EFFECTIVENESS OF HEXANAL AND ITS MODE OF ACTION ON THE POST-HARVEST QUALITY OF BANANA FRUITS (*MUSA* SPP)

SUBMITTED BY

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DEPARTMENT OF PLANT SCIENCE AND CROP PROTECTION

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UNIVERSITY OF NAIROBI

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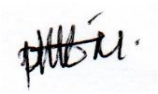
DECLARATION



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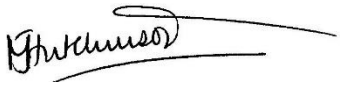

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DEDICATION

ACKNOWLEDGEMENTS

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GENERAL ABSTRACT

‘Grand nain’ and ‘sweet banana’ varieties produced under

ts on the fruits’

green ‘Grand nain’ banana fruits were treated with either hexanal, ethylene, 1

[illegible]

[illegible] *p* [illegible] 0.05) delayed time to fruit harvesting by 12 days and 18 days in 'Grand nain' variety produced in [illegible] 'sweet banana' variety in both zones compared to [illegible] s in fruits dipped for 2.5 minutes in 'Grand nain' and 'sweet banana' variety respectively. In the [illegible] on the TSS levels with 'sweet banana' having higher levels ([illegible]) compared to 'Grand nain' fruits (2[illegible] untreated controls. 'Grand nain' fruits [illegible]

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Horticulture plays a significant role in the Kenyan economy and it's the fastest growing subsector

M r et al 2 et al 2 r r M r r et al 2 5 r

r r d r d r et al 2 r r d r r r r d r r r r d r r r r

1.2. Problem statement

different agro ecological zones. Since hexanal's effect is deemed to be physiological, it is possible

1.3. Justification of the study

1.4. Study Objectives

1.4.1. General objective

1.4.2. Specific objectives

1.5. Hypothesis

CHAPTER TWO

2.0 Literature Review

2.1. Background information

tion in the world's leading producers such as Brazil, Phillipines, India and China (FAO, 2019).

2.2. Banana production in Kenya

Small scale farmers dominate Kenya's banana farming with an average holdings of about 0

(20%), Murang'a (11.7%), Kirinyaga (8.1%), Taita Taveta (6.6%) and Th

et al

sukari ndisi

muraru

et al

Kiganda, Uganda green, ng'ombe, nusu ng'ombe, mutahato

Gradi Shisikame

et al

et al.

et al.

Table 1: Banana production statistics in selected Counties, 2015-2018

COUNTY	2015		2016		2017		2018	
	Area (Ha)	Volume (Tons)	Area (Ha)	Volume (Tons)	Area (Ha)	Volume (Tons)	Area (Ha)	Volume (Tons)
M r	7,038	251,132	7,503	276,919	11,305	288,266	10,542	308,095
M r	5,757	159,790	5,987	154,172	7,160	166,641	7,214	173,439
r	6,318	142,036	6,670	145,036	6,208	122,850	5,485	152,409
	2,891	67,865	4,288	63,300	2,528	58,420	2,972	74,231
r	4,204	75,544	3,734	76,633	3,622	74,940	4,112	87,540
	4,856	132,253	4,288	63,300	6,233	117,951	4,262	70,194
	3,088	60,975	3,919	77,415	4,193	67,986	3,791	64,158
r	1,985	22,692	1,852	23,091	1,861	24,246	1,400	23,550
M	2,206	20,544	2,572	23,334	2,742	20,716	4,419	42,299
	3,402	38,929	3,824	34,717	2,210	31,723	2,518	38,380
r	2,005	30,708	2,259	42,475	1,943	44,000	1,898	37,840
	2,057	30,856	1,987	40,098	2,765	30,667	2,829	42,014
	850	28,050	862	27,584	1,706	45,828	1,801	49,628
r	1,730	39,584	1,876	37,230	1,264	26,597	1,531	35,194
r	12,332	189,192	13,013	188,254	10,547	175,149	10,744	162,875
TOTAL	**60,718**	**1,290,150**	**63,299**	**1,288,588**	**69,376**	**1,357,162**	**68,248**	**1,419,176**

Source: (HCD reports 2016 & 2018)

