potash having good water holding capacity with good drainage. The soil was considered quite suitable for banana crop under South Gujarat condition.

3.3 Climate and weather

The climate of this region is typically tropical characterized by hot summer, moderately cold winter and

humid and warm monsoon. In general, the monsoon sets during the second fortnight of June and ends by the second fortnight of September. Pre-monsoon rains in the last week of May and or first week of June are most uncommon.

Winter commences from October onwards and ends by the middle of February. The temperature falls down from the beginning of November. December and January are the coldest months of the year. The summer season commences from the middle of February and ends by the first week of June. April and May are the hottest months of summer.

The mean monthly meteorological data on maximum and minimum temperatures, rainfall, relative humidity and sunshine hours during the course of investigation recorded at observatory of the N.M. College of Agriculture, Navsari Agricultural University, Navsari are presented in Appendix- III

3.4 Location

The experiment was laid out in Plot No -2 of the Block-E at the experimental farm of Regional Horticultural Research Station, N.A.U., Navsari during the year 2008- 2009.

3.5 Land preparation

The experimental plot was prepared by deep ploughing, harrowing and leveling. The pits of 30 x 30 x 30 cm were dug out at 1.8 X 1.8 m spacing and well-decomposed fine textured FYM @ 10 kg per pit was applied at planting.

3.6 Planting material

Well hardened, healthy tissue cultured plants of Grand Nain banana having 5-6 leaf stage were used for planting.

3.7 Planting time

Planting was done on 7th July 2007.

3.8 Application of fertilizers

Each plant was fed with 300g N; 90g P_2O_5; 200g K_2O. Nitrogen and potash were applied at 3rd, 4th and 5th months after planting in three equal split doses while complete dose of phosphorus was applied at 3rd month after planting.

The soil application method was adopted to give the fertilizer treatments. The fertilizers N, P and K were applied in the form of urea, single superphosphate and muriate of potash, respectively. The fertilizers were applied by making shallow ring around the pseudostem and were covered with a thin layer of soil.

3.9 Cultural practices

The cultural practices were adopted according to the recommendations for the cultivation of banana crop. Earthing up was done after complete application of fertilizer dose in order to support the plants.

Weeding was done manually to keep the experimental plot weed free; desuckering was also done manually with the help of sharp sickles. The dry and diseased leaves were removed regularly in order to keep the field clean and hygienic. Propping was done after inflorescence emergence with the help of bamboo poles or wooden stakes to support the plants. Denavelling (removal of male flower bud) was done after complete opening of bunch.

3.10 Irrigation

The crop was irrigated at 5-7 days interval and 10-12 days interval in summer and winter seasons, respectively.

Whenever there was a dry spell, if needed, the crop was irrigated in monsoon months.

3.11 Selection of inflorescence

In the field, 36 healthy inflorescence were selected randomly just after emergence.

3.12 Harvesting of the bunch

The stage of harvesting was determined on the basis of number of days after inflorescence emergence. Based on the above criteria, in cv. Grand Nain 100 days from shooting (flowering) to harvest was determined as time required for full maturity and it was fixed as 100% maturity. Accordingly, 90 and 75 days after shooting were fixed for 90 and 75% maturity respectively for harvesting of fruit.

3.13 Method of storage

The separated hands in bunch fruit were kept in cold storage at 12^0, 14^0 and 16^0C in Post Harvest Technology Center, ASPEE college of horticulture and forestry, N.A.U., Navsari. The fruits of control treatment were stored at room temperature in laboratory, Department of pomology, ASPEE college of horticulture and forestry, N.A.U, Navsari, having aeration, for recording the required observations.

3.14 Method and time of fruit sampling

On every sampling date, one finger was sampled from the middle portion of the third hand and utilized for chemical analysis. All the observations for physical parameters and bio-chemical parameters were recorded at two days intervals till the fruits were ripen.

3.15 Chemical analysis

A portion of the pulp from the middle of the fruits was used as per the procedure of Desai and Despande (1975). Fruit pulp was homogenized in a blender and used for chemical analysis.

3.16 Experimental details

Salient features of variety:

It is a tall mutant of 'Dwarf Cavendish'. It is gaining popularity among growers of South Gujarat. It is more vigorous and robust with well-spaced hands, fingers of bigger size and heavy bunches.

3.16.1 Year and season : 2008-09, *kharif*

3.16.2 Crop and Variety : Banana cv. Grand Nain

3.16.3 Design of experiment

The experiment was conducted with Complete Randomized Design with factorial concept. At the time of experiment fruits were stored at different temperatures and when fruits in portioned on treatment completed their shelf life were not considered for next analysis.

3.16.4 Number of treatments combination : 12

3.16.5 Repetition : 3

3.16.6 Treatments details

3.16.6.1 Factor I: - Stage of maturity

M_1 : 75% maturity (75 days after shooting)

M_2 : 90% maturity (90 days after shooting)

M_3 : 100% maturity (100 days after shooting)

3.16.6.2 Factor II: – Storage temperature

T_1 : 12^0C

T_2 : 14^0C

T_3 : 16^0C

T_4 : Room température

3.16.7 Treatments combination details

M_1T_1 :- 75% maturity: 12^0 C temperature

M_1T_2 :- 75% maturity: 14^0 C temperature

M_1T_3 :- 75% maturity: 16^0 C temperature

M_1T_4 :- 75% maturity: Room temperature

M_2T_1 :- 90% maturity: 12^0 C temperature

M_2T_2 :- 90% maturity: 14^0 C temperature

M_2T_3 :- 90% maturity: 16^0 C temperature

M_2T_4 :- 90% maturity: Room temperature

M_3T_1 :- 100% maturity: 12^0 C temperature

M_3T_2 :- 100% maturity: 14^0 C temperature

M_3T_3 :- 100% maturity: 16^0 C temperature

M_3T_4 :- 100% maturity: Room temperature

Plate 1: General view of bunch at 75 % maturity in field

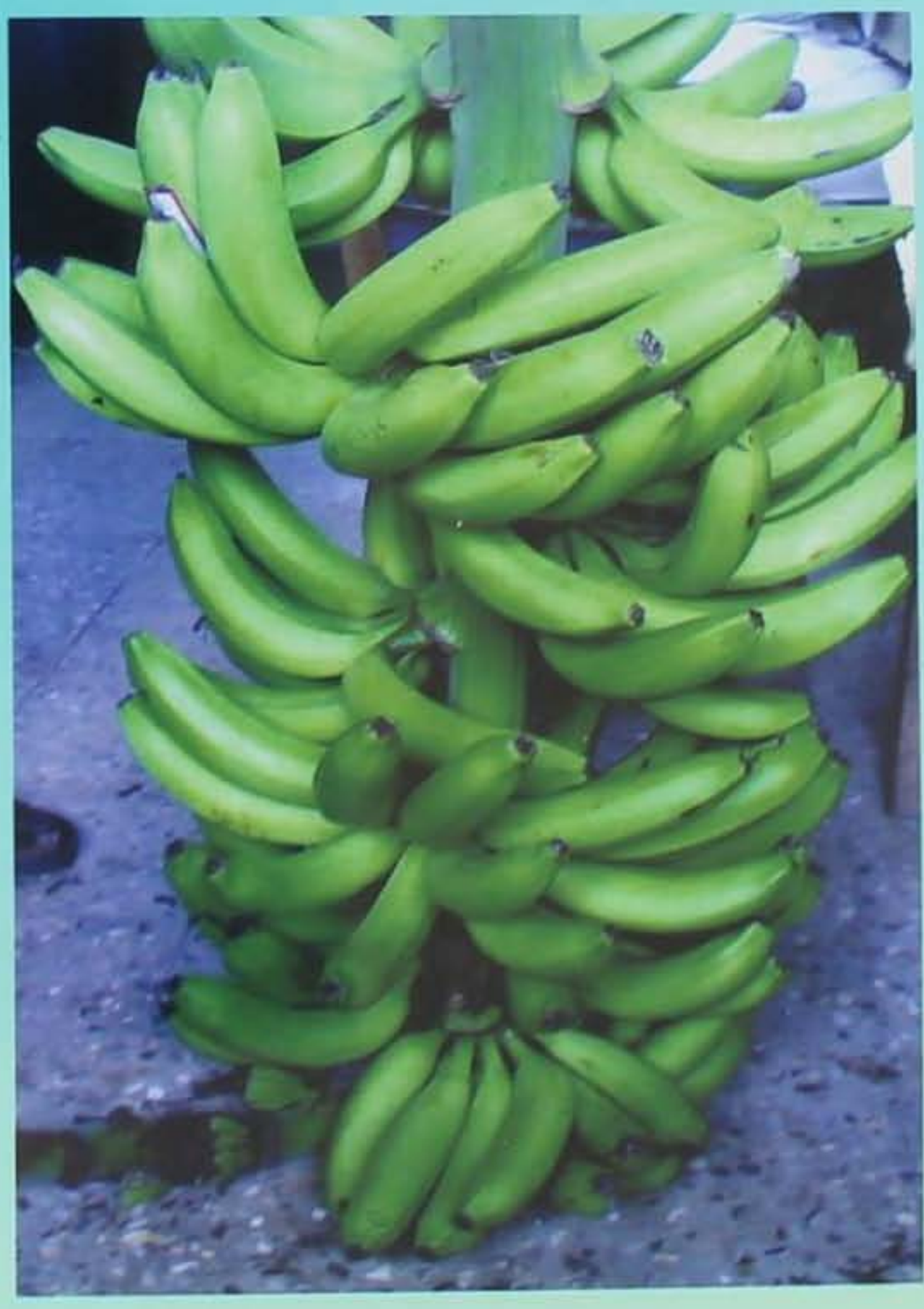


Plate 2: Close up view of bunch harvested at 75 % maturity

Plate 3: General view of bunch at 90% maturity in the field

Plate 4: General view of bunch at 100% maturity in the field

3.16.8 Observations to be recorded

During the storage period, the following observations were recorded:

3.16.8.1 Physical observation

1. Date of shooting
2. Weight of bunch
3. Number of fingers per bunch
4. Weight of fingers
5. Green, yellow and shelf life of fruits (days)
6. Physiological loss in weight (%) at two days interval
7. Organoleptic qualities at ripening (colour, flavor, texture and taste)
8. Firmness of fruit at two days interval (kg/cm^2)
9. Pulp: Peel ratio at ripening

3.16.8.2 Chemical observation [at two days interval]

1. Total soluble solids (^{0} Brix)
2. Titrable acidity (%)
3. Reducing sugar (%)
4. Total sugars (%)

3.17 Methodology adopted for recording above-mentioned observations is as under.

3.17.1 Physical observation

3.17.1.1 Date of shooting

After emergence of flower, date of shooting was noted. From the noted date the bunches were harvested after 75, 90, and 100 days.

3.17.1.2 Weight of bunches

After harvesting weight of bunches were measured on the electronic weighing machine. The whole bunch was kept on electronic weighing machine and there weights were noted in kg.

3.17.1.3 Number of fingers per bunch

After the harvesting of bunch the hands were detached and the number of fingers per bunch were counted.

3.17.1.4 Weight of finger

Fingers were weighted on the first day of treatment and their weight was recorded. The fingers were selected randomly from the first, third and fifth hands position on the bunch. For each replication four fingers were selected and their mean weight considered as average weight of finger.

3.17.1.5 Green, yellow and shelf life of fruits (days)

Days taken to colour braking stage that was, from green to yellow stage, it was considered as green life of the fruit. After occurrence of yellow colour, up to the stage in which fruits were showed the indication of senescence or before going to senescence stage was considered as the yellow

life of fruits. Total days of green life and yellow life were considered as a shelf life of fruits.

3.17.1.6 Physiological loss in weight (%) at two days interval

Four fingers were weighted on electronic weighing machine on the first day of treatment and their mean weight was recorded in g. Subsequently at 2 days interval, their weight was recorded and the loss in weight was expressed as percentage over the initial weight.

$$PLW\ \% = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100$$

3.17.1.7 Organoleptic qualities at ripening (colour, flavor, texture and taste)

The organoleptic evaluation for assessing the flavour, taste, colour of skin, colour of pulp, texture and overall acceptability was done at ripen fruit stage by the panal of five judges by using 10 points Hedonic scale.

3.17.1.8 Fruit firmness (kg/cm^2)

The firmness of the fruit was tested by a pocket penetrometer (Fruit Tester FT 327). One fruit was selected and the penetrometer was pierced through the fruit pulp after removing peel and the pressure required was recorded in kilograms per square centimeter at two days interval. Each time punctures were made at two locations on fruit surface and their average was considered.

3.17.1.9 Pulp: Peel ratio

The fruits, which were used for recording the weight loss during ripening, were used to calculate pulp: peel ratio. Pulp to Peel ratio was calculated by dividing respective pulp weight by respective peel weight.

3.17.2 Chemical observations

3.17.2.1 Total soluble solids (%)

The total soluble solids of the pulp were recorded using a hand refrectometer having the range of 0-32^0 Brix.

3.17.2.2 Titrable acidity (%)

The method described by Ranganna (1979) was adopted for estimation of titrable acidity. Weighed amount of pulp was transferred to a volumetric flask and the volume was made up with distilled water to a known amount. After thirty minutes, the suspension was filtered through Whatman No. 1 filter paper and the filtrate was used subsequently.

An aliquot was taken and titrated against standard sodium hydroxide using phenolphthalein as an indicator. Titrable acidity was expressed as percentage malic acid equivalent adopting the following formula.

$$\text{Acidity (\%)} = \frac{\text{Titre x Normality of alkali}}{\text{Volme of sample taken for estimation}} \times \frac{\text{Volume made up}}{\text{Weight of sample}} \times \frac{\text{Eq. Wt. of Malic acid}}{1000} \times 100$$

3.17.2.3 Reducing sugar (%)

The titrimetric method of Lane and Eynon described by Ranganna (1979) was adopted for estimation of reducing

sugar. The method is based on the principle that invert sugar or reducing sugar reduced the copper in the Fehling's solution to red insoluble cuprous oxide. Sugar in a sample was estimated by determining the volume of unknown sugar solution required to completely reduce a measured volume of Fehling's solution. Before using the mixture (1:1) of Fehling's solution A and B was standardized against standard glucose for obtaining glucose equivalent and to arrive at a conversion factor.

Procedure:

A weighed amount of the pulp was taken in a volumetric flask and 2 milliliter of 45 per cent basic lead acetate solution was added for clarification. After 10 minutes, the solution was deleaded by adding potassium oxalate crystals in excess (added till excess of crystals remained undissolved) and the volume was made up to a known amount with distilled water and filtered through Whatman No. 1 filter paper. The filtrate was taken in a burette and titrated against boiling Fehling's mixture (5 ml of Fehling's solution A + 5 ml of Fehlings solution B) till the blue colour faded. Then 1 ml of methylene blue indicator (1%) was added and titration was continued till the contents attained a brick red colour and titre value was noted. The percentage of reducing sugar was calculated according to following formula.

$$\text{Reducing sugar (\%)} = \frac{\text{Glucose Eq. (0.05)}}{\text{Titre}} \times \frac{\text{Total volume made up}}{\text{Weight of the pulp}} \times 100$$

3.17.2.4 Total sugars (%)

For estimation of total sugars, the filtrate obtained in the above estimation was used. An aliquot of 25 ml from the filtrate was taken and to one-fifth of its volume, hydrochloride acid (1:1) was added and the inversion was carried out at room temperature for 24 hours. Subsequently, the contents were cooled and neutralized with 40 per cent sodium hydroxide using phenolphthalein as an indicator and the final volume 100 ml was made. The solution was filtered through Whatman No. 1 filter paper and titration was carried out using filtrate as detailed for reducing sugar.

The total sugars content were expressed as percentage in terms of invert sugars according to the formula.

$$\text{Total sugar (\%)} = \frac{\text{Glucose Eq. of Fehling's solutions (0.05)}}{\text{Titre}} \times \frac{\text{Total volume made up}}{\text{Weight of pulp taken}} \times \frac{\text{Volume made up after inversion}}{\text{Aliquot taken for inversion}} \times 100$$

3.18 Statistical Analysis

The statistical analysis of data for the different characters studied during the investigation was carried out with Complete Randomized Design with factorial concept as per the procedure given by Panse and Sukhatme (1967) and the treatment means were compared by means of critical differences at five Per cent level of probability.

EXPERIMENTAL RESULTS

IV. EXPERIMENTAL RESULTS

The experimental results of the present investigation entitled "Effect of maturity and storage temperature on shelf life and quality of banana (*Musa paradisiaca* L.) cv. Grand Nain" was conducted to enhance the shelf-life and improve the quality of banana. Experiment was conducted at Regional Horticultural Research Station, and Post Harvest Technology Centre, Navsari Agricultural University, Navsari during 2008-2009 are presented in this chapter.

In present chapter, the results are interpreted with the help of statistical inferences and presented under following subheads:

Shelf life of banana fruits subjected to M_3T_4 and M_2T_4 was 10 and 11.67 days, respectively. After 10 days of fruits storage, 80% of fruits decayed in treatment M_3T_4 and with remaining 20% fruits on 12^{th} day the analysis were done. On same day treatment M_2T_4 was also analyzed. Data are mentioned in table for both the treatments on 13^{th} day for physiological loss in weight, firmness of fruit, total soluble solids, titrable acidity, reducing sugar and total sugars.

A) Physical observations

4.1 Date of shooting

A perusal of data presented in table 4.1 revealed about date of shooting for respective treatments. The date of shooting was selected in treatment M_3 (100% maturity) in duration between 20^{th} to 31^{st} May 2008, treatment M_2 (90% maturity) was selected in between 4^{th} June to 9^{th} June and

treatment M_1 (75% maturity) was selected in between 17th and 18th June 2008. This duration adjusted according to harvesting time 75, 90 and 100 days after shooting.

4.2 Weight of bunch (kg)

The data pertaining to weight of bunch at different stage of maturity are presented in table 4.2 and graphically depicted in fig-1.

The data on weight of bunch indicated significant differences among different maturity stages. The weight of bunch was observed significantly higher in treatment M_3 (100% maturity) which was followed by M_2 (90% maturity) which was 21.80 kg and 19.51 kg, respectively. The minimum weight of bunch (17.83 kg) was observed in 75% maturity (M_1).

4.3 Number of fingers per bunch

The data presented in table 4.2 for number of fingers per bunch of banana cv. Grand Nain showed non-significant differences among various treatments of maturity. However, in treatment M_1 (75% maturity) the number of fingers per bunch was higher (132.17) which was followed by with the treatment M_2 (90% maturity).

4.4 Weight of finger (g)

The data recorded on weight of finger under different maturity stages are presented in table 4.2 and graphically depicted in fig-2.

The weight of finger significantly affected by different maturity treatments. The highest weight of finger (168.12 g) was observed in treatment M_3 (100% maturity)

whereas, the minimum weight of finger (137.22 g) was observed in treatment M_1 (75% maturity).

4.5 Green, yellow and shelf life of fruits (days)

The data pertaining to green, yellow and shelf life of banana fruits under different maturity and storage temperature treatments are presented in table 4.3 and graphically depicted in fig-3.

4.5.1 Effect of maturity on green, yellow and shelf life of fruits (days)

The data recorded (table 4.3) on green, yellow and shelf life of banana fruits under different treatments of maturity stages showed significant differences.

Green, yellow and shelf life of fruits under different maturity stages were recorded significantly the highest (23.25, 8.25 and 31.50 days, respectively) in treatment M_1 (75% maturity) which was followed by M_2 (90% maturity). At 100% maturity (M_3) green, yellow and shelf life (16.92, 5.83 and 22.75 days, respectively) of fruits were observed minimum.

4.5.2 Effect of storage temperature on green, yellow and shelf life of fruits (days)

From the data (table 4.3), it was observed that there were significant differences occur in green, yellow and shelf life of fruits due to different treatments of storage temperature.

The data revealed that the green and shelf life of fruits were significantly maximum (29.89 and 38.67 days, respectively) in treatment T_1 (12^0C) which was followed by T_2 (14^0C). The minimum green and shelf life (8.11, 3.56 and

Table 4.1: Shooting period of banana Cv. Grand Nain

Treatment combination		Date of shooting
M_1T_1	75% maturity: 12^0 C temperature	17th June 2008
M_1T_2	75% maturity: 14^0 C temperature	17th June 2008
M_1T_3	75% maturity: 16^0 C temperature	17th June 2008
M_1T_4	75% maturity: Room temperature	17th June 2008
M_2T_1	90% maturity: 12^0 C temperature	9th June 2008
M_2T_2	90% maturity: 14^0 C temperature	11th June 2008
M_2T_3	90% maturity: 16^0 C temperature	12th June 2008
M_2T_4	90% maturity: Room temperature	14th June 2008
M_3T_1	100% maturity: 12^0 C temperature	1st June 2008
M_3T_2	100% maturity: 14^0 C temperature	29th may 2008
M_3T_3	100% maturity: 16^0 C temperature	1st June 2008
M_3T_4	100% maturity: Room temperature	3rd June 2008

Table 4.2: Effect of maturity on weight of bunch, number of fingers per bunch and weight of the finger of banana Cv. Grand Nain

Treatments	Weight of bunch (kg)	Number of fingers per bunch	Weight of the fruit (g)
Maturity (M)			
M_1 – 75%	17.83	132.17	137.22
M_2– 90%	19.51	129.83	153.46
M_3– 100%	21.80	132.08	168.12
S. Em.±	0.29	2.52	4.21
C. D. at 5%	0.86	NS	12.30
CV%	5.17	6.65	9.54

Fig 1: Effect of maturity on weight of bunch

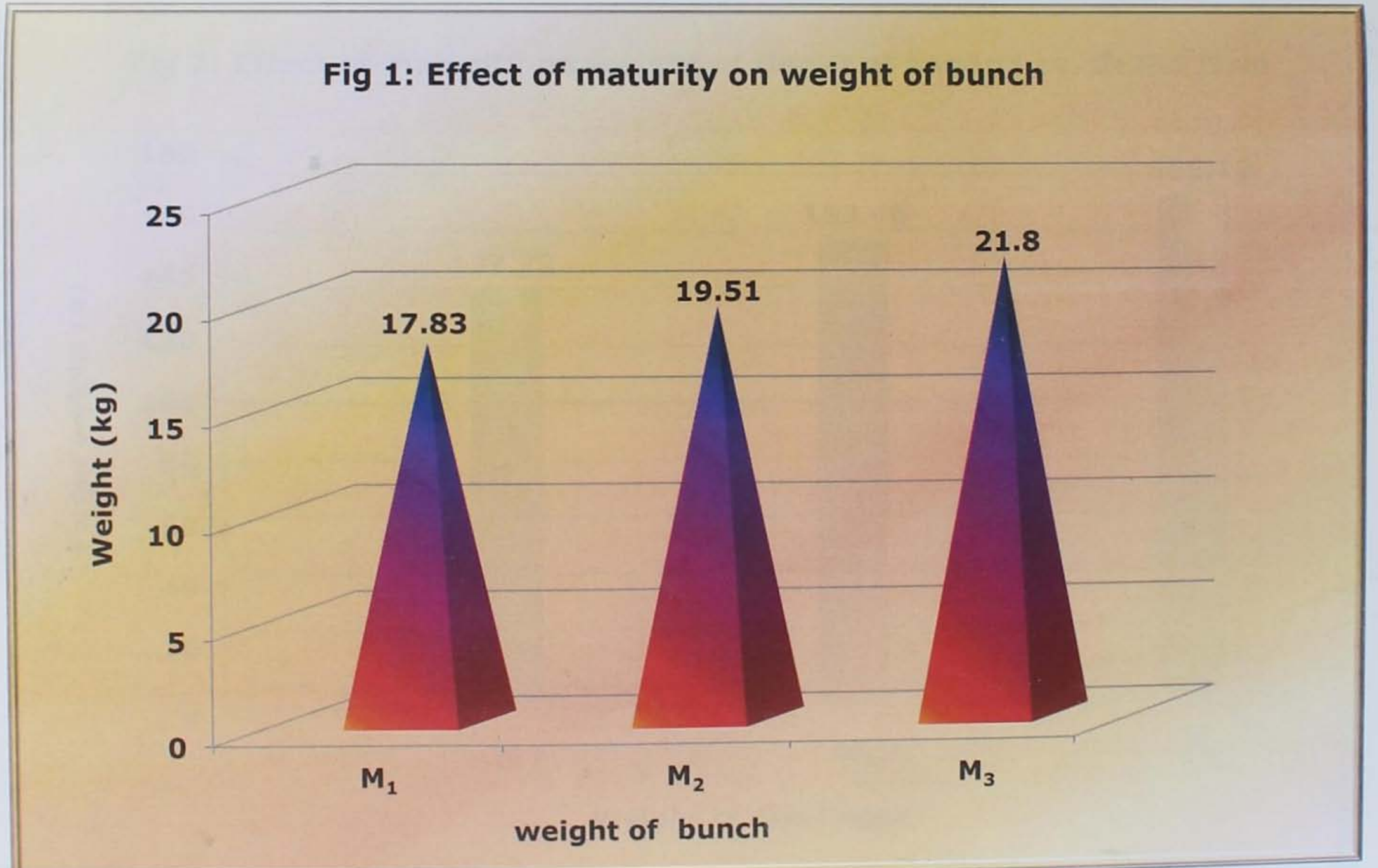
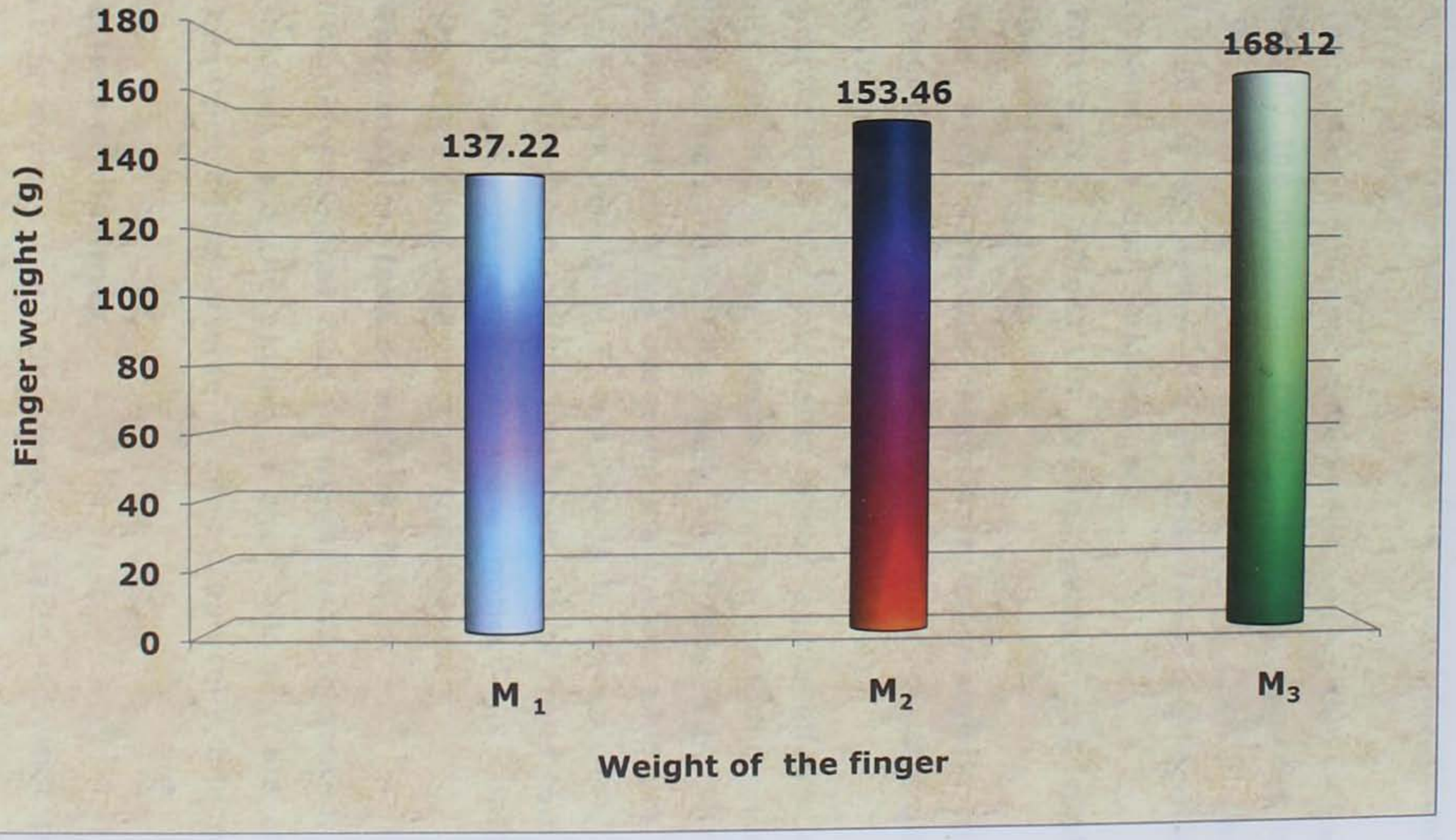


Fig 2: Effect of maturity on weight of finger of banana cv. Grand Nain



11.67 days, respectively) were observed in control treatment T_4 (room temperature).

There was significant differences among the yellow life of fruits and the maximum (9.78 days) was recorded in treatment T_2 (14^0C) which was followed by T_1 (12^0C). The minimum (3.56 days) yellow life of fruit was recorded in control treatment T_4 (room temperature).

4.5.3 Interaction effect on green, yellow and shelf life of fruit (days)

The mean data on interaction of maturity and storage temperature on green, yellow and shelf life of fruits showed significant differences (table 4.4 and fig-4).

Significantly the maximum green and shelf life of banana fruits (35 and 45 days, respectively) were found under the treatment combination M_1T_1 which was followed by M_1T_2. However, yellow life of fruits observed maximum (12 days) in the treatment combination M_1T_2 which was followed by M_2T_2. Whereas, minimum green, yellow and shelf life of fruits (6.67, 3.33 and 10 days, respectively) were noticed in control treatment (M_3T_4) as compared to other treatments.

4.6 Physiological loss in weight (%)

The physiological loss in weight was measured at two days interval upto the ending of shelf life of fruits and data have been presented in table 4.5 and graphically depicted in fig-5.

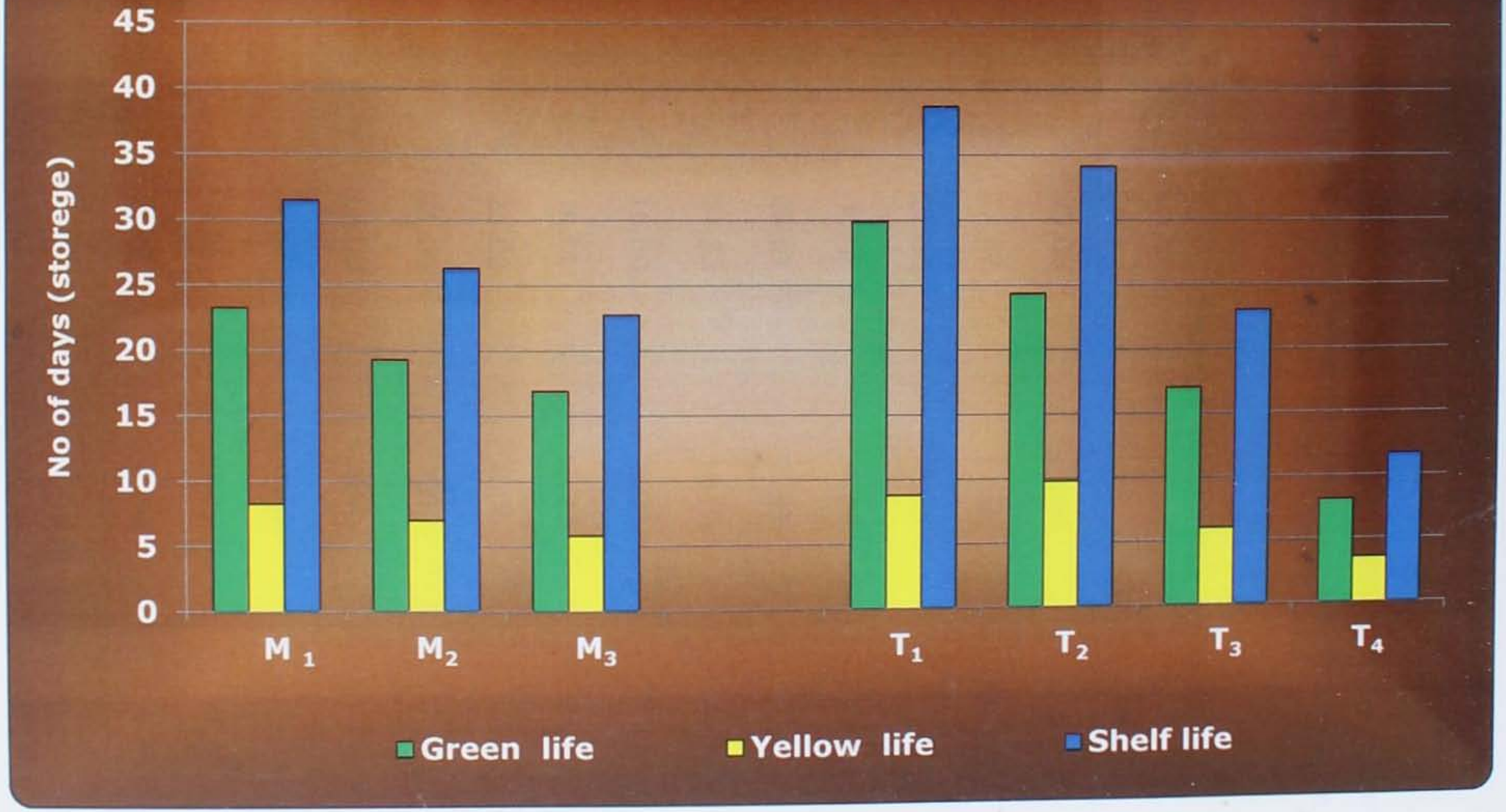
4.6.1 Effect of maturity

It is evident from the data in table 4.5 that the physiological loss in weight was significantly influenced by

Table 4.3: Effect of maturity and storage temperature on green yellow and shelf life of banana cv. Grand Nain

Treatments	Storage Period (No. of days)		
	Green life	Yellow life	Shelf life
Maturity (M)			
M_1 – 75%	23.25	8.25	31.50
M_2 – 90%	19.33	7.00	26.33
M_3 – 100%	16.92	5.83	22.75
S. Em.±	0.12	0.13	0.13
C. D. at 5%	0.34	0.37	0.37
Storage temperature (T)			
T_1 - 12^{0}C	29.89	8.78	38.67
T_2 - 14^{0}C	24.33	9.78	34.11
T_3 - 16^{0}C	17.00	6.00	23.00
T_4 – control	8.11	3.56	11.67
S. Em.±	0.14	0.15	0.15
C. D. at 5%	0.40	0.43	0.43
Interaction Effect (M x T)			
S. Em.±	0.24	0.25	0.25
C. D. at 5%	0.69	0.74	0.74
CV%	2.06	6.27	1.64

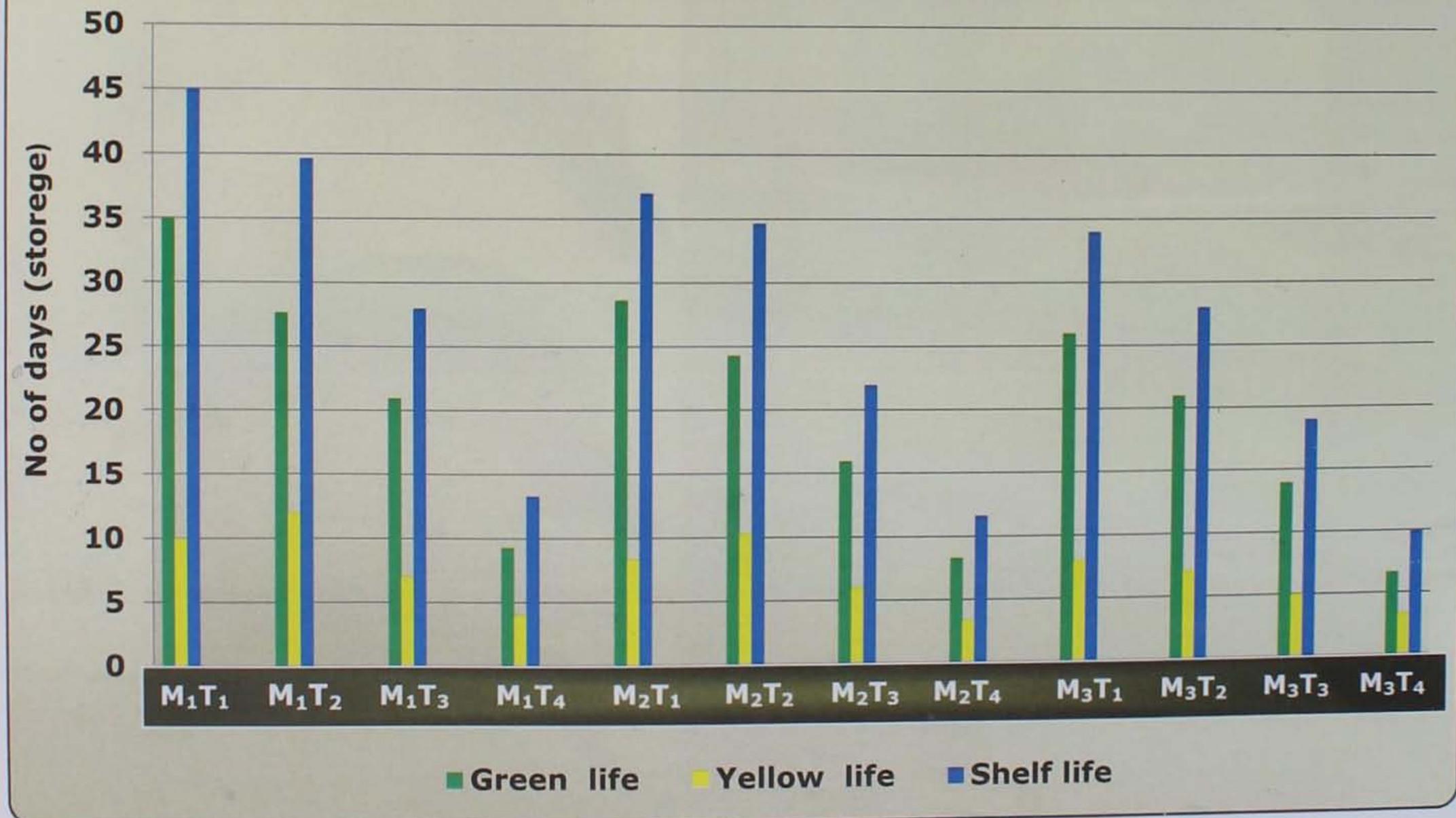
Fig 3: Effect of maturity and storage temperature on green yellow and shelf life of banana cv. Grand Nain



4.4 Table: Interaction effect of maturity and storage temperature on green, yellow and shelf life of banana cv. Grand Nain

Treatments Combination	Storage Period (No. of days)		
	Green life	Yellow life	Shelf life
M_1T_1	35.00	10.00	45
M_1T_2	27.67	12.00	39.67
M_1T_3	21.00	7.00	28
M_1T_4	9.33	4.00	13.33
M_2T_1	28.67	8.33	37
M_2T_2	24.33	10.33	34.67
M_2T_3	16.00	6.00	22
M_2T_4	8.33	3.33	11.67
M_3T_1	26.00	8.00	34
M_3T_2	21.00	7.00	28
M_3T_3	14.00	5.00	19
M_3T_4	6.67	3.33	10
S. Em.±	0.24	0.25	0.25
C. D. at 5%	0.69	0.74	0.74

Fig 4: Interaction effect of maturity and storage temperature on green, yellow and shelf life of banana cv. Grand Nain



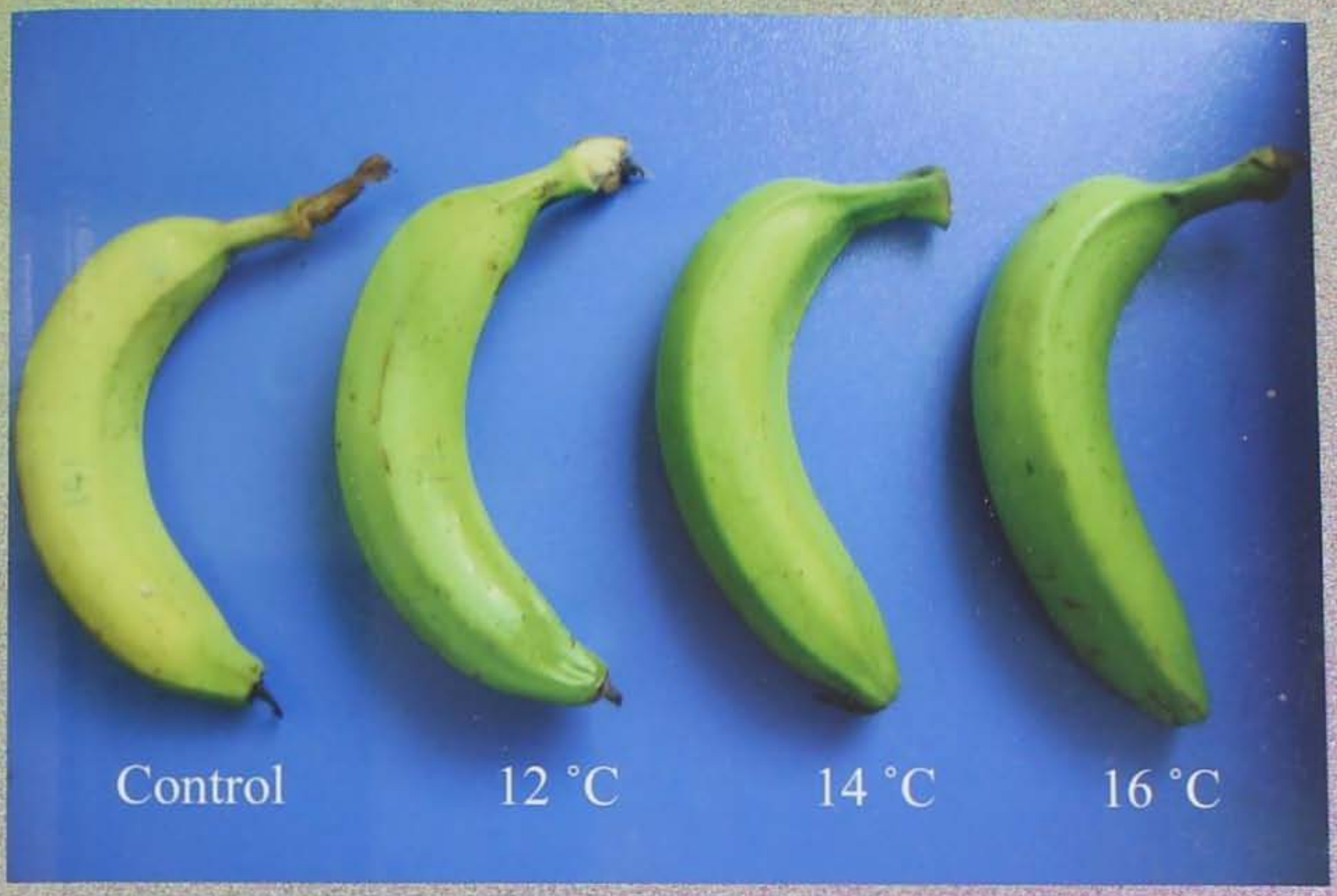


Plate 5: Fruits of 75 % maturity after 10 days of storage

Plate 6: Fruits of 75 % maturity after 23 days of storage

Plate 7: Fruits at 90% maturity of banana
cv. Grand Nain

Plate 8: Fruits at 100% maturity of banana
cv. Grand Nain

various treatments of maturity stages. Consistently, significantly minimum physiological loss in fruits weight was observed in treatment M_1 (75% maturity) at 4^{th}, 7^{th}, 10^{th}, 13^{th}, 16^{th} and 19^{th} day of fruits storage (1.97, 3.77, 6.17, 7.93, 6.55 and 7.84 per cent, respectively) which was at par with M_2 at 10^{th}, 16^{th} and 19^{th} day of fruits storage. The highest physiological loss in weight was observed in M_3 (100% maturity) at 4^{th}, 7^{th}, 10^{th} and 13^{th} day of fruits storage (2.27, 4.41, 6.94, 9.45, per cent, respectively).