2.3 Nutritional value of Banana fruit

r d r d r r r d M r 2 5 d r r dr r r r d M r 2 5 r dr r 2 r d d r *et al* 2 r r r r d d d d d d

[illegible]

Table 2: [illegible]

Constituents	Unit	Ripening banana	Plantain
[illegible]	[illegible]	89	122
[illegible]	[illegible]	74	65
[illegible]	[illegible]	1.1	1.3
[illegible]	[illegible]	0.3	0.4
[illegible]	[illegible]	21.8	32
[illegible]	[illegible]	2	3
[illegible]	[illegible]	1	4
[illegible]	[illegible]	385	500
[illegible]	[illegible]	8	3
[illegible]	[illegible]	30	35
[illegible]	[illegible]	22	30
[illegible]	[illegible]	12	20
[illegible]	[illegible]	40	80
[illegible]	[illegible]	70	40
[illegible]	[illegible]	610	600
[illegible]	[illegible]	280	0
[illegible]	[illegible]	470	0
[illegible]	[illegible]	23	0

Source: Modified table adopted from Aurore et al., (2009)

2.4. Post-harvest physiology of banana fruit

The fruits' acceptance by the

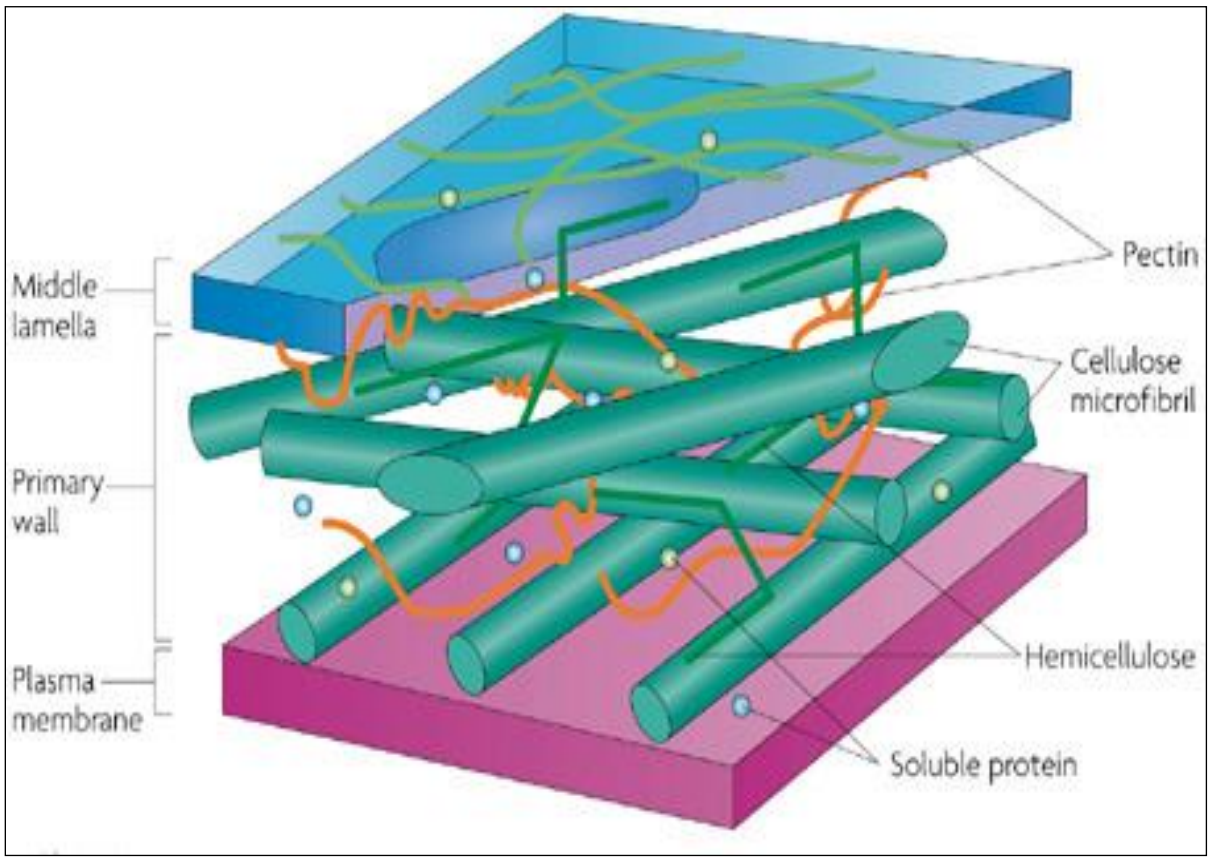

Figure 1:

2.4.1.2. Cell membrane structure and changes during ripening

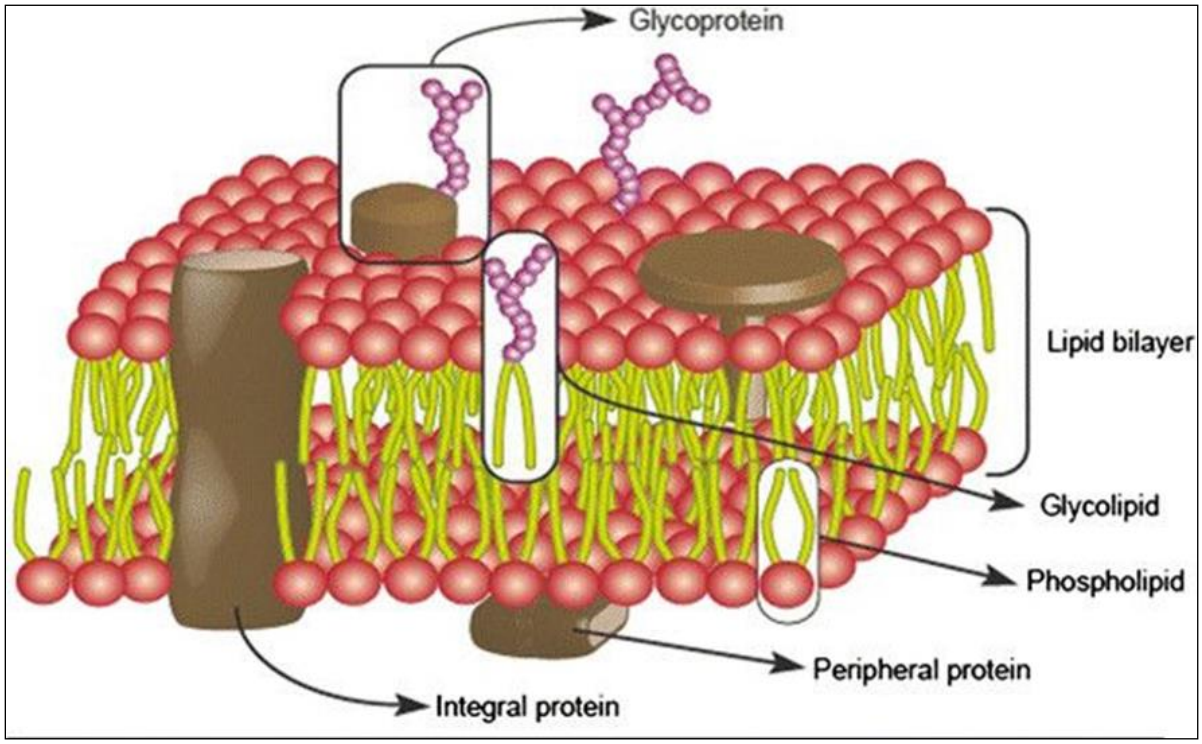

Figure 2:

2.4.1.2.1. Role of enzyme phospholipase D in membrane deterioration

2.4.2. Applicable technologies to preserve post-harvest quality of banana fruits

2.4.2.1. Controlled atmosphere (CA) and Modified atmosphere (MA) storage

2.4.2.2. Cold storage

2.4.2.3. 1-Methylcyclopropene (1-MCP)