4.6.2 Effect of storage temperature

Physiological loss in weight was significantly differed at various storage treatments (table 4.5).

Significantly the minimum physiological loss in weight was observed in treatment T_1 (12^0C) at 4^{th}, 7^{th}, 10^{th}, 13^{th}, 16^{th} and 19^{th} day of fruit storage (1.44, 2.56, 4.37, 5.38, 6.72 and 7.93 per cent, respectively). At 10^{th} and 19^{th} day of fruit storage, treatment T_1 (12^0C) was at par with treatment T_2 (14^0C). In control treatment T_4 (room temperature) physiological loss in weight was observed higher at 4^{th}, 7^{th} 10^{th} and 13^{th} day of fruit storage (3.54, 7.62, 11.90 and 17.10 per cent, respectively).

4.6.3 Interaction effect up to 19^{th} day

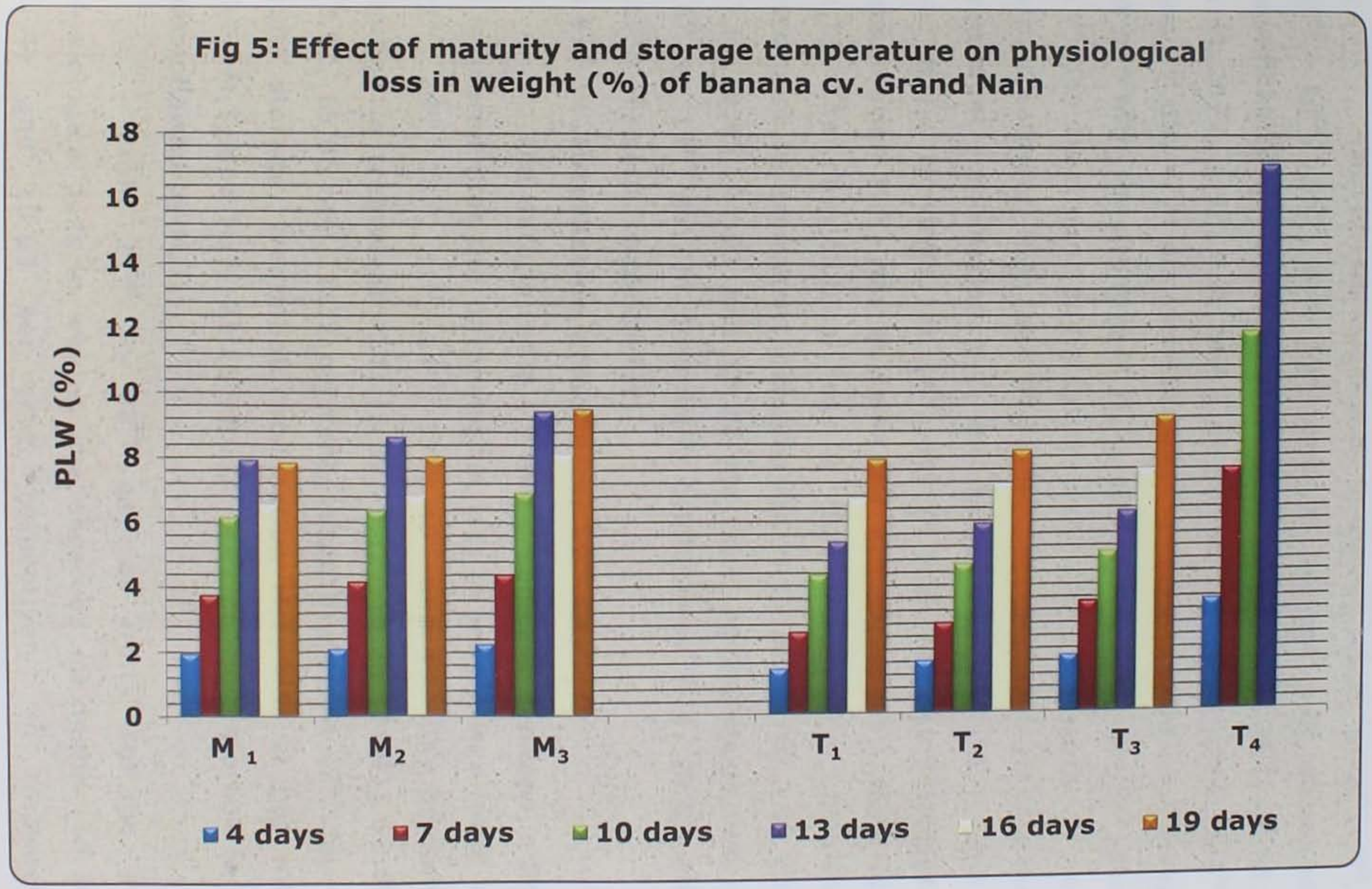
The mean data given in table 4.6 indicated that effect of interaction between maturity and storage temperature was found significant with regard to physiological loss in fruit weight.

Table 4.5: Effect of maturity and storage temperature on physiological loss in weight (%) of banana cv. Grand Nain

Treatments	Storage period (No. of days)					
	4th	7th	10th	13th	16th	19th
Maturity (M)						
M_1 – 75%	1.97	3.77	6.17	7.93	6.55	7.84
M_2 – 90%	2.10	4.17	6.39	8.66	6.82	8.04
M_3 – 100%	2.27	4.41	6.94	9.45	8.09	9.50
S. Em.±	0.03	0.06	0.09	0.10	0.09	0.11
C. D. at 5%	0.08	0.17	0.27	0.28	0.28	0.34
Storage temperature (T)						
T_1 - 12°C	1.44	2.56	4.37	5.38	6.72	7.93
T_2 - 14°C	1.66	2.82	4.68	5.93	7.15	8.20
T_3 - 16°C	1.80	3.48	5.05	6.30	7.60	9.25
T_4 – control	3.54	7.62	11.90	17.10	**	**
S. Em.±	0.03	0.07	0.11	0.11	0.09	0.11
C. D. at 5%	0.09	0.20	0.32	0.32	0.28	0.34
Interaction Effect (M x T)						
S. Em.±	0.06	0.11	0.19	0.19	0.16	0.20
C. D. at 5%	0.16	0.34	0.55	0.56	0.49	0.59
CV%	4.57	4.83	5.00	3.83	3.96	4.03

** – The fruits were not available for analysis due to decayed.

Fig 5: Effect of maturity and storage temperature on physiological loss in weight (%) of banana cv. Grand Nain



The physiological loss in fruits weight at 4th, 7th, 10th, 13th, 16th and 19th day of storage was observed significantly minimum in treatment combination M_1T_1 (1.41, 2.41, 3.72, 4.92, 6.33 and 7.69 per cent, respectively). At 4th and 7th day of fruits storage, treatment combination M_1T_1 was at par with the treatment M_2T_1, M_3T_1, and M_1T_2. At 10th and 13th day treatment combination M_1T_1 was statistically at par with treatment M_2T_1 and M_1T_2. At 16th day of fruit storage treatment combination M_1T_1 was at par with M_2T_1, M_1T_2, M_1T_3 and M_2T_2. However, at 19th day of fruit storage treatment combination M_1T_1 was at same bar with M_2T_1, M_1T_2, M_2T_2 and M_1T_3. The physiological loss in fruit weight was observed maximum in treatment combination M_3T_4 at 4th to 13th day (3.81, 8.05, 11.91 and 18.23 per cent, respectively) and at 16th to 19th day in treatment combination M_3T_3 (9.02 and 11.30 per cent, respectively).

4.6.4 Interaction effect after 19th day

The data in table 4.7 and graphically depicted in fig-6 indicated that the physiological loss in weight was lower at 22nd, 25th, 28th, 31st, 34th, 37th, 40th and 43rd day of fruits storage in treatment M_1T_1 (8.37, 9.12, 10.05, 11.41, 12.67, 13.91, 15.06 and 17.32 per cent, respectively). At 22nd day of fruits storage, treatment combination M_1T_1 was at par with M_2T_1, M_1T_2 and M_2T_2. At 25th to 34th day of fruits storage M_1T_1 was followed by M_1T_2.

From 22nd to 28th day of fruits storage the physiological loss in weight was observed maximum (10.36, 11.41 and 13.63 per cent, respectively) in treatment

Table 4.6: Interaction effect of maturity and storage temperature on physiological loss in weight (%) of banana cv. Grand Nain

Treatments combination	Storage period (No. of days)					
	4th	7th	10th	13th	16th	19th
M_1T_1	1.41	2.41	3.72	4.92	6.33	7.69
M_1T_2	1.52	2.75	4.26	5. 46	6.61	7.83
M_1T_3	1.66	2.88	4.76	5.66	6.72	8.01
M_1T_4	3.28	7.06	11.94	15.67	**	**
M_2T_1	1.45	2.54	4.20	5. 35	6.58	7.73
M_2T_2	1.65	2.79	4.58	5.75	6.82	7.93
M_2T_3	1.75	3.63	4.95	6.12	7.07	8.44
M_2T_4	3.53	7.74	11.84	17.41	**	**
M_3T_1	1.47	2.74	5.20	5.87	7.25	8.37
M_3T_2	1.82	2.92	5.19	6.57	8.00	8.84
M_3T_3	1.99	3.92	5.45	7.11	9.02	11.30
M_3T_4	3.81	8.05	11.91	18.23	**	**
S. Em.±	0.06	0.11	0.19	0.19	0.16	0.20
C. D. at 5%	0.16	0.34	0.55	0.56	0.49	0.59

** – The fruits were not available for analysis due to decayed.

combination M_3T_2. While it was maximum at 31st and 34th day (14.14 and 16.42 per cent, respectively) in treatment combination M_3T_1, at 37th day in treatment combination M_2T_1 (16.43 per cent) and at 40th day in M_1T_2 (17.3 per cent).

4.7 Organoleptic qualities at ripening (colour, flavour, texture and taste)

The mean data regarding the organoleptic qualities at ripening influenced by various treatments of maturity and storage temperature are presented in table 4.8.

4.7.1 Effect of maturity

The data pertaining to organoleptic qualities showed no significant effect at ripening except flavour. The maximum points for flavour obtained (7.18) in treatment M_3 (100% maturity) which was at par with M_2 (90% maturity).

4.7.2 Effect of storage temperature

The data in table 4.8 revealed that the organoleptic quality was influenced significantly by different storage temperature.

Organoleptic qualities related to colour, flavour, texture and taste at ripening, was observed significantly the maximum (7.85, 7.50, 7.59 and 7.58, respectively) in treatment T_3 which was at par with treatment T_2 (14^0C) with respect to texture and taste. The minimum ranking was observed in control treatment T_4 (room temperature) for colour, flavour, texture and taste (6.18, 6.72, 6.71 and 7.11 ,respectively).

Table 4.7: Interaction effect of maturity and storage temperature on physiological loss in weight (%) of banana cv. Grand Nain (after 19th day)

Treatments combination	Storage period (No. of days)							
	22nd *	25th *	28th *	31st *	34th *	37th	40th	43rd
M_1T_1	8.37	9.12	10.05	11.41	12.67	13.91	15.06	17.32
M_1T_2	8.95	10.05	11.21	12.37	13.52	15.81	17.3	**
M_1T_3	9.41	10.25	11.5	**	**	**	**	**
M_2T_1	8.89	10.07	11.41	12.62	13.76	16.43	**	**
M_2T_2	8.98	10.71	11.74	12.88	14.59	**	**	**
M_2T_3	9.67	**	**	**	**	**	**	**
M_3T_1	9.93	11.37	13.32	14.14	16.42	**	**	**
M_3T_2	10.36	11.41	13.63	**	**	**	**	**
S. Em.±	0.21	0.24	0.22	0.26	0.26	--	--	--
C. D. at 5%	0.63	0.72	0.65	0.81	0.82	--	--	--
CV%	3.93	3.93	3.16	3.49	3.18	--	--	--

*- Data were analyzed using Complete Randomized Design (CRD).
**- The fruits were not available for analysis due to decayed.

Fig 6: Interaction effect of maturity and storage temperature on physiological loss in weight (%) of banana cv. Grand Nain (after 19th day)

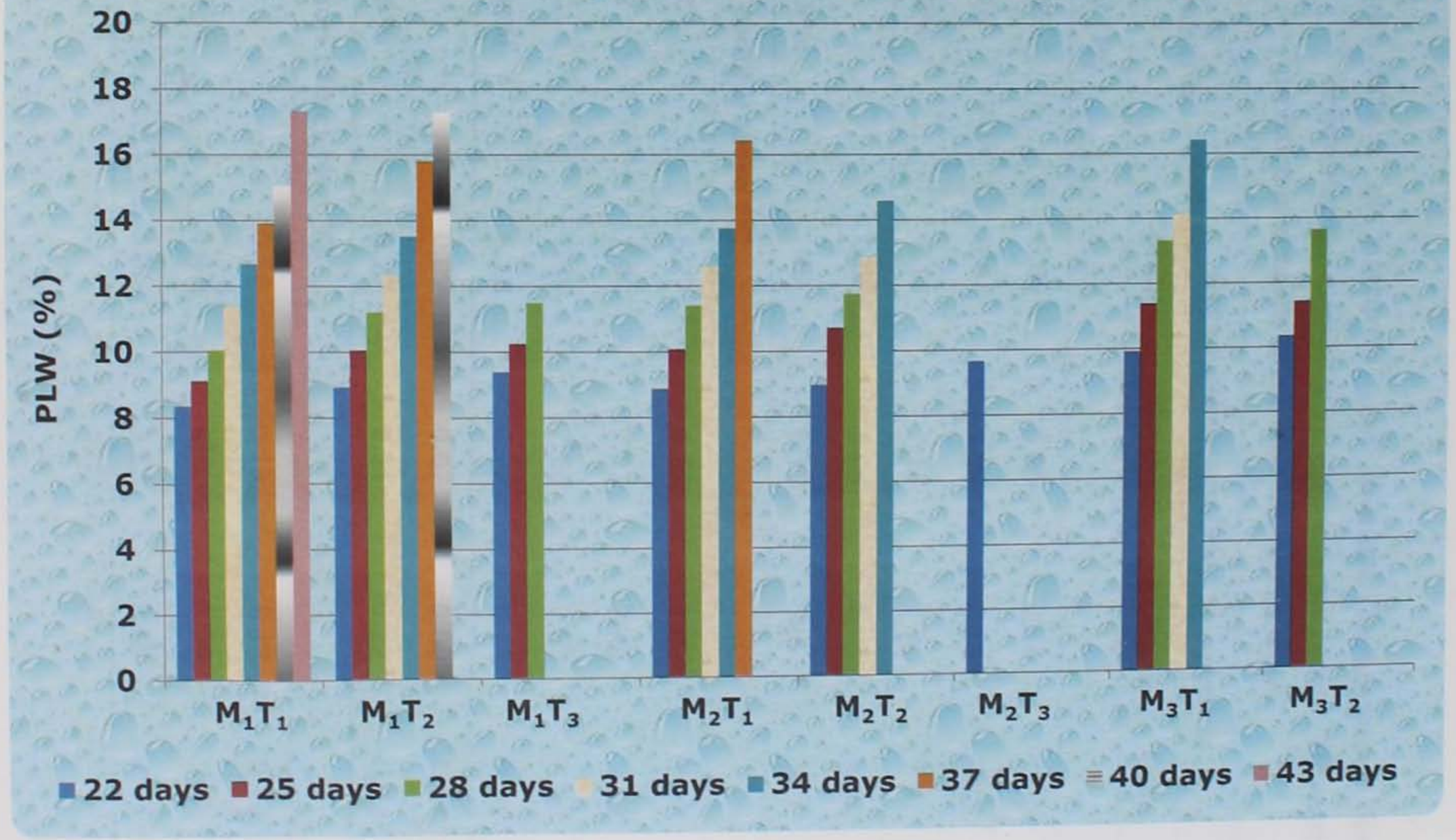


Table 4.8: Effect of maturity and storage temperature on organoleptic qualities at ripening on colour, flavour, texture and taste of banana cv. Grand Nain

Treatments	Organoleptic qualities at ripening			
	Colour	Flavour	Texture	Taste
Maturity (M)				
M_1 – 75%	6.88	6.85	7.14	7.29
M_2 – 90%	6.94	7.04	7.16	7.35
M_3 – 100%	7.10	7.18	7.30	7.37
S. Em.±	0.08	0.06	0.07	0.08
C. D. at 5%	NS	0.19	NS	NS
Storage temperature (T)				
T_1 - 12°C	6.77	6.65	7.01	7.13
T_2 - 14°C	7.09	7.23	7.49	7.53
T_3 - 16°C	7.85	7.50	7.59	7.58
T_4 – control	6.18	6.72	6.71	7.11
S. Em.±	0.09	0.07	0.08	0.07
C. D. at 5%	0.27	0.21	0.22	0.21
Interaction Effect (M x T)				
S. Em.±	0.16	0.13	0.13	0.12
C. D. at 5%	0.47	NS	0.39	NS
CV%	3.96	3.13	3.19	2.93

4.7.3 Interaction effect

The data in table 4.9 showed that the organoleptic quality of fruits due to interaction effect of maturity and storage temperature was significant for colour and taste. While flavour and texture were failed to show any significant difference.

The interaction effect indicated that the best colour and texture were observed at 16^0C (T_3) at all maturity stages as compared to other treatments. The highest scored for colour and texture was found (8.17 and 7.92, respectively) in treatment combination M_3T_3 which was at par with M_2T_3 in respect of colour and with M_3T_2 in respect of texture.

The treatments combinations of all maturity stages with room temperature (M_3T_4, M_2T_4, and M_1T_4) were scored minimum as compared to other treatments in respect of colour and taste.

4.8 Firmness of fruit (kg/cm^2)

The mean data pertaining to firmness of fruit (kg/cm^2) are presented in table 4.10 and graphically depicted in fig-7.

4.8.1 Effect of maturity

Firmness of fruit varied significantly under different maturity stages (table 4.10). The significantly higher firmness at 4th, 7th, 10th, 13th, 16th and 19th day of fruit storage (17.17, 15.58, 13.58, 12.09, 13.30 and 11.98 kg/cm^2, respectively) was recorded in treatment M_1 (75% maturity) which was followed by M_2 (90% maturity). Whereas, minimum firmness of fruit at all above stage (15.43, 13.73, 11.02, 8.84, 9.24 and

Table 4.9: Interaction effect of maturity and storage temperature on organoleptic qualities at ripening on colour and texture of banana cv. Grand Nain

Treatments combination	Organoleptic qualities at ripening	
	Colour	Texture
M_1T_1	6.76	7.04
M_1T_2	6.47	7.20
M_1T_3	7.50	7.43
M_1T_4	6.80	6.87
M_2T_1	6.52	6.85
M_2T_2	7.40	7.40
M_2T_3	7.88	7.43
M_2T_4	5.96	6.96
M_3T_1	7.04	7.14
M_3T_2	7.40	7.87
M_3T_3	8.17	7.92
M_3T_4	5.79	6.29
S. Em.±	0.16	0.13
C. D. at 5%	0.47	0.39

Plate 9: Fruits after colour breaking stage under different maturity stages at 16 °C

Plate 10: Fruit goes under senescence at 16 °C in banana cv. Grand Nain

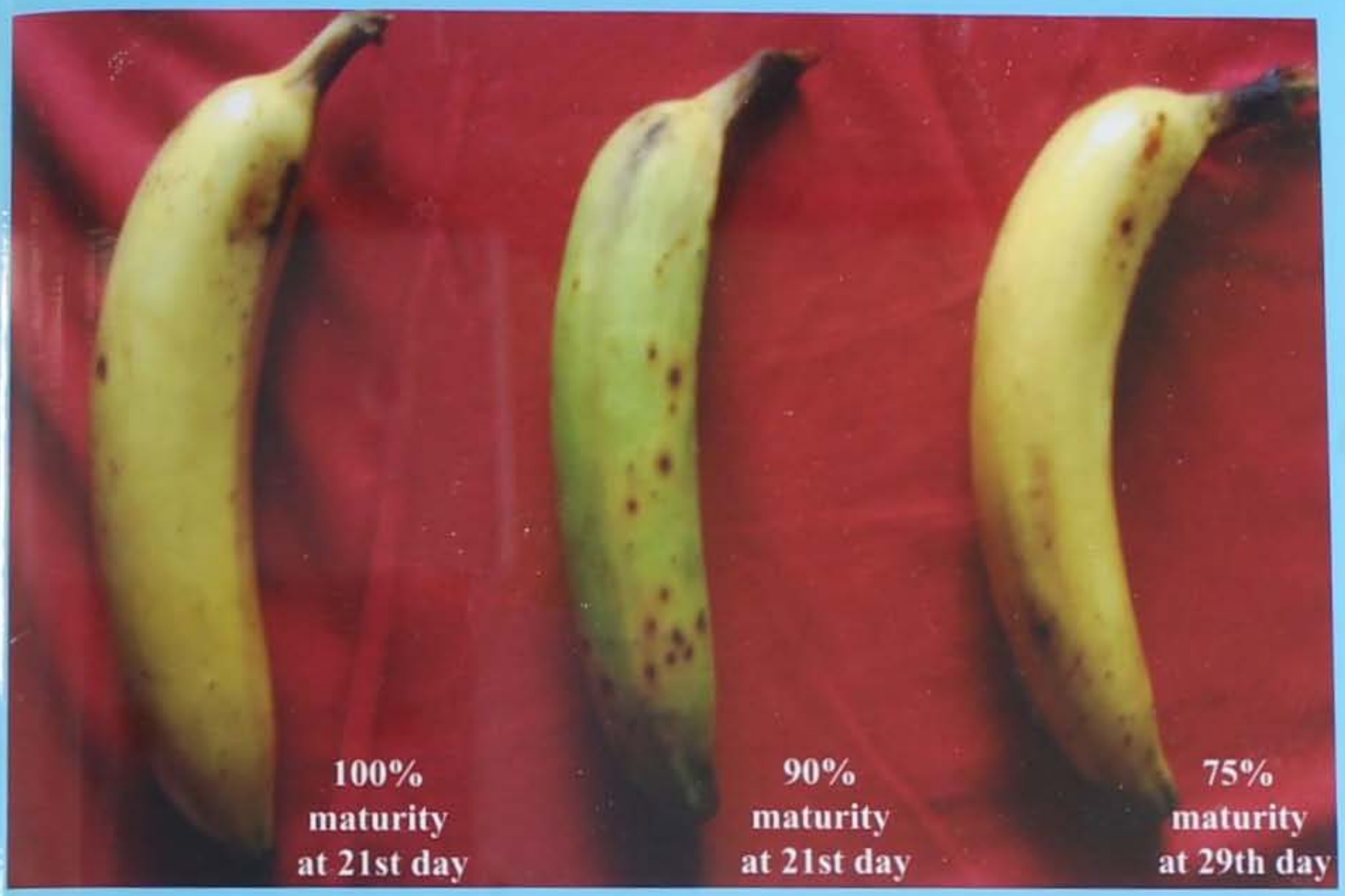


Plate 11: Fruits of different maturity stages at colour breaking stage under 14° C

Plate 12: Fruits at 100% maturity of banana cv. Grand Nain

7.60 kg/cm^2, respectively) was observed in treatment M_3 (100% maturity).

4.8.2 Effect of storage temperature

The data in table 4.10 revealed that firmness of fruit was significantly maximum in treatment T_1 (12^{0}C) at 4th, 7th, 10th, 13th, 16th and 19th day of storage (16.66, 16.49, 15.53, 14.60, 13.27 and 12.07 kg/cm^2, respectively).

At 4th day, treatment T_1 was at par with treatment T_2 (14^{0}C) and T_3 (16^{0}C) while at 7th and 10th day treatment T_1 was at par with T_2. Whereas, at 13th to 19th day treatment T_1 was followed by treatment T_2.

The minimum firmness of fruit at 4th to 13th day of storage (15.88, 10.36, 5.54 and 3.19 kg/cm^2, respectively) was observed in control treatment T_4 (room temperature).

After 13th day of storage the fruits were decayed in treatment T_4 and fruits were not available for analysis therefore, at 16th and 19th day of fruit storage minimum (9.24 and 6.84 kg/cm^2, respectively) firmness of fruit was recorded in treatment T_3 (16^{0}C).

4.8.3 Interaction effect upto 19th day.

The mean data related to firmness of fruit affected by interaction between maturity and storage temperature are presented in table 4.11.

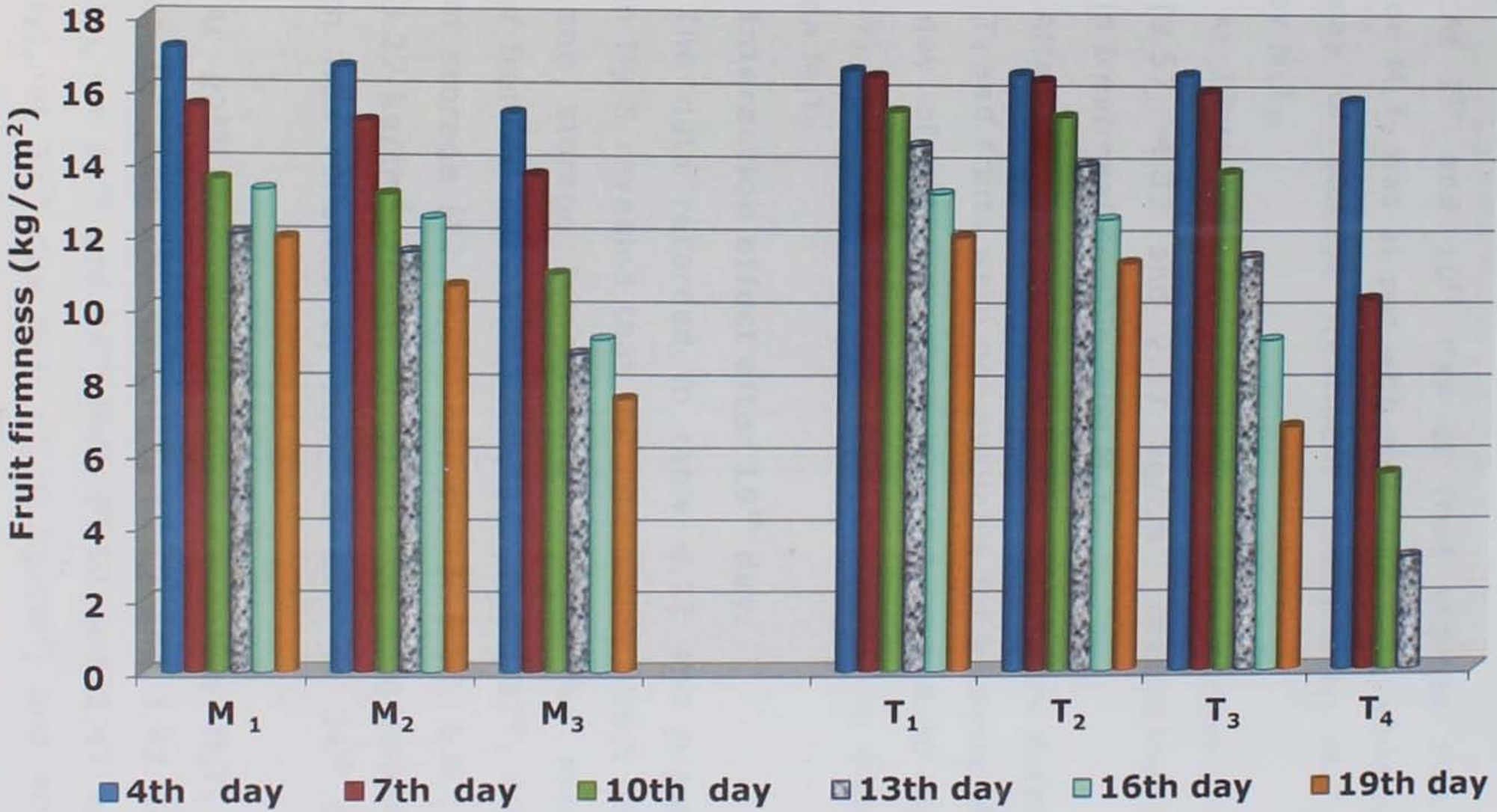
The firmness of fruit was failed to show significant influence at 4th day of storage while it was significantly influenced at 7th to 19th day of storage. The maximum

Table 4.10: Effect of maturity and storage temperature on fruit firmness (kg/cm^2) of banana cv. Grand Nain

Treatments	Storage period (No. of days)					
	4th	7th	10th	13th	16th	19th
Maturity (M)						
M_1 – 75%	17.17	15.58	13.58	12.09	13.30	11.98
M_2 – 90%	16.68	15.19	13.18	11.61	12.54	10.69
M_3 – 100%	15.43	13.73	11.02	8.84	9.24	7.60
S. Em.±	0.05	0.06	0.07	0.06	0.08	0.08
C. D. at 5%	0.15	0.17	0.21	0.16	0.23	0.23
Storage temperature (T)						
T_1 - 12°C	16.66	16.49	15.53	14.60	13.27	12.07
T_2 - 14°C	16.58	16.39	15.41	14.06	12.58	11.36
T_3 - 16°C	16.58	16.09	13.87	11.54	9.24	6.84
T_4 – control	15.88	10.36	5.54	3.19	**	**
S. Em.±	0.06	0.07	0.09	0.07	0.08	0.08
C. D. at 5%	0.17	0.19	0.25	0.19	0.23	0.23
Interaction Effect (M x T)						
S. Em.±	0.10	0.11	0.15	0.11	0.13	0.14
C. D. at 5%	NS	0.33	0.43	0.33	0.39	0.41
CV%	1.06	1.34	2.03	1.80	1.96	2.34

** – The fruits were not available for analysis due to decayed.

Fig 7: Effect of maturity and storage temperature on fruit firmness (kg/cm²) of banana cv. Grand Nain



firmness of fruit was noted under treatment combination M_1T_1 at all stages of observations.

At 7^{th} and 10^{th} day of fruit storage treatment combination M_1T_1 was at par with M_1T_2 and M_1T_3 while at 13^{th} to 19^{th} day of storage treatment combination M_1T_1 was followed by M_1T_2.

At 7^{th} to 13^{th} day of storage the minimum firmness of fruit (9.57, 4.33 and 2.57 kg/cm^2, respectively) was observed in treatment combination M_3T_4.

After 13^{th} day of storage the fruits were decayed in treatment T_4 and fruits were not available for analysis. At 16^{th} and 19^{th} day of storage minimum (5.3 and 4.00 kg/cm^2, respectively) firmness of fruit was observed in treatment combination M_3T_3.

4.8.4 Interaction effect after 19^{th} day.

The data recorded in table 4.12 and graphically depicted in fig-8 revealed that the interaction effect between maturity and storage temperature showed the maximum firmness of fruit at 22^{nd}, 25^{th}, 28^{th}, 31^{st}, 34^{th}, 37^{th}, 40^{th} and 43^{rd} day of storage (12.50, 11.40, 10.33, 8.80, 6.67, 5.17, 4.43 and 3.27 kg/cm^2, respectively) in treatment combination M_1T_1 which was followed by M_1T_2 at 22^{nd} to 34^{th} day of storage.

At 22^{nd} day, treatment combination M_2T_3 (4.63 kg/cm^2), at 25^{th} and 28^{th} day M_3T_2 (5.17 and 3.47 kg/cm^2, respectively), at 31^{st} and 34^{th} M_3T_1 (3.57 and 2.47 kg/cm^2, respectively), at 37^{th} day M_2T_1 (3.10 kg/cm^2) and 40^{th} day

Table 4.11: Interaction effect of maturity and storage temperature on fruit firmness (kg/cm^2) of banana cv. Grand Nain

Treatments combination	Storage period (No. of days)				
	7th	10th	13th	16th	19th
M_1T_1	17.20	16.17	15.57	14.5	13.40
M_1T_2	17.10	16.10	15.17	13.9	12.80
M_1T_3	17.10	15.73	13.87	11.5	9.73
M_1T_4	10.90	6.30	3.77	**	**
M_2T_1	16.77	15.70	14.70	13.47	12.67
M_2T_2	16.80	15.63	14.47	13.23	12.60
M_2T_3	16.60	15.37	14.03	10.93	6.80
M_2T_4	10.60	6.00	3.23	**	**
M_3T_1	15.50	14.73	13.53	11.83	10.13
M_3T_2	15.27	14.50	12.53	10.6	8.67
M_3T_3	14.57	10.50	6.73	5.3	4.00
M_3T_4	9.57	4.33	2.57	**	**
S. Em.±	0.11	0.15	0.11	0.13	0.14
C. D. at 5%	0.33	0.43	0.33	0.39	0.41

** – The fruits were not available for analysis due to decayed.

M_1T_2 (3.00 kg/cm^2) noted minimum firmness of fruits at their ripening stages.

4.9 Pulp: Peel ratio at ripening

The data on pulp: peel ratio of ripened fruits as affected by maturity stages and storage temperature are presented in table 4.13.

4.9.1 Effect of maturity

There were significant differences observed in the maturity treatments with respect to pulp: peel ratio (table 4.13). The data showed that the pulp: peel ratio at ripening was significantly maximum (3.39) in treatment M_3 (100% maturity), which was followed by M_2 (90% maturity). The minimum (2.37) pulp: peel ratio was observed in treatment M_1 (75% maturity).

4.9.2 Effect of storage temperature

The effect of storage temperature on pulp: peel ratio was found to be significantly higher (3.02) in control treatment T_4 (room temperature) which was followed by treatment T_3 (16^{0}C). The minimum (2.72) pulp: peel ratio was observed at 12^{0}C (T_1).

4.9.3 Interaction effect

Interaction effect between maturity stages of fruit and storage temperature failed to show any significant differences on pulp: peel ratio.

Table 4.12: Interaction effect of maturity and storage temperature on fruit firmness (kg/cm^2) of banana cv. Grand Nain (after 19th day)

Treatments combination	Storage period (No. of days)							
	22nd *	25th *	28th *	31st *	34th *	37th	40th	43rd
M_1T_1	12.50	11.40	10.33	8.80	6.67	5.17	4.43	3.27
M_1T_2	11.67	10.20	9.70	7.53	5.57	4	3	**
M_1T_3	8.20	6.53	4.90	**	**	**	**	**
M_2T_1	11.37	10.37	7.93	6.33	4.47	3.10	**	**
M_2T_2	9.77	7.90	5.60	4.57	3.43	**	**	**
M_2T_3	4.63	**	**	**	**	**	**	**
M_3T_1	8.37	5.67	4.73	3.57	2.47	**	**	**
M_3T_2	6.60	5.17	3.47	**	**	**	**	**
S. Em.±	0.13	0.14	0.09	0.13	0.08	--	--	--
C. D. at 5%	0.39	0.42	0.28	0.43	0.27	--	--	--
CV%	2.47	2.90	2.36	3.80	3.23	--	--	--

*- Data were analyzed using Complete Randomized Design (CRD).
**- The fruits were not available for analysis due to decayed.

Fig 8: Interaction effect of maturity and storage temperature on fruit firmness (kg/cm²) of banana cv. Grand Nain (after 19th day)

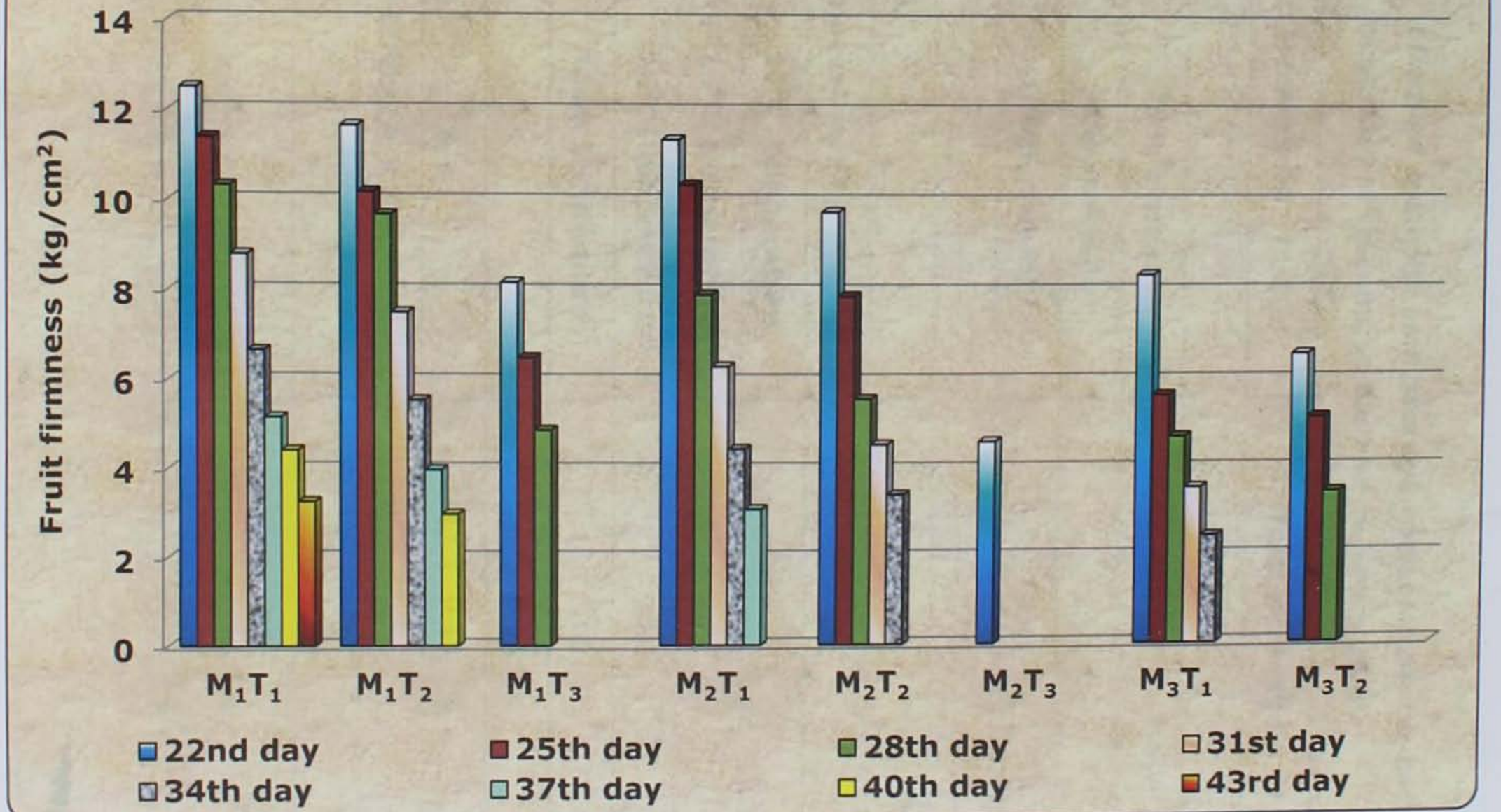


Table 4.13: Effect of maturity and storage temperature on pulp: peel ratio at ripening in banana cv. Grand Nain.

Treatments		Pulp: peel ratio
Maturity (M)		
M_1	**75% maturity**	2.37
M_2	**90% maturity**	2.73
M_3	**100% maturity**	3.39
S. Em.±		0.03
C. D. at 5%		0.08
Storage temperature (T)		
T_1	**12^{0}C temperature**	2.72
T_2	**14^{0}C temperature**	2.77
T_3	**16^{0}C temperature**	2.80
T_4	**Room temperature**	3.02
S. Em.±		0.03
C. D. at 5%		0.10
Interaction Effect (M x T)		
S. Em.±		0.06
C. D. at 5%		NS
CV%		3.52

B) Chemical observation

4.10 Total soluble solids (^{0}Brix)

The data on total soluble solids (^{0}Brix) noted at two days intervals upto fully ripened stage of fruits are presented in table 4.14 and graphically depicted in fig-9.

4.10.1 Effect of maturity

The data in table 4.14 revealed that total soluble solids (^{0}Brix) were significantly influenced by various treatments of maturity. Consistently, at 4th, 7th, 10th, 13th, 16th and 19th day of fruits storage significantly higher total soluble solids (4.78, 5.98, 9.38, 11.76, 11.33 and 13.63 ^{0}Brix, respectively) was observed in treatment M_3 (100% maturity) which was followed by M_2 (90% maturity). The minimum total soluble solids were observed in 75 % maturity of fruit (M_1) at 4th to 19th day of fruits storage (3.98, 4.48, 6.40, 9.85, 6.67 and 8.46 ^{0}Brix, respectively).

4.10.2 Effect of storage temperature

The data in table 4.14 revealed that at 4th, 7th, 10th and 13th day of fruits storage, significantly higher total soluble solids were noted (5.57, 7.91, 14.64, 22.04 ^{0}Brix, respectively) in control treatment T_4 (room temperature), which was followed by T_3 (16^{0}C).

The fruits subjected to room temperature (T_4) were decayed after 13th day. At 16th and 19th day of storage, total soluble solids were significantly higher (14.78 and 17.92 ^{0}Brix, respectively) in treatment T_3 (16^{0}C) which was followed by T_2 (14^{0}C).