2.4.2.4. Hexanal and Enhanced Freshness Formulation (EFF) Application

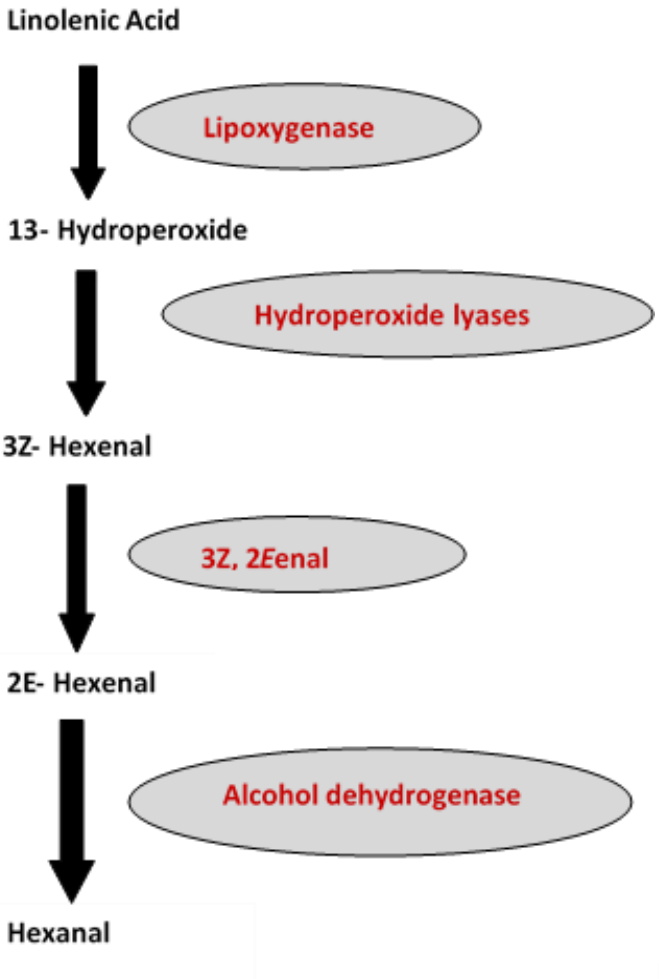

Figure 3:

rmitted daily intake) is estimated at 1800µg per day for compounds

to form an ‘Enhanced Freshness Formulation’ (EFF)

to 30 days at 4º C.

2.4.2.4.1. Effects of hexanal and its formulations on post-harvest shelf life and quality

CHAPTER 3

3.0. Efficacy of Hexanal on the physical and physiological post-harvest characteristics of Banana Fruits (*Musa* spp) in Kenya

3.1 Abstract

‘Grand nain’ and ‘sweet banana’ fruits evaluated on ‘Grand nain’ and ‘sweet banana’ varieties.

harvest shelf life of various banana varieties such as ‘Sucrier’ (Romphophak *et al*., 2 ‘Cavendish’ (Chauchan *et al*., 2006) and ‘Robusta’ (Kudachikar *et al*., 2

et al., 2 *et al*., 2

Alternaria alternate d *Botrytis Cinerea,*

[illegible] *et al.* [illegible] *et al.* [illegible] *et al.* [illegible] ‘[illegible]’ apple, a concentration of 2% [illegible] 1% in ‘Delicious’ and ‘IdaRed’ varieties when applied as a pre[illegible] *et al.* [illegible]

[illegible]

3.3 Materials and Methods

3.3.1 Site description

[illegible] On the other hand, Machakos County is a semi-arid zone (AEZ IV) that lies at an elevation of between 1000- 1600 meters above sea level with an average temperature of 25[illegible] and

annual average rainfall of 600mm (FAO, 1996). The soils in Machakos County [illegible] A detailed soil analysis of the two study sites is presented below (Table 3). Meru County is currently the leading producer of banana fruits in Kenya (HCD, 2018) while Machakos county is located in a dry region where banana production is practiced on a limited scale. 'Grand nain' [illegible] farmers' field [illegible] The experiment were conducted in two successive seasons, July to November 2016 and January to April 2017.