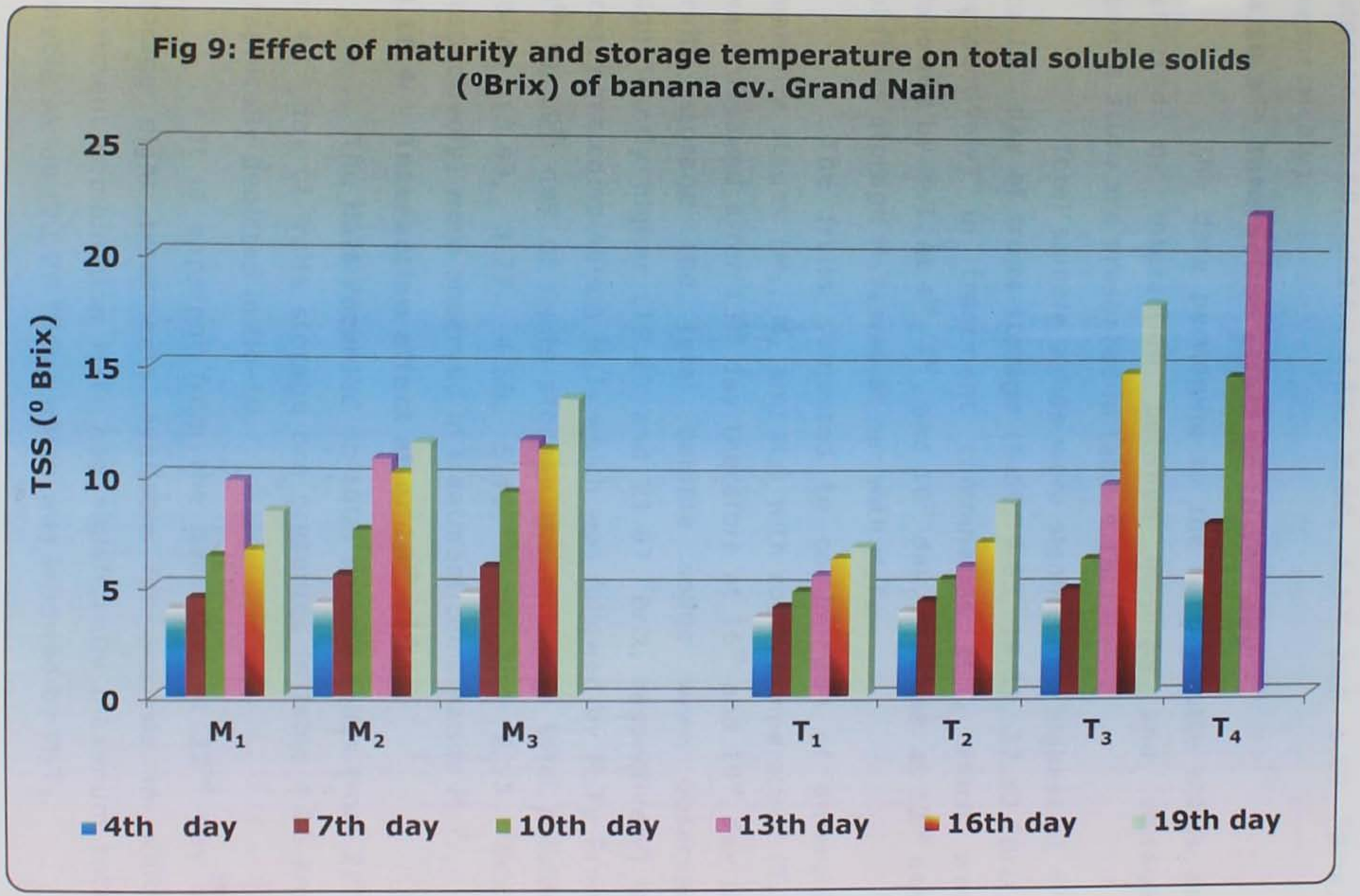
The minimum total soluble solids were observed in treatment T_1 (75% maturity) at 4th to 19th day of fruits

Table 4.14: Effect of maturity and storage temperature on total soluble solids (^{0}Brix) of banana cv. Grand Nain

Treatments	Storage period (No. of days)					
	4th	7th	10th	13th	16th	19th
Maturity (M)						
M_1 – 75%	3.98	4.48	6.40	9.85	6.67	8.46
M_2 – 90%	4.29	5.58	7.63	10.90	10.23	11.61
M_3 – 100%	4.78	5.98	9.38	11.76	11.33	13.63
S. Em.±	0.07	0.09	0.10	0.10	0.11	0.11
C. D. at 5%	0.20	0.25	0.29	0.28	0.31	0.34
Storage temperature (T)						
T_1 - 12^{0}C	3.68	4.14	4.86	5.60	6.37	6.89
T_2 - 14^{0}C	3.90	4.40	5.40	5.98	7.09	8.89
T_3 - 16^{0}C	4.26	4.93	6.31	9.72	14.78	17.92
T_4 – control	5.57	7.91	14.64	22.04	**	**
S. Em.±	0.08	0.10	0.11	0.11	0.11	0.11
C. D. at 5%	0.23	0.29	0.33	0.33	0.31	0.34
Interaction Effect (M x T)						
S. Em.±	0.14	0.17	0.20	0.19	0.18	0.20
C. D. at 5%	0.40	0.50	0.57	0.57	0.54	0.58
CV%	5.43	5.57	4.34	3.11	3.35	3.02

** – The fruits were not available for analysis due to decayed.

Fig 9: Effect of maturity and storage temperature on total soluble solids (⁰Brix) of banana cv. Grand Nain



storage (3.68, 4.14, 4.86, 5.60, 6.37 and 6.89 ^{0}Brix, respectively).

4.10.3 Interaction effect up to 19th day

The data pertaining to the total soluble solids as affected by interaction between maturity and storage temperature are presented in table 4.15.

Total soluble solids were significantly highest at 4th to 13th day of fruits storage (6.50, 9.63, 19.63, 22.30 ^{0}Brix, respectively) in treatment combination M_3T_4 which was followed by M_2T_4 at 4th, 7th, and 10th day. Whereas, at 13th day of fruits storage M_3T_4 was at par with M_2T_4.

The fruits subjected to combination of different maturity stages (M_1, M_2 and M_3) with room temperature (T_4) were decayed after 13th day therefore at 16th and 19th day of fruits storage the total soluble solids were observed significantly higher (19.20 and 21.67 ^{0}Brix, respectively) in treatment combination M_3T_3 which was followed by M_2T_3. From 4th to 19th day of fruits storage the minimum total soluble solids (3.43, 3.77, 4.50, 5.40, 6.10 and 6.53 ^{0}Brix, respectively) were observed in treatment combination M_1T_1.

4.10.4 Interaction effect after 19th day

The data recorded on total soluble solids from 22nd to 43rd day of fruits storage are presented in table 4.16 and graphically depicted in fig-10.

It is apparent from the data that at 22nd day of storage eight treatments available for analysis in which treatment combination M_2T_3 had significantly maximum total soluble solids (22.20 ^{0}Brix) which was followed by M_3T_2.

Table 4.15: Interaction effects of maturity and storage temperature on total soluble solids (^{0}Brix) of banana cv. Grand Nain

Treatments combination	Storage period (No. of days)					
	4th	7th	10th	13th	16th	19th
M_1T_1	3.43	3.77	4.50	5.40	6.10	6.53
M_1T_2	3.57	4.13	5.17	5.77	6.23	7.23
M_1T_3	4.07	4.70	5.87	6.60	7.67	11.60
M_1T_4	4.87	5.33	10.07	21.63	**	**
M_2T_1	3.67	4.27	4.80	5.57	6.50	6.90
M_2T_2	3.97	4.43	5.30	5.83	6.73	7.43
M_2T_3	4.20	4.87	6.20	10.00	17.47	20.50
M_2T_4	5.33	8.77	14.23	22.20	**	**
M_3T_1	3.93	4.40	5.27	5.83	6.50	7.23
M_3T_2	4.17	4.63	5.73	6.33	8.30	12.00
M_3T_3	4.50	5.23	6.87	12.57	19.20	21.67
M_3T_4	6.50	9.63	19.63	22.30	**	**
S. Em.±	0.14	0.17	0.20	0.19	0.18	0.20
C. D. at 5%	0.40	0.50	0.57	0.57	0.54	0.58

** – The fruits were not available for analysis due to decayed.

The data on total soluble solids revealed that with remaining seven treatments at 25th and 28th day of fruits storage, treatment combination M_1T_3 had significantly higher total soluble solids (21.37 and 22.23 ^{0}Brix, respectively) which was followed by M_3T_2 and M_2T_2.

The data on total soluble solids at 31st and 34th day of fruits storage in remaining five treatments, M_2T_2 had significantly higher total soluble solids (21.10 and 22.70 ^{0}Brix, respectively) which was followed by M_3T_1. However, at 37th, 40th and 43rd day of storage, it was higher in M_2T_1 (22.27 ^{0}Brix), M_1T_2 (22.60 ^{0}Brix) and M_1T_1 (22.40 ^{0}Brix), respectively.

Total soluble solids were observed minimum in treatment M_1T_1 at 22nd to 40th day of fruit storage (7.07, 7.57, 7.9, 9.73, 11.47, 14.50 and 18.73 ^{0}Brix, respectively).

4.11 Titrable acidity (%)

Data recorded on titrable acidity of banana fruit cv. Grand Nain under the different treatments of maturity and storage temperature are presented in table 4.17.

4.11.1 Effect of maturity

It is clear from the data that there were significant differences in titrable acidity under different maturity treatments.

Titrable acidity was found significantly minimum (0.096, 0.138, 0.202, 0.244, 0.229 and 0.283 per cent, respectively) in treatment M_1 (75% maturity) which was followed by M_2 (90% maturity) upto 4th to 16th day and at 19th day of fruits storage treatment M_1 was at par with M_2. However, in treatment M_3 (100% maturity) maximum titrable

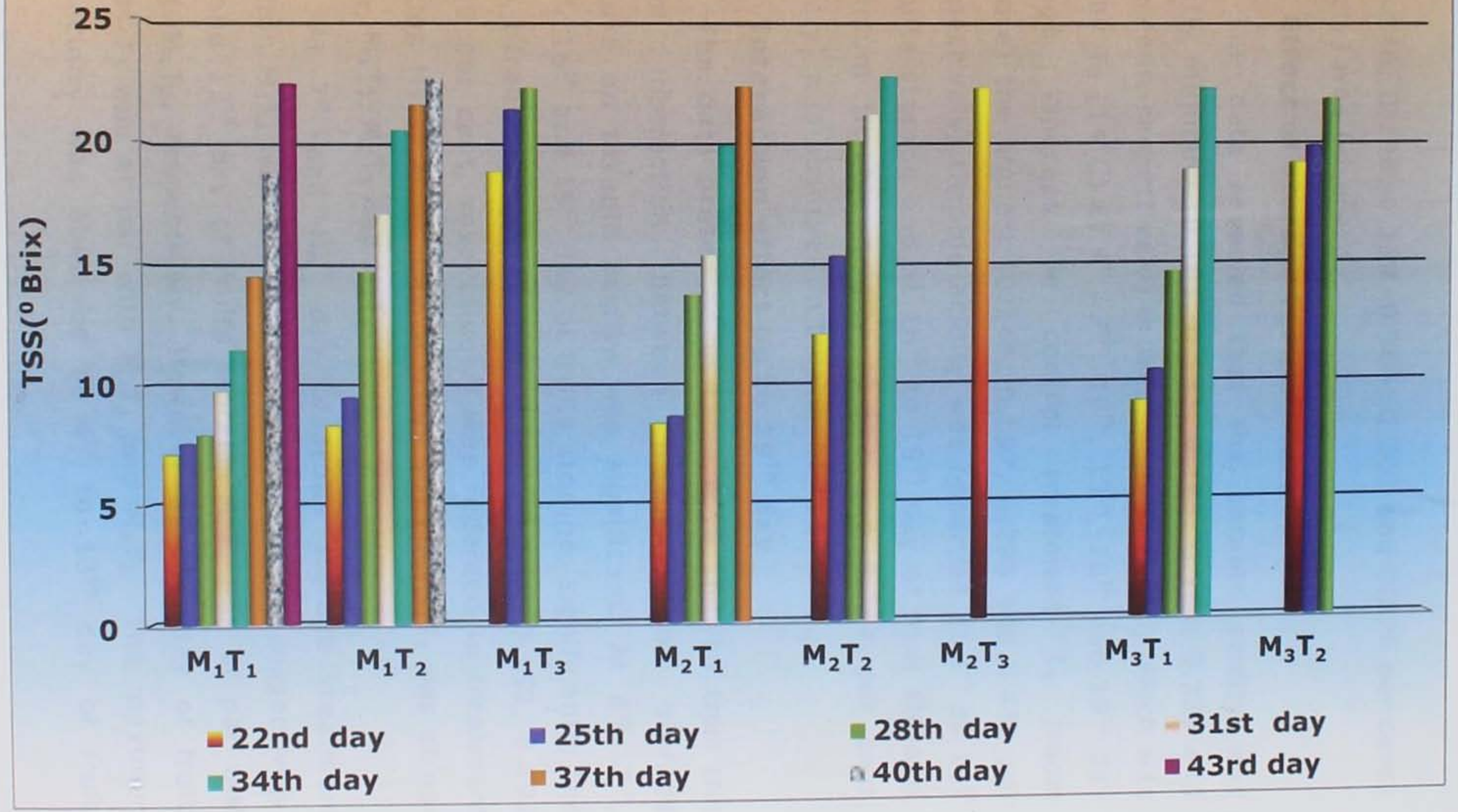
Table 4.16: Interaction effect of maturity and storage temperature on total soluble solids (^{0}Brix) of banana cv. Grand Nain (after 19th day)

Treatments combination	Storage period (No. of days)							
	22nd *	25th *	28th *	31st *	34th *	37th	40th	43rd
M_1T_1	7.07	7.57	7.9	9.73	11.47	14.50	18.73	22.4
M_1T_2	8.30	9.50	14.7	17.07	20.53	21.53	22.60	**
M_1T_3	18.80	21.37	22.23	**	**	**	**	**
M_2T_1	8.37	8.70	13.73	15.37	19.87	22.27	**	**
M_2T_2	12.07	15.33	20.03	21.10	22.70	**	**	**
M_2T_3	22.20	**	**	**	**	**	**	**
M_3T_1	9.17	10.50	14.6	18.83	22.23	**	**	**
M_3T_2	19.10	19.83	21.77	**	**	**	**	**
S. Em.±	0.17	0.25	0.15	0.24	0.12	--	--	--
C. D. at 5%	0.52	0.75	0.46	0.75	0.37	--	--	--
CV%	2.31	3.22	1.62	2.50	1.04	--	--	--

*- Data were analyzed using Complete Randomized Design (CRD).

**- The fruits were not available for analysis due to decayed.

Fig 10: Interaction effect of maturity and storage temperature on total soluble solids (⁰Brix) of banana cv. Grand Nain (after 19th day)



acidity (0.146, 0.190, 0.238, 0.304, 0.307 and 0.376 per cent, respectively) was observed.

4.11.2 Effect of storage temperature

The data revealed that the titrable acidity was significantly minimum (0.101, 0.133, 0.163, 0.184, 0.229 and 0.264 per cent, respectively) in treatment T_1 (12^0C) which was followed by T_2 (14^0C) at 4^{th}, 7^{th}, 10^{th}, 13^{th}, 16^{th} and 19^{th} day of storage. Whereas, in control treatment T_4 (room temperature) the highest (0.144, 0.197, 0.293 and 0.453 per cent, respectively) titrable acidity was observed at 4^{th} to 13^{th} day of fruits storage and at 16^{th} to 19^{th} day of fruit storage, the maximum titrable acidity (0.312 and 0.384 per cent, respectively) was observed in treatment T_3 (16^0C).

4.11.3 Interaction effect up to 19^{th} day

The data presented in table 4.18 showed that the effect of interaction between maturity and storage temperature on titrable acidity was significant. At 4^{th}, 7^{th}, 10^{th}, 13^{th}, 16^{th} and 19^{th} day of fruits storage, significantly the minimum titrable acidity (0.088, 0.096, 0.144, 0.152, 0.192 and 0.240 per cent, respectively) was recorded in treatment combination M_1T_1. At 4^{th} day of fruits storage M_1T_1 was at par with M_1T_2, M_1T_3, M_2T_1 and M_1T_4.

At 7^{th} and 16^{th} day of fruits storage treatment combination M_1T_1 was followed by M_1T_2 and M_2T_1, respectively. At 10^{th} and 13^{th} day of fruits storage M_1T_1 was at par with M_2T_1 and M_1T_2, respectively. However at 19^{th} day of fruits storage M_1T_1 was at par with M_2T_1 and M_1T_2. The maximum titrable acidity was observed at 4^{th} to 13^{th} day of fruits

Table 4.17: Effect of maturity and storage temperature on titratable acidity (%) of banana cv. Grand Nain

Treatments	Storage period (No. of days)					
	4th	7th	10th	13th	16th	19th
Maturity (M)						
M_1 – 75%	0.096	0.138	0.202	0.244	0.229	0.283
M_2 – 90%	0.128	0.166	0.216	0.274	0.269	0.299
M_3 – 100%	0.146	0.190	0.238	0.304	0.307	0.376
S. Em.±	0.0026	0.0028	0.0026	0.0047	0.005	0.007
C. D. at 5%	0.0075	0.0083	0.0075	0.014	0.014	0.021
Storage temperature (T)						
T_1 - 12°C	0.101	0.133	0.163	0.184	0.229	0.264
T_2 - 14°C	0.120	0.155	0.192	0.213	0.264	0.309
T_3 - 16°C	0.128	0.173	0.227	0.246	0.312	0.384
T_4 – control	0.144	0.197	0.293	0.453	**	**
S. Em.±	0.0030	0.0033	0.0030	0.0054	0.005	0.007
C. D. at 5%	0.0087	0.0095	0.0087	0.016	0.014	0.021
Interaction Effect (M x T)						
S. Em.±	0.0052	0.0057	0.0052	0.0094	0.008	0.012
C. D. at 5%	0.015	0.017	0.015	0.027	0.025	0.036
CV%	7.25	5.95	4.09	5.93	5.44	6.63

** – The fruits were not available for analysis due to decayed.

Table 4.18: Interaction effect of maturity and storage temperature on titratable acidity (%) of banana cv. Grand Nain

Treatments combination	Storage period (No. of days)					
	4th	7th	10th	13th	16th	19th
M_1T_1	0.088	0.096	0.144	0.152	0.192	0.240
M_1T_2	0.096	0.136	0.168	0.176	0.240	0.272
M_1T_3	0.096	0.152	0.216	0.232	0.256	0.336
M_1T_4	0.104	0.168	0.280	0.416	**	**
M_2T_1	0.096	0.144	0.152	0.192	0.224	0.256
M_2T_2	0.120	0.160	0.192	0.224	0.264	0.296
M_2T_3	0.136	0.168	0.224	0.241	0.320	0.344
M_2T_4	0.160	0.192	0.296	0.440	**	**
M_3T_1	0.120	0.160	0.192	0.208	0.272	0.296
M_3T_2	0.144	0.168	0.216	0.240	0.288	0.360
M_3T_3	0.152	0.200	0.240	0.264	0.360	0.472
M_3T_4	0.168	0.232	0.304	0.504	**	**
S. Em.±	0.0052	0.0057	0.0052	0.0094	0.008	0.012
C. D. at 5%	0.015	0.017	0.015	0.027	0.025	0.036

** – The fruits were not available for analysis due to decayed.

storage (0.168, 0.232, 0.304 and 0.504 per cent, respectively) in treatment combination M_3T_4.

The fruits subjected to combination of different maturity stages (M_1, M_2 and M_3) with room temperature (T_4) were decayed after 13th day therefore at 16th to 19th day of fruit storage the maximum (0.360 and 0.472 per cent, respectively) titrable acidity was observed in treatment combination M_3T_3.

4.11.4 Interaction effect after 19th day

Titrable acidity of banana fruit from 22nd to 43rd day of storage are presented in table 4.19.

The data revealed that titrable acidity was found significantly minimum at 22nd, 25th, 28th, 31st and 34th day of fruit storage (0.272, 0.304, 0.320, 0.368 and 0.416 per cent, respectively) in the treatment combination M_1T_1. At 22nd day M_1T_1 was followed by M_2T_1.

At 25th to 31st day M_1T_1 was followed by M_1T_2 and on 34th day at par value obtained with same treatment.

From 37th to 43rd day of storage minimum titrable acidity (0.46, 0.51 and 0.54 per cent, respectively) was observed in M_1T_1 as compared to other remaining treatment combinations.

Titrable acidity was observed maximum at 22nd day in treatment combination M_2T_3 (0.44 per cent), at 25th day in M_1T_3 (0.464 per cent), at 28th day in M_3T_2 (0.520 per cent), at 31st and 34th day in M_2T_2 (0.488 and 0.544 per cent, respectively) and at 37th and 40th in treatment combinations M_2T_1 and M_1T_2, respectivaly.

Table 4.19: Interaction effect of maturity and storage temperature on titratable acidity (%) of banana cv. Grand Nain (after 19th day)

Treatments combination	Storage period (No. of days)							
	22nd *	25th *	28th *	31st *	34th *	37th	40th	43rd
M_1T_1	0.272	0.304	0.320	0.368	0.416	0.46	0.51	0.54
M_1T_2	0.320	0.352	0.384	0.408	0.432	0.50	0.54	**
M_1T_3	0.408	0.464	0.512	**	**	**	**	**
M_2T_1	0.312	0.392	0.416	0.456	0.488	0.54	**	**
M_2T_2	0.344	0.424	0.464	0.488	0.544	**	**	**
M_2T_3	0.440	**	**	**	**	**	**	**
M_3T_1	0.352	0.424	0.440	0.464	0.533	**	**	**
M_3T_2	0.416	0.440	0.520	**	**	**	**	**
S. Em.±	0.010	0.012	0.009	0.009	0.014	--	--	--
C. D. at 5%	0.029	0.037	0.028	0.028	0.045	--	--	--
CV%	4.74	5.24	3.60	3.48	5.08	--	--	--

*- Data were analyzed using Complete Randomized Design (CRD).
**- The fruits were not available for analysis due to decayed.

4.12 Reducing sugar (%)

The data revealed to reducing sugar content in banana fruits cv. Grand Nain are presented in table 4.20 and graphically depicted in fig-11.

4.12.1 Effect of maturity

The reducing sugar content of banana fruits under the influence of various treatments of maturity showed significant differences (table 4.20).

The treatment M_3 (100% maturity) showed higher (1.45, 2.04, 3.41, 4.96, 3.71 and 5.04 per cent, respectively) reducing sugar which was followed by M_2 (90% maturity) at 4^{th}, 7^{th}, 10^{th}, 13^{th}, 16^{th} and 19^{th} day of fruit storage. Whereas, minimum (1.24, 1.38, 1.87, 3.23, 1.47 and 2.42 per cent, respectively) reducing sugar was observed in M_1 (75% maturity).

4.12.2 Effect of storage temperature

The data showed higher percentage of reducing sugar (1.57, 2.18, 5.19 and 9.70 per cent, respectively) in control treatment T_4 (room temperature) which was followed by T_3 at 4^{th}, 7^{th}, 10^{th} and 13^{th} day of fruits storage.