Table 3: Soil analysis results for the two study sites (AEZ II and AEZ IV)

Soil parameters	AEZ II	AEZ IV
[illegible]	[illegible]	[illegible]
[illegible]	6[illegible]	6[illegible]6[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]2[illegible]	[illegible]
[illegible]	22[illegible]6[illegible]	[illegible]
[illegible]	[illegible]2[illegible]	[illegible]
M[illegible]	[illegible]2[illegible]	2[illegible]

3.3.2. Experimental designs and treatments

[illegible] 2[illegible] 5[illegible] 5[illegible]

3.3.3 Sample preparation

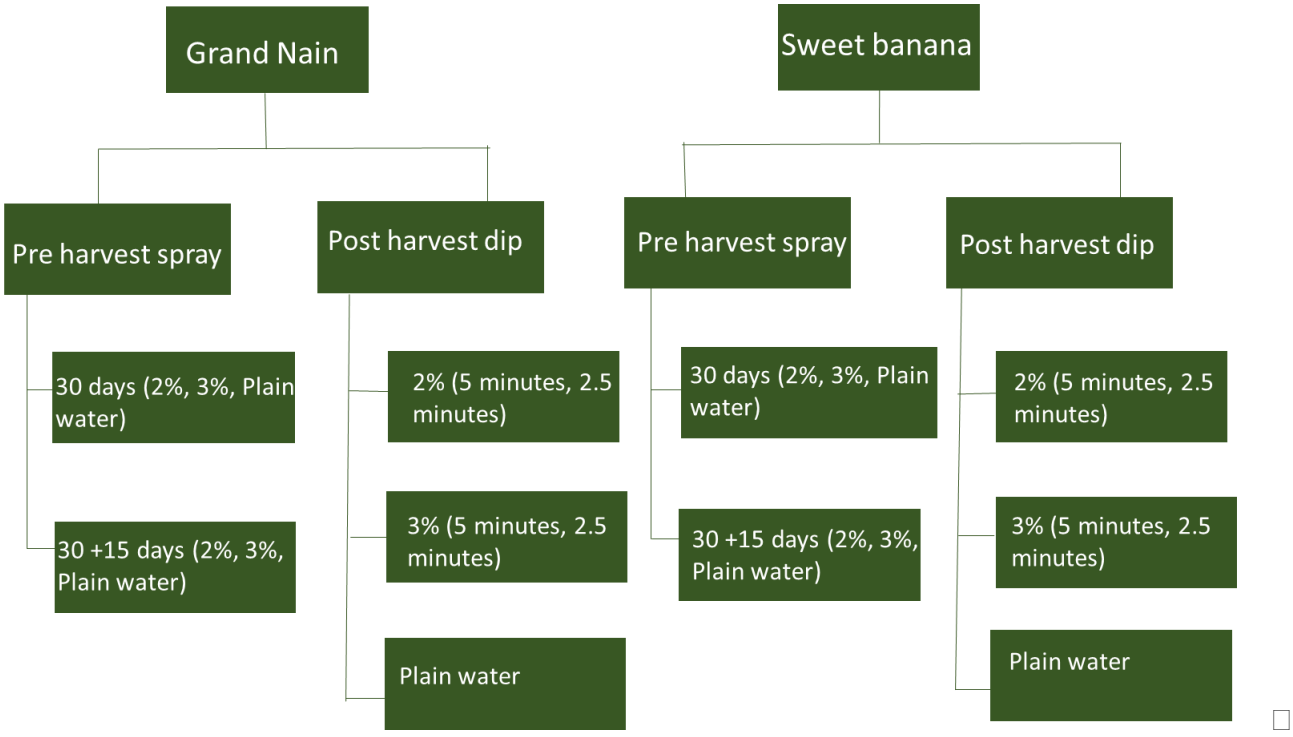

Figure 4:

3.3.4 Evaluation of Physical and Physiological Attributes

3.3.4.1. Number of days to fruit harvesting

3.3.4.2. Shelf-life

3.3.4.3. Rate of respiration and ethylene production

3.3.4.4. Percentage weight loss (PWL)

3.3.4.5. Peel and pulp firmness

3.3.4.6. Peel Color

3.3.5 Statistical analyses

using Fisher's protected test.

3.4 Results

3.4.1 Days to fruit harvesting and shelf life

both varieties and in ‘sweet banana’ from AEZ II. However, hexanal, delayed in ‘Grand nain’ milar trend was observed in ‘ changes in peel color were more drastic in ‘sweet banana’ variety as compared to ‘Grand nain’ in both AEZs.