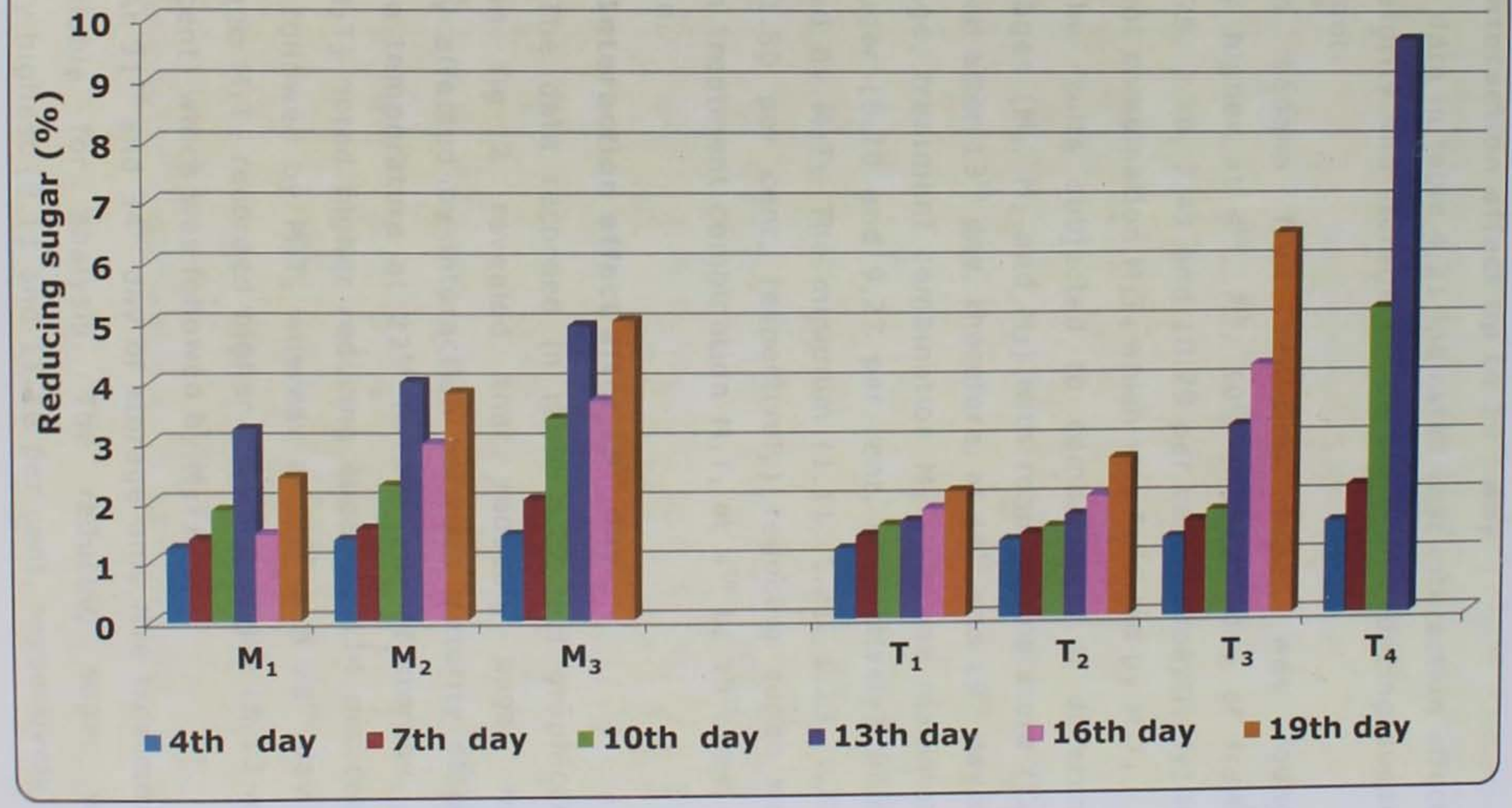
The fruits subjected to combination of different maturity stages (M_1,M_2 and M_3) with room temperature (T_4) were decayed after 13^{th} day, therefore, at 16^{th} and 19^{th} day of fruits storage, reducing sugar was found higher (4.25 and 6.47 per cent, respectively) in treatment T_3 (16^0C) which was followed by T_2 (14^0C). The minimum reducing sugar was observed in treatment T_1 (12^0C) at 4^{th} to 19^{th} day of fruits storage (1.19, 1.41, 1.58, 1.65, 1.86 and 2.15 per cent, respectively).

Table 4.20: Effect of maturity and storage temperature on reducing sugars (%) of banana cv. Grand Nain

Treatments	Storage period (No. of days)					
	4th	7th	10th	13th	16th	19th
Maturity (M)						
M_1 – 75%	1.24	1.38	1.87	3.23	1.47	2.42
M_2 – 90%	1.37	1.55	2.28	4.02	2.99	3.84
M_3 – 100%	1.45	2.04	3.41	4.96	3.71	5.04
S. Em.±	0.010	0.016	0.026	0.06	0.03	0.05
C. D. at 5%	0.030	0.047	0.077	0.16	0.10	0.14
Storage temperature (T)						
T_1 - 12°C	1.19	1.41	1.58	1.65	1.86	2.15
T_2 - 14°C	1.31	1.42	1.53	1.73	2.05	2.69
T_3 - 16°C	1.33	1.61	1.78	3.22	4.25	6.47
T_4 – control	1.57	2.18	5.19	9.70	**	**
S. Em.±	0.012	0.019	0.030	0.06	0.03	0.05
C. D. at 5%	0.034	0.055	0.088	0.19	0.10	0.14
Interaction Effect (M x T)						
S. Em.±	0.020	0.032	0.052	0.11	0.06	0.08
C. D. at 5%	0.059	0.095	0.153	0.32	0.17	0.25
CV%	2.61	3.40	3.60	4.69	3.53	3.86

** – The fruits were not available for analysis due to decayed.

FIg 11: Effect of maturity and storage temperature on reducing sugar (%) of banana cv. Grand Nain



4.12.3 Interaction effect up to 19th day

A data in table 4.21 indicated that interaction effect between maturity and storage temperature on reducing sugar was significant.

In banana fruit reducing sugar was found significantly higher at 4th, 7th, 10th and 13th day of fruits storage (1.79, 2.70, 7.47 and 10.29 per cent, respectively) in the treatment combination M_3T_4 which was followed by M_2T_4.

The fruits subjected to combination of different maturity stages (M_1, M_2 and M_3) with room temperature (T_4) were decayed after 13th day, therefore, at 16th and 19th day of fruits storage, treatment combination M_3T_3 showed maximum reducing sugar (6.20 and 9.27 per cent, respectively) which was followed by M_2T_3. The minimum (1.11, 1.21, 1.23, 1.27, 1.33 and 1.80 per cent, respectively) reducing sugar was observed in treatment combination M_1T_1 at 4th to 19th day of fruit storage.

4.12.4 Interaction effect after 19th day

The data recorded in table 4.22 and graphically depicted in fig-12 revealed that reducing sugar was significantly affected by interaction between maturity stages and storage temperature at 22nd to 34th day of storage. At 22nd day M_2T_3 noted higher reducing sugar (11.14 per cent) which was followed by M_3T_2 whereas at 25th and 28th day of fruits storage M_1T_3 recorded higher reducing sugar (8.53 and 10.73 per cent) which was followed by M_3T_2.

At 31st and 34th day of storage only five treatments were available for analysis. The reducing sugar was significantly highest (8.11 and 11.16 per cent, respectively) in

Table 4.21: Interaction effect of maturity and storage temperature on reducing sugars (%) of banana cv. Grand Nain

Treatments combination	Storage period (No. of days)					
	4th	7th	10th	13th	16th	19th
M_1T_1	1.11	1.21	1.23	1.27	1.33	1.80
M_1T_2	1.21	1.27	1.22	1.28	1.43	2.26
M_1T_3	1.28	1.35	1.33	1.48	1.64	3.21
M_1T_4	1.35	1.67	3.69	8.89	**	**
M_2T_1	1.21	1.30	1.50	1.61	1.96	2.16
M_2T_2	1.32	1.34	1.54	1.73	2.12	2.44
M_2T_3	1.34	1.39	1.65	2.85	4.91	6.92
M_2T_4	1.59	2.16	4.42	9.90	**	**
M_3T_1	1.24	1.72	2.01	2.08	2.31	2.49
M_3T_2	1.41	1.63	1.82	2.16	2.62	3.36
M_3T_3	1.36	2.09	2.35	5.31	6.20	9.27
M_3T_4	1.79	2.70	7.47	10.29	**	**
S. Em.±	0.020	0.032	0.052	0.11	0.06	0.08
C. D. at 5%	0.059	0.095	0.153	0.32	0.17	0.25

** – The fruits were not available for analysis due to decayed.

treatment combination M_3T_1 which was at par with M_2T_2 at 31st day and followed by it at 34th day of fruits storage.

The reducing sugar was maximum at 37th, 40th and 43rd day of fruits storage in M_2T_1 (8.47 per cent), M_1T_2 (8.57 per cent) and M_1T_1 (8.59 per cent), respectively.

Among all the treatment combinations in the treatment combination M_1T_1, the rate of increasing of reducing sugar was minimum (1.92, 1.97, 2.45, 3.38, 4.26, 5.35, 6.99 and 8.59 per cent, respectively) at 22nd, 25th, 28th, 31st, 34th, 37th, 40th and 43rd day of fruits storage.

4.13 Total sugars (%)

The mean data related to total sugars of banana fruits cv. Grand Nain as influenced by various treatments which are presented in table 4.23 and graphically illustrated in fig-13.

4.13.1 Effect of maturity

It is apparent from data that the total sugars were significantly influenced due to various treatments of maturity. The highest total sugars (4.20, 4.56, 7.73, 11.60, 10.75 and 14.06) were observed in treatment M_3 (100% maturity) which was followed by M_2 (90% maturity) 4th, 7th, 10th, 13th, 16th and 19th day of fruits storage. The minimum total sugars (3.64, 3.96, 5.53, 8.44, 4.71 and 6.83 per cent, respectively) were recorded in treatment M_1 (75% maturity).

4.13.2 Effect of storage temperature

The total sugars percentage of fruits significantly influenced by various treatments of storage temperature.

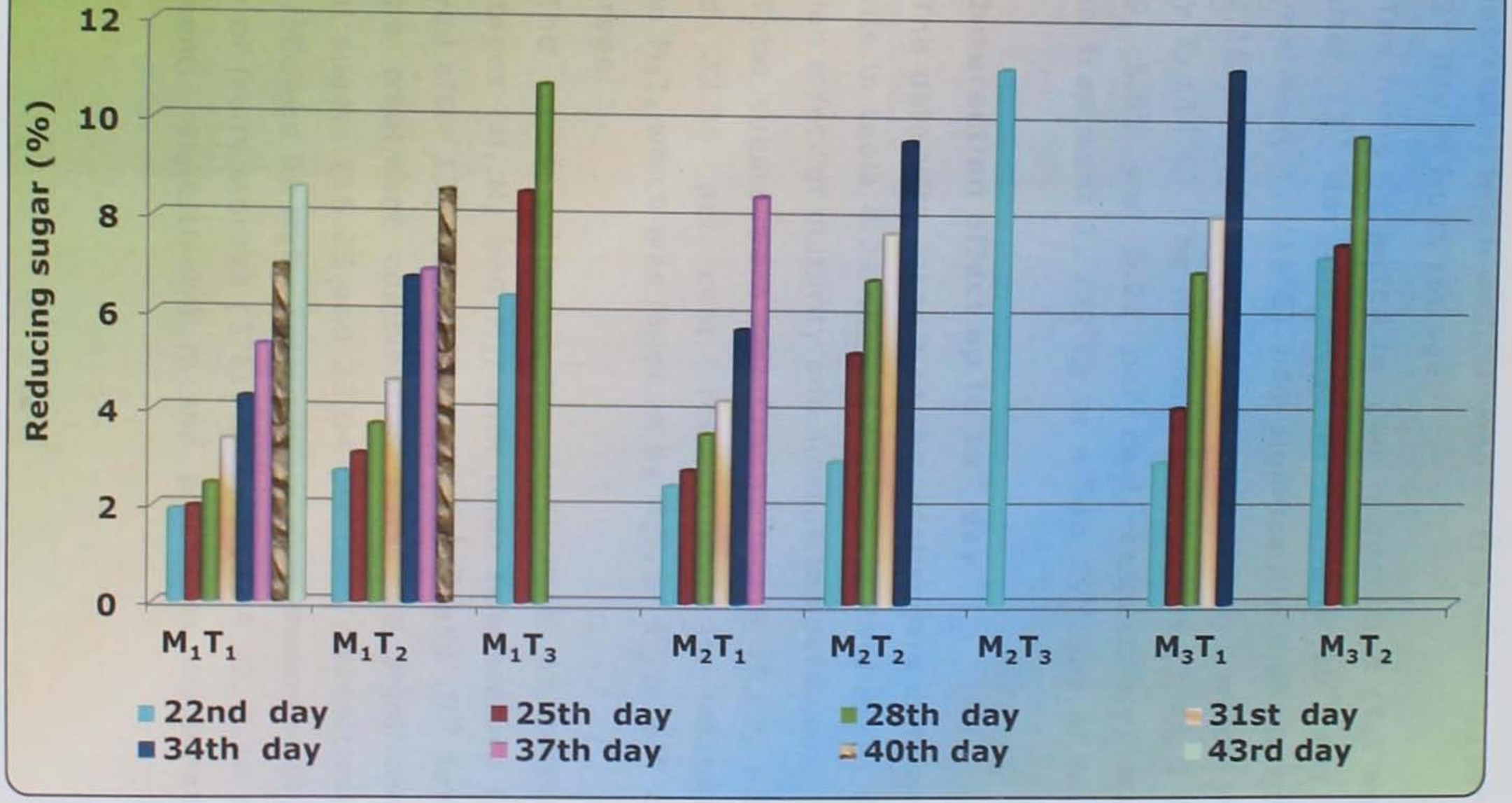
Total sugars were the highest (4.50, 4.90, 12.19 and 21.31 per cent, respectively) in control treatment T_4

Table 4.22: Interaction effect of maturity and storage temperature on reducing sugars (%) of banana cv. Grand Nain (after 19th day)

Treatments combination	Storage period (No. of days)							
	22nd *	25th *	28th *	31st *	34th *	37th	40th	43rd
M_1T_1	1.92	1.97	2.45	3.38	4.26	5.35	6.99	8.59
M_1T_2	2.74	3.10	3.72	4.63	6.76	6.92	8.57	**
M_1T_3	6.40	8.53	10.73	**	**	**	**	**
M_2T_1	2.48	2.79	3.55	4.25	5.73	8.47	**	**
M_2T_2	3.01	5.25	6.77	7.74	9.64	**	**	**
M_2T_3	11.14	**	**	**	**	**	**	**
M_3T_1	3.00	4.13	6.96	8.11	11.16	**	**	**
M_3T_2	7.29	7.56	9.83	**	**	**	**	**
S. Em.±	0.09	0.11	0.11	0.13	0.13	--	--	--
C. D. at 5%	0.26	0.32	0.33	0.41	0.42	--	--	--
CV%	3.20	3.85	3.01	4.00	3.08	--	--	--

*- Data were analyzed using Complete Randomized Design (CRD).
**- The fruits were not available for analysis due to decayed.

Fig 12: Interaction effect of maturity and storage temperature on reducing sugar (%) of banana cv. Grand Nain (after 19th day)



(room temperature) which was followed by treatment T_3 (16^0C) at 4^{th} to 13^{th} day of fruits storage.

The fruits subjected to room temperature (T_4) were decayed after 13^{th} day therefore, at 16^{th} and 19^{th} day of storage, treatment T_3 (16^0C) had significantly highest total sugars (12.36 and 16.61 per cent, respectively) which was followed by T_2 (14^0C). The minimum total sugars (3.43, 3.75, 4.21, 4.59, 5.85 and 6.21 per cent, respectively) were observed in treatment T_1 (12^0C) at 4^{th} to 19^{th} day of fruits storage.

4.13.3 Interaction effect up to 19^{th} day

The data with respect to the total sugars content in banana fruits in table 4.24 showed significant differences due to interaction effect of maturity and storage temperature.

Total sugars were significantly higher (5.03, 5.52, 16.07 and 22.35 per cent, respectively) in treatment combination M_3T_4 which was followed by M_2T_4 at 4^{th} to 13^{th} day of fruit storage.

The fruits subjected to combination of different maturity stages (M_1,M_2 and M_3) with room temperature (T_4) were decayed after 13^{th} day, therefore, at 16^{th} and 19^{th} day of storage, the treatment combination M_3T_3 had significantly higher total sugars (16.23 and 23.04 per cent, respectively), which was followed by M_2T_3. Total sugars were minimum at 4^{th} to 19^{th} day of fruits storage (3.11, 3.63, 3.98, 4.22, 4.38 and 4.88 per cent, respectively) in the treatment combination M_1T_1.

Table 4.23: Effect of maturity and storage temperature on total sugars (%) of banana cv. Grand Nain

Treatments	Storage period (No. of days)					
	4th	7th	10th	13th	16th	19th
Maturity (M)						
M_1 – 75%	3.64	3.96	5.53	8.44	4.71	6.83
M_2 – 90%	3.88	4.20	5.96	9.48	8.99	9.59
M_3 – 100%	4.20	4.56	7.73	11.60	10.75	14.06
S. Em.±	0.04	0.03	0.09	0.10	0.09	0.11
C. D. at 5%	0.13	0.10	0.26	0.30	0.27	0.33
Storage temperature (T)						
T_1 - 12°C	3.43	3.75	4.21	4.59	5.85	6.21
T_2 - 14°C	3.77	3.96	4.47	4.63	6.27	7.67
T_3 - 16°C	3.91	4.35	4.76	8.82	12.33	16.61
T_4 – control	4.50	4.90	12.19	21.31	**	**
S. Em.±	0.05	0.04	0.10	0.12	0.09	0.11
C. D. at 5%	0.15	0.11	0.30	0.35	0.27	0.33
Interaction Effect (M x T)						
S. Em.±	0.09	0.07	0.18	0.21	0.16	0.19
C. D. at 5%	0.25	0.20	0.51	0.61	0.46	0.57
CV%	3.87	2.73	4.75	3.68	3.31	3.25

** – The fruits were not available for analysis due to decayed.

Fig 13: Effect of maturity and storage temperature on total sugars (%) of banana cv. Grand Nain

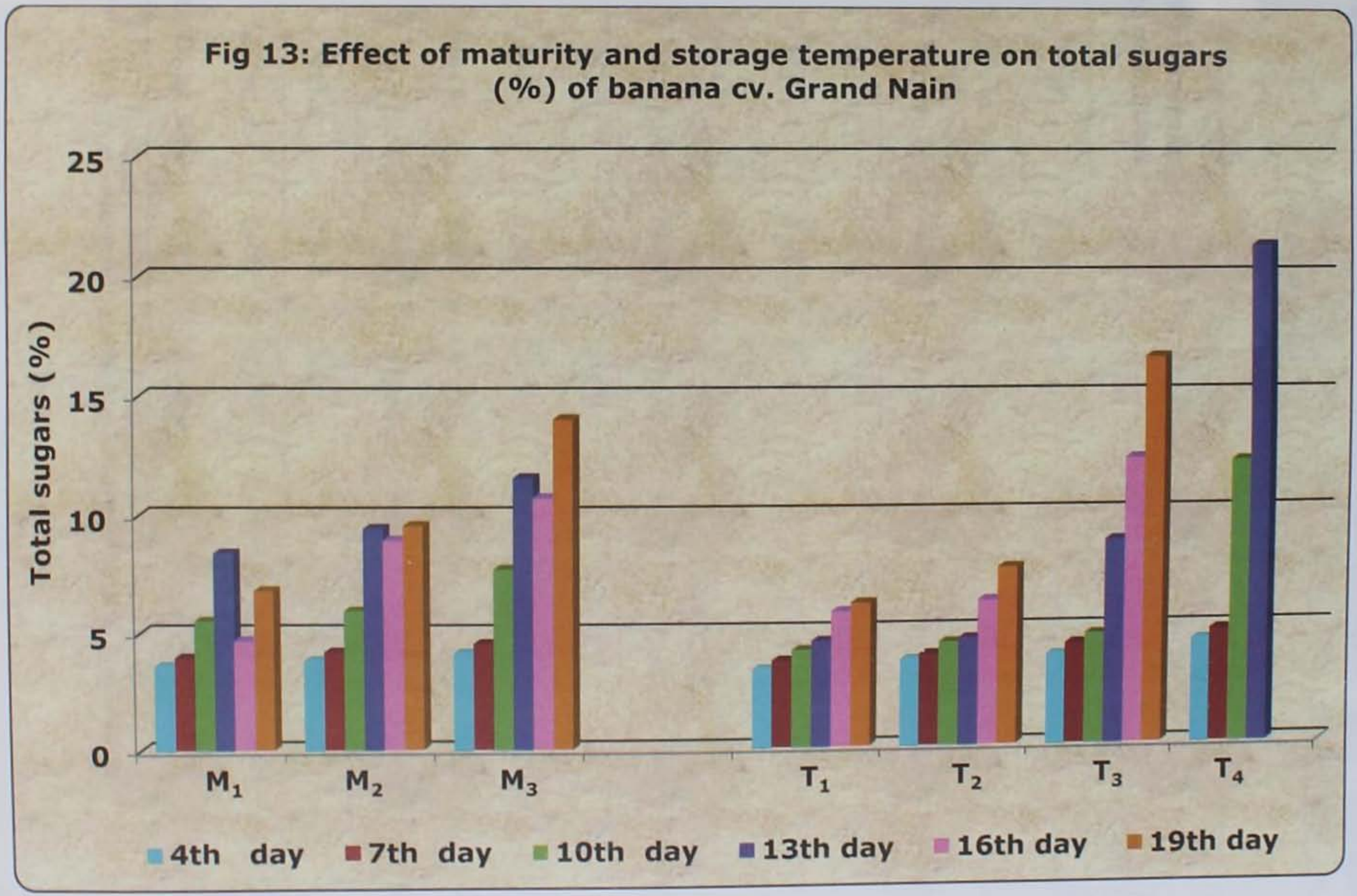


Table 4.24: Interaction effect of maturity and storage temperature on total sugars (%) of banana cv. Grand Nain

Treatments combination	Storage period (No. of days)					
	4th	7th	10th	13th	16th	19th
M_1T_1	3.11	3.63	3.98	4.22	4.38	4.88
M_1T_2	3.65	3.82	4.12	4.44	4.70	5.28
M_1T_3	3.72	4.10	4.25	4.59	5.05	10.33
M_1T_4	4.07	4.31	9.78	20.51	**	**
M_2T_1	3.58	3.74	4.11	4.42	5.49	6.04
M_2T_2	3.74	3.93	4.40	4.60	5.77	6.29
M_2T_3	3.78	4.26	4.61	7.81	15.70	16.45
M_2T_4	4.40	4.86	10.71	21.08	**	**
M_3T_1	3.61	3.87	4.55	5.12	7.69	7.71
M_3T_2	3.93	4.14	4.88	4.87	8.33	11.43
M_3T_3	4.23	4.69	5.43	14.06	16.23	23.04
M_3T_4	5.03	5.52	16.07	22.35	**	**
S. Em.±	0.09	0.07	0.18	0.21	0.46	0.19
C. D. at 5%	0.25	0.20	0.51	0.61	3.31	0.57

** – The fruits were not available for analysis due to decayed.

4.13.4 Interaction effect after 19th day

The data recorded in table 4.25 and graphically depicted in fig-14 revealed that the total sugars were significantly affected by treatment combinations from 22nd to 34th day of fruits storage.