Table 4: [illegible] 'Grand nain' and 'sweet banana' [illegible]

[illegible]	'Grand nain'					'sweet banana'				
[illegible]	2[illegible]	2[illegible]	[illegible]	[illegible]	[illegible]	2[illegible]	2[illegible]	[illegible]	[illegible]	[illegible]
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Mean	**134.8**	**137.9**	**135.6**	**137.9**	**132.8**	**134.3**	**137.5**	**135.1**	**137.4**	**133.1**
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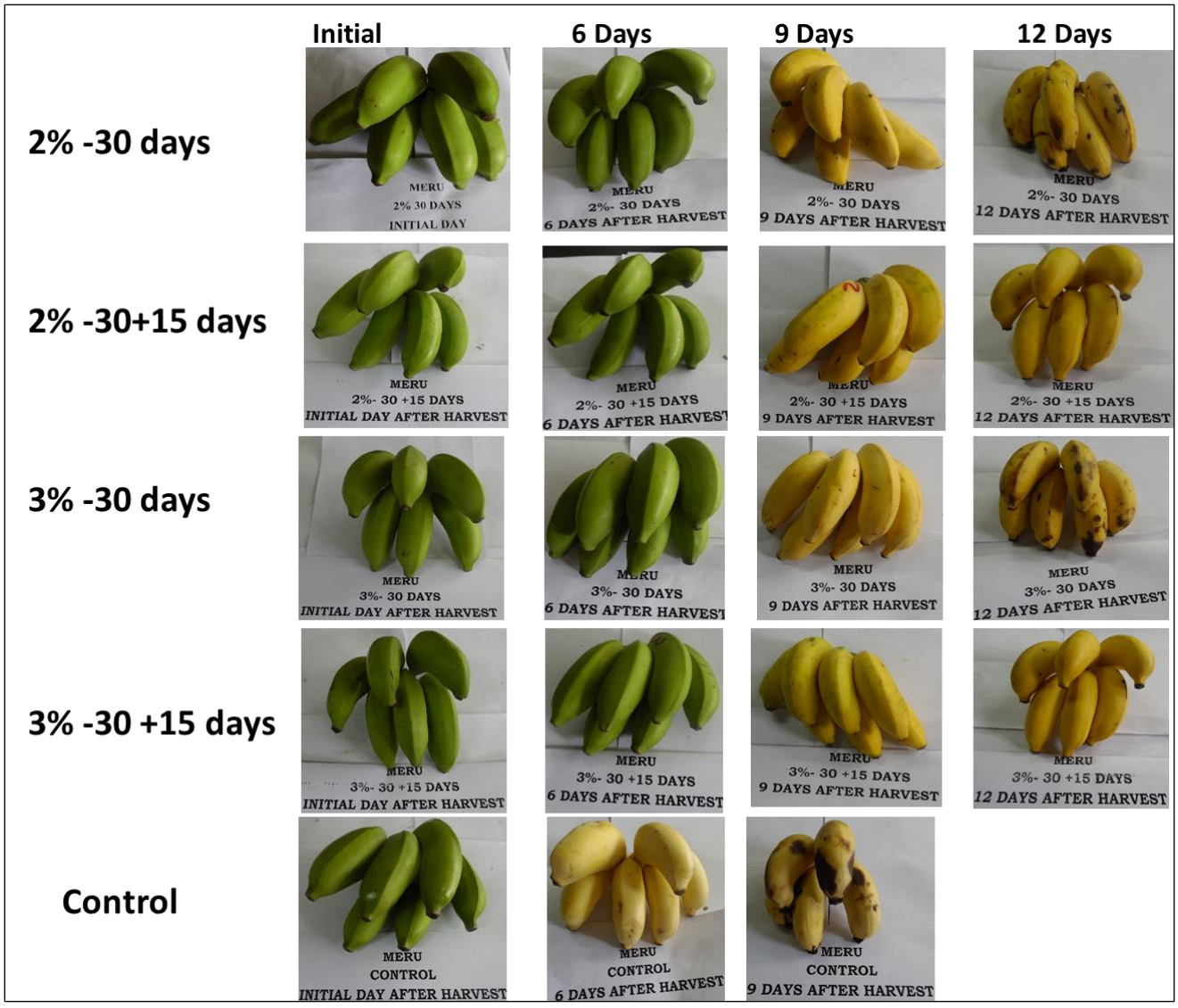