Among remaining eight treatments at 22nd day of fruit storage M_2T_3 had significantly higher total sugars (23.19 per cent) which was followed by M_3T_2. After 22nd day, the fruits subjected to treatment combination M_2T_3 were fully decayed therefore, total sugars were significantly higher (23.07 and 25.42 per cent, respectively) in treatment combination M_3T_2 which was followed by M_1T_3 at 25th and 28th day of fruits storage.

At 31st and 34th day of fruits storage, among remaining five treatments, M_2T_2 had significantly the highest total sugars, (23.09 and 25.77 per cent, respectively) which was followed by M_3T_1.

The total sugars were maximum at 37th, 40th and 43rd day of storage in M_2T_1 (22.22 per cent), M_1T_2 (25.28 per cent) and M_1T_1 (23.38 per cent), respectively.

In treatment combination M_1T_1 the minimum total sugars were observed 22nd, 25th, 28th, 31st, 34th, 37th and 40th day of fruit storage (5.34, 5.92, 7.21, 7.71, 8.35, 11.82 and 17.58 per cent, respectively).

Table 4.25: Interaction effect of maturity and storage temperature on total sugars (%) of banana cv. Grand Nain (after 19th day)

Treatments combination	Storage period (No. of days)							
	22nd *	25th *	28th *	31st *	34th *	37th	40th	43rd
M_1T_1	5.34	5.92	7.21	7.71	8.35	11.82	17.58	23.38
M_1T_2	5.96	9.72	12.46	15.69	21.56	25.28	25.45	**
M_1T_3	16.78	19.81	23.54	**	**	**	**	**
M_2T_1	8.34	9.15	11.29	12.32	18.10	22.22	**	**
M_2T_2	9.35	15.89	18.16	23.09	25.77	**	**	**
M_2T_3	23.19	**	**	**	**	**	**	**
M_3T_1	9.21	12.61	16.4	19.17	23.00	**	**	**
M_3T_2	21.09	23.07	25.42	**	**	**	**	**
S. Em.±	0.28	0.20	0.29	0.38	0.50	--	--	--
C. D. at 5%	0.84	0.59	0.88	1.20	1.58	--	--	--
CV%	3.91	2.46	3.08	4.21	4.48	--	--	--

*- Data were analyzed using Complete Randomized Design (CRD).
**- The fruits were not available for analysis due to decayed.

Fig 14: Interaction effect of maturity and storage temperature on total sugars (%) of banana cv. Grand Nain (after 19th day)

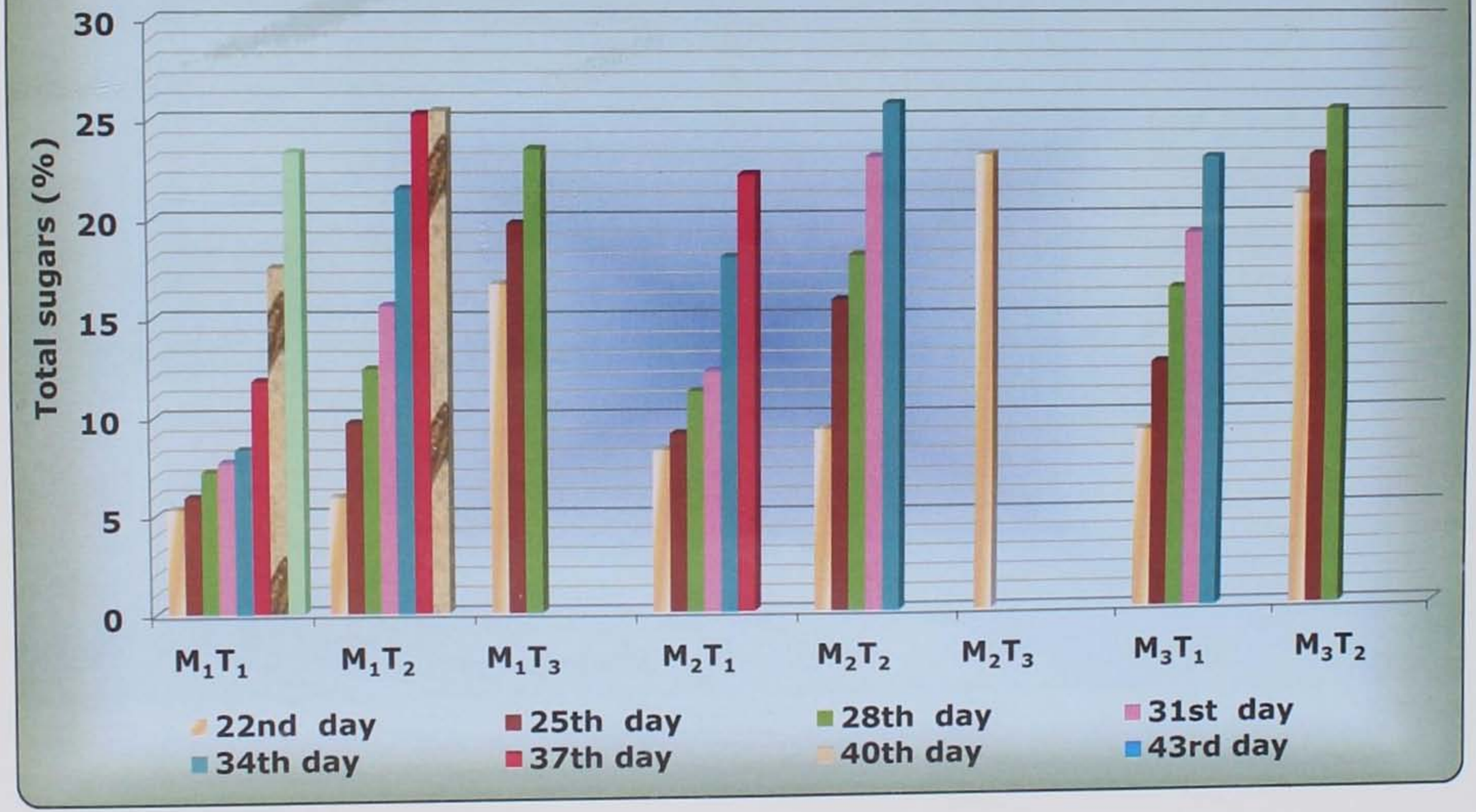


Plate 13: Fruits at 90 % maturity of banana cv. Grand Nain

Plate 14: Fruits stored at 14 °C goes under senescence

Plate 15: Fruits of different maturity stored at 12 °C in banana cv. Grand Nain

Plate 16: Colour breaking stage of banana at 12 °C under different maturity stages

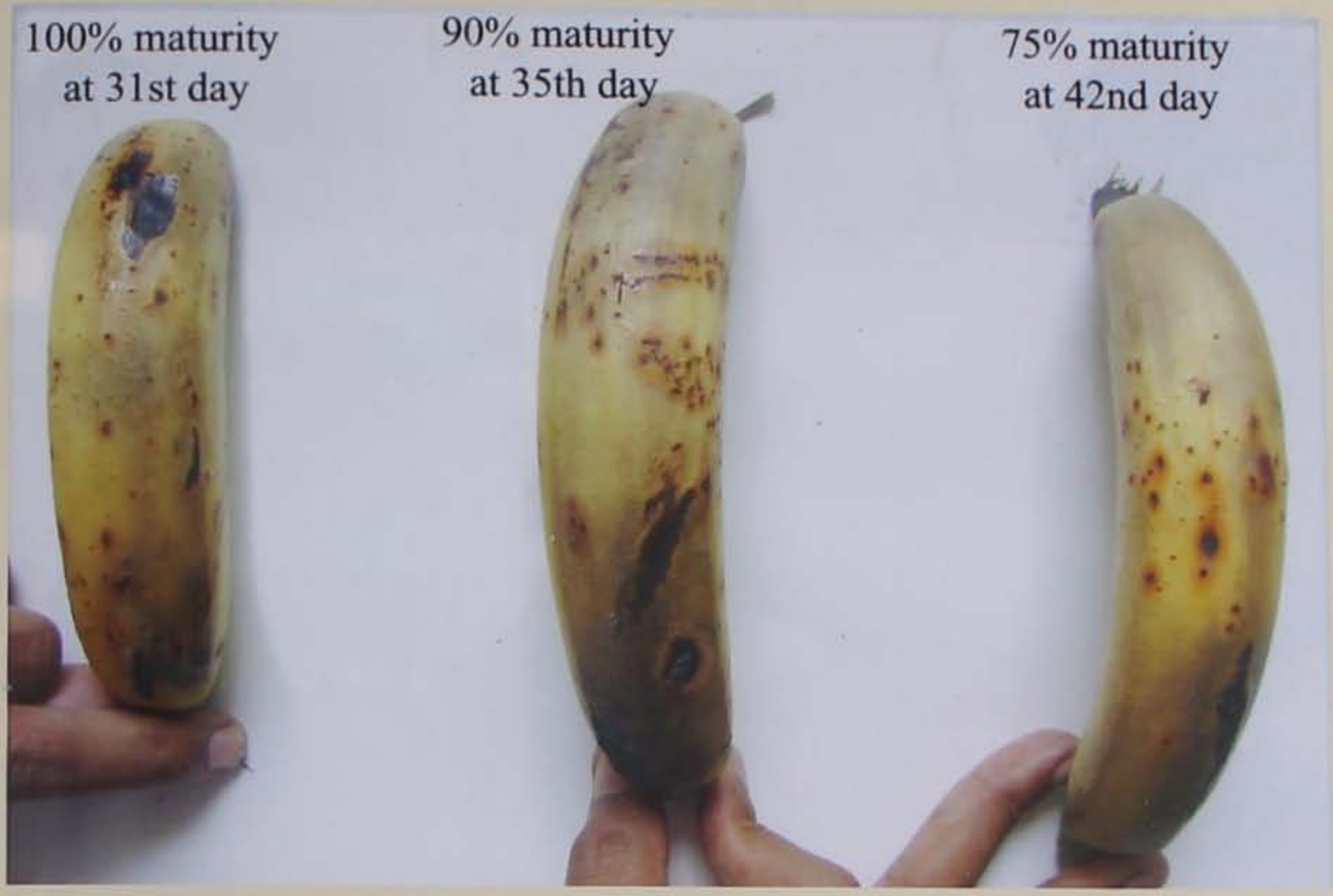


Plate 17: Feeding of yellow colour of the skin at 12° C temperature

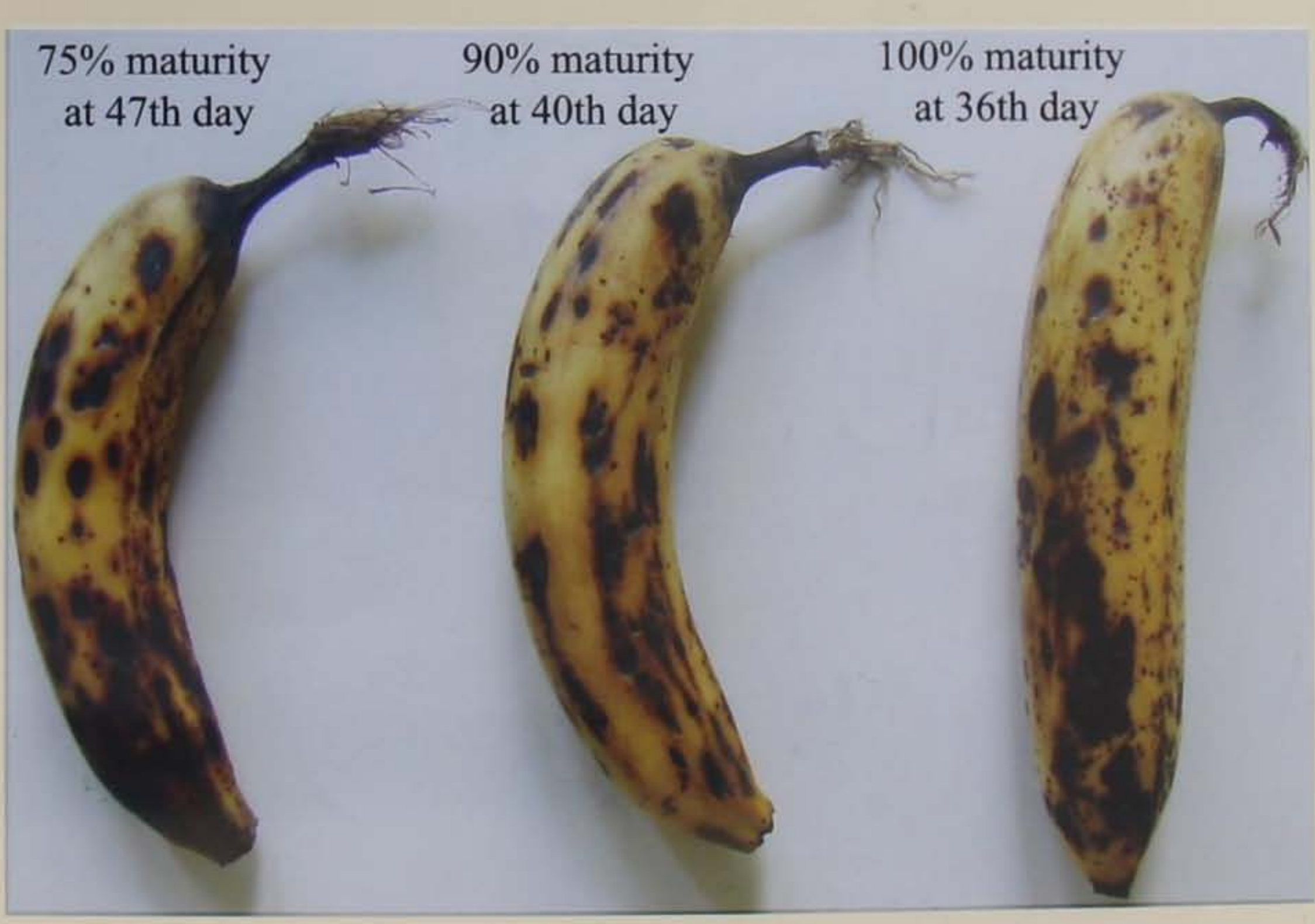


Plate 18: Fruit stored at 12 °C goes under senescence

DISCUSSION

V. DISCUSSION

Results of the present investigation on "Effect of maturity and storage temperature on shelf life and quality of banana (*Musa paradisiaca* L.) cv. Grand Nain" revealed in the previous chapter with the data of various observations *viz.*, physical and chemical parameters are discussed in this chapter along with the support of results obtained by various workers.

A) Physical observation

5.1 Date of shooting

The date of shooting was recorded to decide the maturity stages of banana.

5.2 Weight of bunch (Kg)

The weight of bunch of banana was significantly influenced by different levels of maturity. The maximum and minimum weight of bunch was observed with the treatments 100% maturity (M_3) and 75% maturity (M_1), respectively. At 75% maturity the fruits were matured but it was not fully developed as compared to 90% and 100% maturity. This might be directly associated with harvesting stages of bunch. The plant from which 100% matured bunch was harvested requires more duration in the field which had helped the plant to uptake more nutrient and water from the soil ultimately, the weight of bunch was increased in 100% maturity. Similar results were obtained by Singh *et al.* (1967) and Singh *et al.* (1976).

5.3 Number of fingers per bunch

The number of fingers per bunch remained unaffected among various treatments of maturity in banana. It might be due to selection time of plant after the emergence of

spike and environmental condition at developing stage. A similar result was obtained by Singh *et al.* (1976) when spike emergence period was different in banana.

5.4 Weight of finger (g)

The average weight of finger was significantly influenced due to the various treatments of maturity.

The maximum weight of finger was observed in 100% maturity and minimum in 75% maturity. This might be due to as the maturity increased the fingers in the bunch get more time for development resulted in higher girth of fingers which ultimately resulted in higher weight of fingers in more matured bunches. Similar results were obtained by Lodh *et al.* (1971), Singh *et al.* (1676) and Muastaffa *et al.* (1998) in banana when bunches were harvested at different stages.

5.5 Green, yellow and shelf life of fruits (days)

The results showed that the green, yellow and shelf life of fruits were recorded maximum in 75% maturity and minimum in 100% maturity. This difference occurred might be due to the fruits of 100% maturity exhibited colour change (chlorophyll breakdown) faster than fruits of lower maturity *i.e.* 75% maturity and also higher tannin content in fruits at lower maturity of banana. Similar results were obtained by Chang *et al.* (1990) and Narayana and Mustaffa (2007) in banana.

The green life of fruits was maximum at storage temperature 12^0C (T_1) and minimum at room temperature (T_4). Green life of fruits was associated with increasing rate of respiration. At ambient temperature treatment the rate of respiration was higher due to which the fruits changed their colour more rapidly as compared to cold storage temperature

treatment. The rate of respiration was slow in the fruits at cold room as compared to ambient condition Gane (1936). Similar findings were also observed by Neelakantan and Sadasivam (1977), Ineba *et al.* (1984), Marin *et al.* (1996) and Deka *et al.* (2006) in banana.

The yellow life of fruits observed maximum at 14^{0}C (T_2) and minimum at room temperature whereas, it was medium at 12^{0}C treatment. This might be due to at low temperature the physiological process are very slow as compared to room temperature. Therefore, after picking up yellow colour by fruits kept at the room temperature, the total yellow pigment remained more or less constant for longer period as compared to low temperature, in which early senescence stage attained by the fruits due to high temperature and faster physiological process. Similar findings noted by Patil and Magar (1976), Muthuswamy *et al.* (1971) and Desai and Deshpande (1975) with regard to different storage temperature in banana.

The combination of green life and yellow life of fruits was considered as shelf life of fruits. The maximum shelf life of fruits was observed at 12^{0}C treatment and minimum at room temperature treatment. Similar results were obtained by Muthuswamy *et al.* (1971), Marriott and New (1975), Rippon and Trochoulias (1976), Patil and Magar (1976), Broughton *et al.* (1979), Peacock (1980), Hussein *et al.* (1985), Naglani (1986), and Collin and Dalnic (1991), in banana when fruits were stored at near about to given range or different range in storage temperature.

The interaction between maturity and storage temperature showed significant differences for green, yellow

and shelf life of fruits. At lower maturity treatment and in cold storage temperature treatment the fruits were stored for more days as compared to advanced maturity and at room temperature. The fruits of different maturity when stored at room temperature showed no differences in respect of shelf life.

5.6 Physiological loss in weight (%)

The data revealed that physiological loss in weight was observed significantly minimum in treatment M_1 (75% maturity) and maximum in M_3 (100% maturity). It might be due to at advanced maturity of banana fruits the rate of ripening was faster as compared to lower maturity, ones the early ripening process started in more matured fruits the physiological processes like respiration, hydrolysis of starch *etc.* due to triggered ethylene production in more matured fruits resulted in higher physiological loss in weight. Similar results were obtained by El-Tomi *et al.* (1963), Ramen *et al.* (1971) and Narayana and Mustaffa (2007).

Among storage temperature treatments, the physiological loss in weight was significantly minimum in treatment T_1 (12^0C) and maximum at room temperature upto 13^{th} day of fruits storage. The fruits subjected to room temperature (T_4) were decayed after 13^{th} day of storage. At 16^{th} and 19^{th} day the highest physiological loss in weight was observed at 16^0C treatment. Lower physiological loss in weight was observed in cold storage which might be due to lesser water vapour deficit compared to ambient condition. Similar findings reported by El-Mahmoudi and Eisawi (1968), Saeed Ahmad *et al.* (2006), Ramen *et al.* (1971), Waskar (1989), Deka *et al.* (2006) and Hardenburg *et al.* (1990).

The interaction between 75% maturity and 12^{0}C storage temperature (M_1T_1) showed the minimum physiological loss in weight up to 43rd day of fruits storage constantly. The maximum physiological loss in weight was observed in M_3T_4 (*i.e.* 100% matured fruits stored at room temperature) upto end of the shelf life (13th day). The slow ripening process in cold storage in fruits of all maturity stages resulted in lower gradual physiological loss in weight of fruits as compared to fruits stored at room temperature. The physiological metabolism slowed down in the fruits of all maturity stages when stored at low temperature resulted in lower physiological loss in weight as compared to room temperature.

Similar results were obtained by Ramen *et al.* (1971) Nagaraju and Reddy (1995) and Narayana and Mustaffa (2007).

5.7 Organoleptic qualities at ripening

At different maturity treatments colour, texture and taste were found non-significant except flavour and it was maximum in 100% maturity (M_3). The chemical responsible for flavour in banana were more conditioned in 100% maturated fruits therefore more flavoured fruits were observed in this treatment.

The storage temperatures had significant effect on colour, flavour, texture and taste. The maximum organoleptic scored for all parameters noted in the ripened fruits kept at 16^{0}C (T_3). This might be due to higher and uniform cold storage temperature resulted in uniform ripening as compared to other lower and room temperature.

Interaction between maturity and storage temperature showed significant differences in colour and taste scored. The higher scored for colour and taste were recorded when the fruits of 100% maturity stored in cold storage at different temperature (M_3T_1, M_3T_2 and M_3T_3). This might be due to maintained ethylene production under uniform condition in cold storage as compared to room temperature.

5.8 Firmness of fruit (kg/cm^2)

Firmness of fruit varied significantly under different maturity stages. The maximum firmness of fruit was observed in treatment M_1 (75% maturity) whereas it was minimum in 100% maturity (M_3) up to 19th day of fruit storage. The fruits of 75% maturity were harvested at 25 days before harvesting of 100% maturity, therefore at 75% maturity the starch was hard whereas, in 100% maturity it was soft as compared to other treatments of maturity. Flesh softening of banana after harvest was related to the production of compound in alcohol *i.e.* cellulose, hemicelluloses and pectin (Huet, 1956). These higher matured fruits responded well for the production of alcoholic compound resulted in lower firmness in 100% matured fruits. Similar findings had been observed by Desai and Despande (1978) and Will *et al.* (1984).