Figure 5: Progression of ripening in 'sweet banana' fruits sprayed with hexanal (2 d r d 5 d r r r d d d d r d

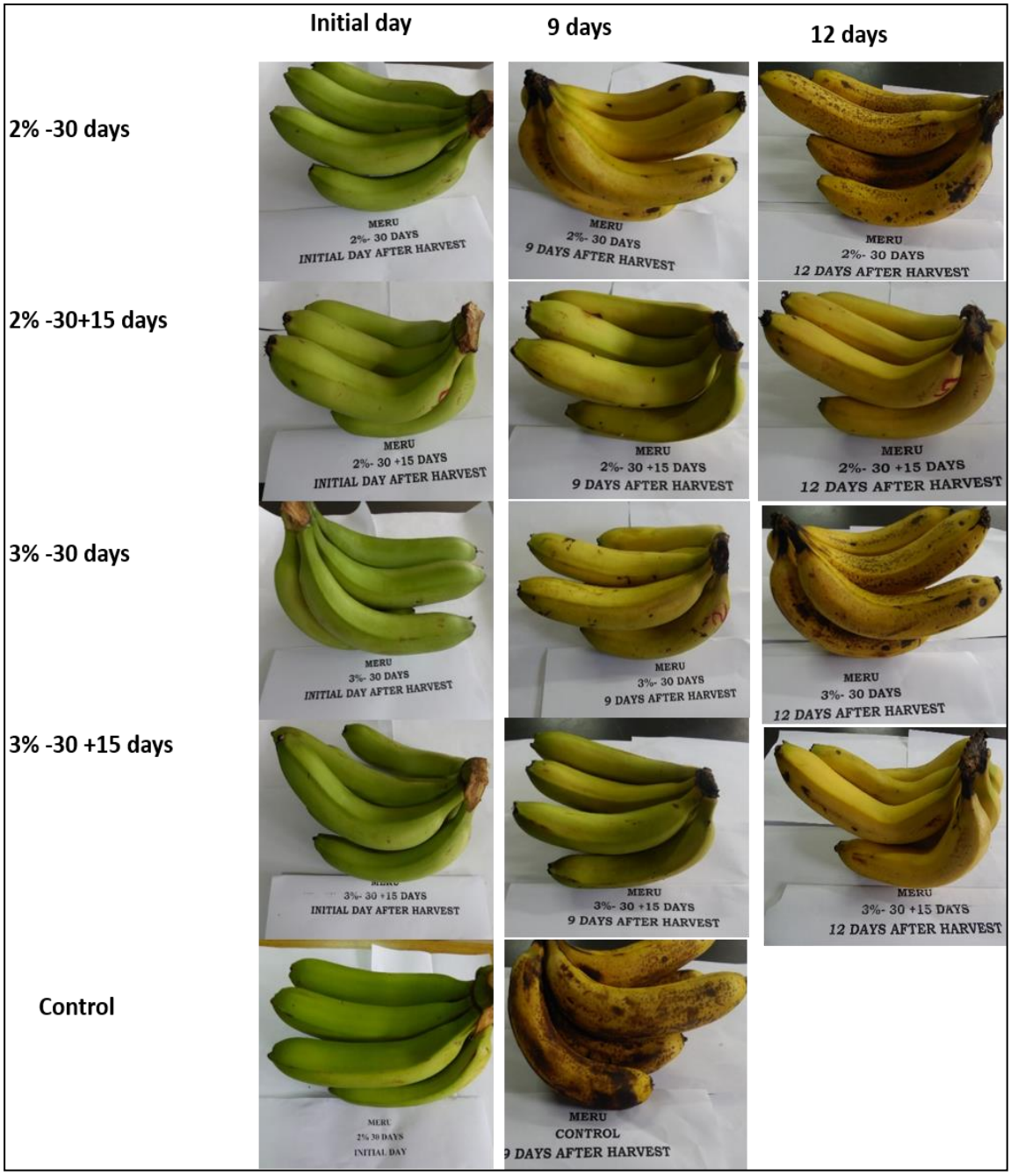


Figure 6: Progression of ripening in 'Grand nain' banana fruits sprayed with 2 d 5 d