The data revealed significant differences in firmness of fruit under the different storage temperature treatment. The fruit firmness was observed maximum in T_1 (12^{0}C) and minimum in control treatment T_4 (room temperature). After ending of shelf life of room temperature treatment (T_4), the minimum firmness was observed at 16^{0}C (T_3) up to 19th day of fruit storage. The decrease in firmness during storage of fruit

was due to changes in nature of pectin substances cementing the cell wall and hydrolysis of starch, hemicelluloses and cellulose during ripening of fruit [Leopold, 1964]. Similar results were obtained by Desai and Despande (1975), Sen and Chaudhuri (1976), Rippon and Trochoulias (1976), Peacock (1980), Smith and Thompson (1987), Wasker (1989) and Collin and Dalnic (1991).

The maximum firmness of fruit was noted constantly in treatment combination M_1T_1. When fruits were at ending of there shelf life, the minimum firmness of fruit was observed in treatment combination M_3T_4, at 7^{th} to 13^{th} day, at 16^{th} to 19^{th} in M_3T_3, at 22^{nd} day in M_2T_3, at 25^{th} and 28^{th} day in M_3T_2, at 31^{st} and 34^{th} day in M_3T_1, at 37^{th} day in M_2T_1 and at 40^{th} day in M_1T_2. Both maturity and storage temperature showed their own effects on the firmness per cent of fruit. The firmness of fruits increased gradually after the colour breaking stage. Similar result was obtained by Nagaraju and Reddy (1995).

5.9 Pulp: Peel ratio at ripening

There were significant differences observed in pulp: peel ratio at different maturity. Through out the ripening process of fruits the maximum pulp: peel ratio was observed in 100% matured fruits and minimum in 75% matured fruits. With advanced in maturity, the percentage of pulp: peel ratio was increased with concomitant decreased in Peel weight. This might be due to the percentage of cellulose and hemicelluloses in the peel portion and this peel cellulose were being converted into starch and peel portion lose its weight (Lodh *et al.*, 1971). The same findings were also reported by Desai and Despande (1978) at full maturity (120 days), Sanchez *et al.*

(1980), Tripathi *et al.* (1981) at third quarter, full maturity and ripened stage of banana fruit.

The maximum pulp: peel ratio was observed in the fruits kept at room temperature as compared to cold storage temperature. The rate of increasing in pulp: peel ratio increased with temperature. This might be due to the ratio of pulp: peel was related to accumulation of moisture in the pulp which was derived from carbohydrates breakdown and the osmotic transfer of water from skin to pulp (Palmer, 1971 and Charles and Tung, 1973). Similar results were obtained by El-Mahmoudi and Eisawi (1968), Raman *et al.* (1971), Desai and Deshpande (1975), Patil and Mager (1976), Chitarra and Lajolo (1985) and Saeed Ahmad *et al.* (2006) in banana with different storage temperature.

The interaction between maturity and storage temperature failed to show any significant difference in pulp: peel ratio of fruits at ripening.

B) Chemical observation

5.10 Total soluble solids (^{0}Brix)

Total soluble solids were observed maximum in treatment M_3 (100% maturity) whereas minimum at 75% maturity. In the initial days the total soluble solids were minimum but when fruits start to ripening process gradually they were increased. This might be due to higher total soluble solid content in fruits of 100% maturity grade was attributed to increases dry matter accumulation particularly starch, which in turn broke down to simple sugar during maturation and ripening (Narayana and Mustaffa , 2007). Similar findings were observed by Dhua *et al.* (1988) and Deca and Harmin

(1997) at different days of harvesting. Tripathi *et al.* (1981), Munasque and Mendoza (1990), Singh *et al.* (1976) and Ahmad *et al.* (2001).

Among storage temperatures, total soluble solids were significantly higher in control treatment T_4 (room temperature) up to 13th day and at 16th to 19th day they were higher in treatment T_3 (16^{0}C). The minimum total soluble solids were observed in treatment T_1 (12^{0}C) up to 19th day of fruit storage. The rate of change in total soluble solids during storage was much lower in cold room as compared to room temperature. This might be due to reduced rate of respiration during storage which ultimately slowed down the conversion of complex carbohydrates into simple sugar. Similar results were obtained by Ramen *et al.* (1971), Smith and Thompson (1987), Shivsanker (2003), Deka *et al.* (2006), and Saeed Ahmad *et al.* (2006).

Total soluble solids were significantly higher in interaction between maturity stages and storage temperature. The maximum total soluble solids were observed in the fruits having 100% maturity kept at room temperature up to 13th day (M_3T_4). The fruits under this treatment combination were decayed after 13th day of storage. Thereafter the total soluble solids in the fruits showed increasing trends with combination of increased maturity and increased temperature until the fruits lost their shelf life. Similar results were found by Aziz *et al.* (1976) and Madamba (1977).

In all given treatments total soluble solid of fruits were increased gradually after the colour breaking stage.

5.11 Titrable acidity (%)

Titrable acidity was significantly minimum in 75% matured fruits (M_1) whereas it was maximum in 100% matured fruits (M_3). With advancing maturity, gradual increase in titrable acidity was observed in present studies. The increase in acidity might be due to excess biosynthesis of oxalic acid in green stage and with advanced of maturity, the oxalic acid constantly decreased while malic acid biosynthesis predominated (Wyman and Palmer, 1963). Similar beneficial results were also found by Lodh *et al.* (1971), Tripathi *et al.* (1981), Dhua *et al.* (1988), Munasque and Mendoza (1990), Deca and Harmin (1997), Narayana and Mustaffa (2007) in banana at different maturity.

In Present investigation, titrable acidity in banana was observed minimum in storage treatment T_1 (12^0C) up to 19^{th} day of fruit storage. Acidity was found maximum up to 13^{th} day of fruit storage at room temperature storage (T_4) and at 16^{th} to 19^{th} day, in treatment T_3 (16^0C). The rate of changes in acidity was much lower in cold room as compared to room temperature. This might be due to the rate of acid production and its subsequent decrease followed the same trend as that of starch hydrolysis *i.e.* when starch hydrolysis was proceeding most rapidly, the acidity was increased most markedly and as the rate of starch hydrolysis was reduced, acidity also become progressively less (Desai and Deshpande, 1975). Similar results were obtained by Nakamura *et al.* (1979), Collin and Dalnic (1991), Shivsanker (2003) at 10^0C and 15^0C and Deka *et al.* (2006) in room temperature and cold room in banana.

The minimum titrable acidity was recorded in treatment combination M_1T_1 constantly whereas maximum titrable acidity was observed in that treatment those at ending stage of their shelf life. Both treatments showed their own effect on each other but storage temperature showed maximum effect on the maturity. At ending of shelf life, titrable acidity was slowly increased at cold storage temperature whereas at room temperature it was rapidly increased due to variation in temperature. Similar beneficial results were reported by Aziz *et al.* (1976), Madamba (1977), Firmen (1991) and Nagaraju and Reddy (1995).

5.12 Reducing sugar (%)

Reducing sugar was observed significantly higher in treatment M_3 (100% maturity) and minimum in 75% maturity. These differences occurred might be due to in many climacteric fruits, starch being the primary energy reserve and were synthesized amyloplast during development. In unripe banana fruit, 20-25% starch on fresh weight basis was recorded which was rapidly degraded into sugar during ripening (Reneta *et al.*, 2002) and also by higher activity of amylase and phosphoryalse enzyme coupled with higher level of starch (substrate) would have been the reasons for increased level of reducing sugar in 100% matured fruits (Chang *et al.*, 1990). Similar results were obtained by Lodh *et al.* (1971) and Narayana and Mustaffa (2007).

The significantly maximum reducing sugar was observed at room temperature (T_4) up to 13^{th} day of fruits storage which were decayed thereafter and at 16^{th} and 19^{th} day it was maximum in treatment T_3 (16^0C). The fruits stored at lower temperature had the less reducing sugar as compared

to room temperature. At room temperature more fluctuation in temperature was observed whereas in cold storage the uniformity was maintained therefore, the fruits stored at room temperature ripened rapidly as compared to cold storage temperature. Due to this rapid ripening process in the fruits stored at room temperature higher remain sugar was recorded at early stage of storage. Similar results were obtained by Ramen *et al.* (1971), Desai and Deshpande (1975), Kim and Lee (1988) and Shivsanker (2003).

Interaction effect of maturity stage and storage on reducing sugar content in the fruit during storage also found significant. The maximum reducing sugar was observed in the fruit having 100% maturity and room temperature storage up to 13^{th} day (M_3T_4). The fruits under this treatment combination were decayed after 13^{th} day of storage. Thereafter, the reducing sugar in the fruits showed increasing trends with combination of increased maturity and increased temperature until the fruits lost their shelf life.

5.13 Total sugars (%)

Total sugars were observed significantly higher in fruits subjected to treatment M_3 (100% maturity) and minimum in 75% maturity (M_1). These differences occurred might be due to in many climacteric fruits, starch being the primary energy reserve, was synthesized amyloplast during development. In unripe banana fruit, 20-25% starch on fresh weight basis was recorded which was rapidly degraded into sugar during ripening (Reneta *et al.*, 2002) and also by higher activity of amylase and phosphoryalse enzyme coupled with higher level of starch (substrate) would have been the reasons for increased level of total sugars (Chang *et al.*, 1990). A

similar findings were observed by Lodh *et al.* (1971), Tripathi *et al.* (1981), Dhua *et al.* (1988), Munasque and Mendoza (1990), Offem and Thomas (1993) and Narayana and Mustaffa (2007).

The significantly maximum total sugars were observed in fruits of room temperature (T_4) up to 13th day of fruit storage and at 16th and 19th day they were maximum in treatment T_3 (16^{0}C). In the storage temperature the minimum total sugars were observed in treatment T_1 (12^{0}C). In room temperature the more fluctuation was observed in temperature whereas in cold storage the uniformity was maintained therefore, the fruits stored in room temperature were gave rapid response to ripening as compared to cold storage temperature and when ripening process start ultimately starch per cent decreased. This might be due to, the most striking chemical changes which were occurred during the postharvest ripening of banana like the hydrolysis of starch and accumulation of sugar (Loesecke, 1950). About 20-25% of the fresh green fruits was starch. From initiation to completion of ripening, the starch was almost completely hydrolyzed only 1-2% remaining in the fully ripe fruit. Sugar normally 1-2% in the pulp of green fruits which increased to 15-20% in the ripe pulp. Total carbohydrates decreased by 2-5% during ripening, presumably as sugars were utilized in respiration. Similar results were obtained by Nakamura *et al.* (1979), Collin and Dalnic (1991), Yoshioka *et al.* (1978), Desai and Deshpande (1975) and Shivashankar, (2003) in banana.

Interaction effect of maturity stage and storage on total sugars content in the fruit during storage also found significant. The maximum total sugars were observed in the

fruit having 100% maturity kept at room temperature storage up to 13th day (M_3T_4). The fruits under this treatment combination were decayed after 13th day of storage. Thereafter, the total sugars in the fruits showed increasing trends with combination of increased maturity and increased temperature until the fruits lost their shelf life.

SUMMARY AND CONCLUSION

VI. SUMMARY AND CONCLUSION

An experiment was conducted during the year 2008-2009 at Regional Horticultural Research Station and Post Harvest Technology Centre, ASPEE college of Horticulture and Forestry, Navsari Agricultural University, Navsari to assess the "Effect of maturity and storage temperature on shelf life and quality of banana (*Musa paradisiaca* L.) cv. Grand Nain" in south Gujarat conditions. The salient features of the results presented and discussed in preceding chapter are epitomized here under.

The weight of bunch and weight of finger significantly influenced due to various treatment of maturity. Fruits were harvested at 100% maturity showed maximum weight of bunch and weight of finger while it was minimum in 75% maturity.

Green, yellow and shelf life of fruits were significantly influenced by maturity, storage temperature and their interaction. At 75% maturity, the maximum green, yellow and shelf life of fruits were observed while it was minimum at 100% maturity. Among different storage temperature, green and shelf life of fruits were maximum at 12^0C and minimum at room temperature. The interaction between above treatments showed maximum green and shelf life of banana, while yellow life was observed maximum in fruits harvested at 75% maturity and stored at 14^0C.

An organoleptic quality in respect of flavour at ripening was significantly higher at 100% maturity. While

colour, texture and taste failed to show any significant difference at ripening. The colour, flavour, texture and taste of fruits scored significantly higher under storage temperature 16^0C (T_3) and they were scored minimum at room temperature. The interaction between 100% maturity and 16^0C storage temperature (M_3T_3) also scored higher for colour and taste.

Throughout the ripening process of fruits the maximum pulp: peel ratio was observed at 100% maturity whereas it was minimum at 75% maturity. At room temperature maximum pulp: peel ratio was observed as compared to cold storage temperature.

Physiological loss in weight and titrable acidity of fruits were observed minimum at 75% maturity and maximum at 100% maturity. Among the different storage temperatures it was minimum at 12^0C (T_1) and maximum at room temperature (T_4) up to 13^{th} day and then up to 19^{th} day, it was maximum at 16^0C storage temperature (T_3). The physiological loss in weight and titrable acidity in fruits were minimum which when harvested at 100% maturity and stored at 12^0C (M_1T_1).

Firmness of fruit was significantly affcted by different maturity stages, storage temperature and their interactions. The maximum firmness of fruit was observed at 75% maturity and minimum at 100% maturity. It was also maximum at storage temperature 12^0C (T_1) and minimum at room temperature (T_4). After ending of shelf life of fruits kept at room temperature (T_4), the higher firmness was observed

at 16^0C storage temperature (T_3) up to 19^{th} day of fruit storage. It was also maximum under the treatment combination M_1T_1 and minimum when fruits were near to fully ripening stage or it was fully ripened in different treatment combinations.

The maximum total soluble solids, reducing sugar and total sugars were noted under 100% maturity while it was minimum at 75% maturity. The maximum total soluble solids, reducing sugar and total sugars were observed up to 13^{th} day at room temperature (T_4) whereas, up to 19^{th} day they were maximum at 16^0C and minimum at 12^0C storage temperature. At full ripening stage of fruits or when it was at near to fully ripening stage the total soluble solids, reducing sugar and total sugars were observed maximum in different treatment combinations while up to 43^{rd} day of fruit storage they were minimum in treatment combination (M_1T_1).

Conclusion

From the investigation it can be concluded that among the different maturity stages of banana, 100% maturity showed higher weight of bunch, weight of finger and pulp: peel ratio. The banana harvested at 75% maturity had extended green life due to shift in climacteric peak and exhibited slow change in physical parameters like physiological loss in weight and firmness and also in chemical parameter like total soluble solids, titrable acidity, reducing sugar and total sugars. The edible qualities of fruits did not significantly influenced by different level of maturity.

Among different storage temperature, the cold storage at 12^0C decreased the rate of ripening and slowed

down the physiological and bio-chemical changes in fruits as compared to ambient condition. While 16^{0}C temperature showed the best result for organoleptic qualities of fruit at ripening.

The combination of 75% maturity and 12^{0}C storage temperature increased the shelf life of fruits. The fruits of Grand Nain banana should be harvested in between 75% to 90% maturity (75 days and 90 days after shooting, respectively) for extension of shelf life and for better quality of fruit under the south Gujarat condition. For local market the fruits should be brought out from cold storage when they attained yellow colour while for distant market fruits should be brought out from the cold storage when they have yellowish green colour stage.

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* Original not seen

APPENDIX

APPENDIX-I: State wise area and production (estimated) of Banana in India in year 2007-2008

Name of State	Area in 000 Hectores	Production in 000 M.T	Productivity in M.T./Hect
Tamil Nadu	114.1	6116.5	53.6
Maharashtra	80.0	4962.9	62.0
Gujarat	57.7	3157.7	54.8
Andhra Pradesh	75.1	2254.3	30.0
Karnataka	59.9	1513.3	25.3
Bihar	30.5	1329.4	43.6
West Bangal	37.4	892.2	23.9
Madhya Pradesh	15.2	788.2	51.9
Assam	44.1	610.9	13.8
Kerala	61.5	493.9	8.0
Others	71.4	1085.4	15.2
Total	**646.9**	**23204.8**	**35.9**

Source: Indian Horticulture database, National Horticulture board, Ministry of Agriculture, Government of India.

APPENDIX-II: District wise area and production (estimated) of Banana in Gujarat State in year 2007-2008

Name of District	Area in Hectores	Production in M.T	Productivity in M.T./Hect
Ahmadabad	59	1475	25.00
Amreli	265	7950	30.00
Banaskantha	0	0	0.00
Bharuch	13493	855138	63.38
Narmada	4900	301350	61.50
Bhavnagar	1613	51376	31.85
Dang	15	450	30.00
Gandhinagar	23	920	40.00
Jamnagar	20	187	9.35
Junagadh	2140	85600	40.00
Porbandar	0	0	0.00
Kutch	830	20750	25.00
Kheda	532	21280	40.00
Anand	12195	585360	48.00
Mehsana	0	0	0.00
Patan	0	0	0.00
Panchmahal	210	6300	30.00
Dahod	5	75	15.00
Rajkot	0	0	0.00
Sabarkantha	230	6900	30.00
Surat	10370	622200	60.00
Surendranagar	0	0	0.00
Baroda	8513	459702	54.00
Valsad	475	26125	55.00
Navsari	400	20800	52.00
TOTAL	**1380**	**83800**	**60.72**

Source: Indian Horticulture database, National Horticulture board, Ministry of Agriculture, Government of India.

Appendix-III: Meteorological data during the experimental period (July 2007- Sep 2008)

Month	Std. week	Average Temperature (°c)		Relative Humidity (%)		Sunshine (Hrs.)	Rainfall (mm)
		Max.	Min.	Morning	Evening		
July 2007	27	30.7	21.0	87	80	0.5	40.14
	28	31.2	24.1	91	78	1.6	7.00
	29	31.8	25.4	87	82	5.8	1.60
	30	32.7	24.3	93	77	3.9	24.71
Aug. 2007	31	30.1	22.9	93	88	7.4	43.29
	32	30.5	24.2	95	85	0.9	45.00
	33	30.9	25.0	93	82	2.3	3.31
	34	31.2	22.5	97	79	3.7	1.57
	35	30.2	25.5	97	88	1.0	38.71
Sept. 2007	36	31.7	24.8	93	77	5.3	11.14
	37	32.6	25.2	96	66	7.2	1.71
	38	33.1	23.7	97	78	3.1	53.17
	39	32.7	23.5	93	69	4.2	4.74
Oct. 2007	40	33.7	20.5	95	60	8.4	0.00
	41	35.2	21.0	93	54	8.1	0.00
	42	35.9	16.4	91	58	9.7	0.00
	43	36.2	16.0	71	47	9.8	0.00
Nov. 2007	44	35.3	19.3	85	55	5.7	0.71
	45	35.2	19.9	86	52	8.9	0.00
	46	34.7	15.3	81	56	8.6	0.00
	47	33.6	10.1	79	47	9.6	0.00
	48	33.5	12.5	77	49	8.2	0.00
Dec. 2007	49	32.1	13.1	75	59	7.2	0.00
	50	31.1	13.2	86	46	7.6	0.00
	51	33.9	13.3	82	34	8.4	0.00
	52	32.5	10.8	87	57	9.2	0.00
Jan. 2008	1	30.5	8.7	96.4	56.4	9.1	0.00
	2	32.7	12.0	95.4	49.7	8.1	0.00
	3	32.1	11.6	94.8	48.8	9.0	0.00
	4	27.8	6.3	94.7	39.7	9.5	0.00
	5	28.5	6.5	92.1	31.7	9.6	0.00
Feb. 2008	6	20.5	6.7	85.3	32.6	8.9	0.00
	7	31.7	9.7	79.1	31.6	10.1	0.00
	8	32.3	10.0	86.5	31.8	10.0	0.00
	9	34.4	10.1	84.3	28.1	9.9	0.00
March 2008	10	34.8	12.4	91.0	31.6	9.8	0.00
	11	35.4	16.2	90.9	39.1	8.8	0.00
	12	35.6	15.5	85.6	39.1	10.0	0.00
	13	34.4	19.0	91.1	52.6	9.4	0.00

contd... Appendix-III

Month	Std. week	Average Temperature (°c)		Relative Humidity (%)		Sunshine (Hrs.)	Rainfall (mm)
		Min.	Max.	Morning	Evening		
April 2008	14	32.0	17.8	88.0	51.7	9.5	0.00
	15	37.2	19.5	71.0	34.0	9.6	0.00
	16	36.8	19.4	85.3	36.0	10.6	0.00
	17	38.5	19.6	81.8	36.3	10.5	0.00
	18	36.2	22.8	86.1	47.3	10.1	0.00
May 2008	19	33.9	22.9	82.3	57.8	10.2	0.00
	20	33.9	23.3	78.7	55.0	11.2	0.00
	21	37.9	20.7	80.5	41.5	10.7	0.00
	22	35.3	26.3	80.4	52.0	11.0	0.00
June 2008	23	34.91	24.31	87	65	5.5	2.14
	24	35.5	25.0	85	61	5.6	0.43
	25	34.8	24.0	92	66	3.5	14.86
	26	32.1	21.9	95	81	2.7	14.79
July 2008	27	28.8	26.0	92.0	87.0	271.0	4.0
	28	29.9	25.6	93.0	86.0	232.0	6.0
	29	30.4	25.7	93.0	77.0	25.0	2.0
	30	29.2	25.5	95.0	86.0	171.0	5.0
	31	28.3	24.6	95.0	92.0	248.0	6.0
ıug. 2008	32	27.8	24.9	95.0	91.0	411.0	6.0
	33	28.5	25.2	93.0	84.0	110.0	5.0
	34	30.0	24.8	93.0	79.0	35.0	3.0
	35	31.7	24.8	94.0	70.0	3.0	0.0
;ept. 2008	36	31.1	25.0	94.0	79.0	44.0	3.0
	37	30.6	24.7	95.0	82.0	151.0	6.0
	38	28.8	24.4	95.0	88.0	158.0	4.0
	39	31.2	23.1	91.0	70.0	0.0	0.0

ıurce: Agricultural Meteorological Observatory, Agricultural Experimental Station, Navsari Agricultural University.

CERTIFICATE

This is to certify that I have no objection to supply one copy of any part of this thesis at a time to any scientist through reprographic process, if necessary for rendering reference service in a library or documentation centre.

Place: Navsari

Date : 07th July 2009

(Gonge Amol Pralhad)