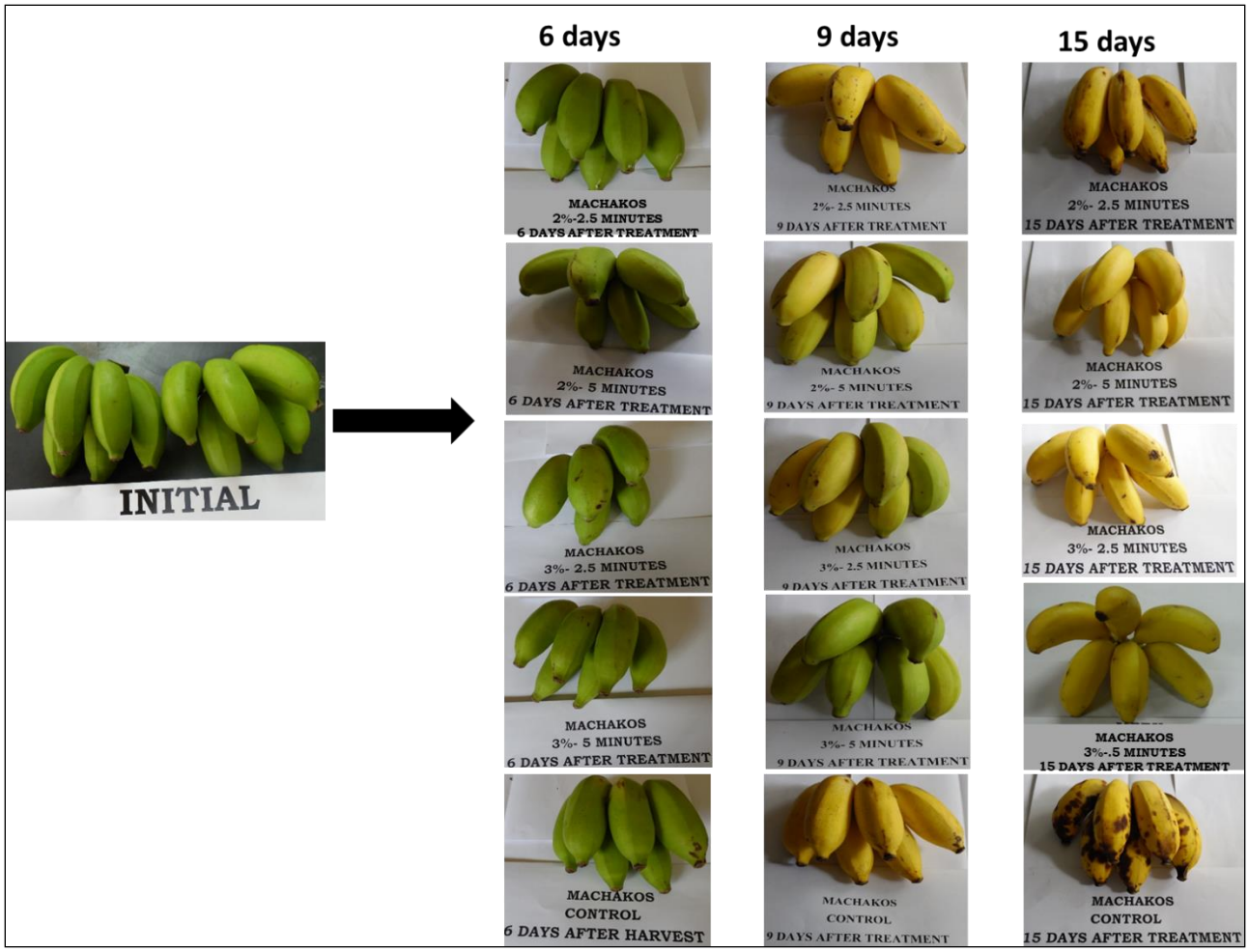


Figure 7: Progression of ripening in 'sweet banana' fruits post

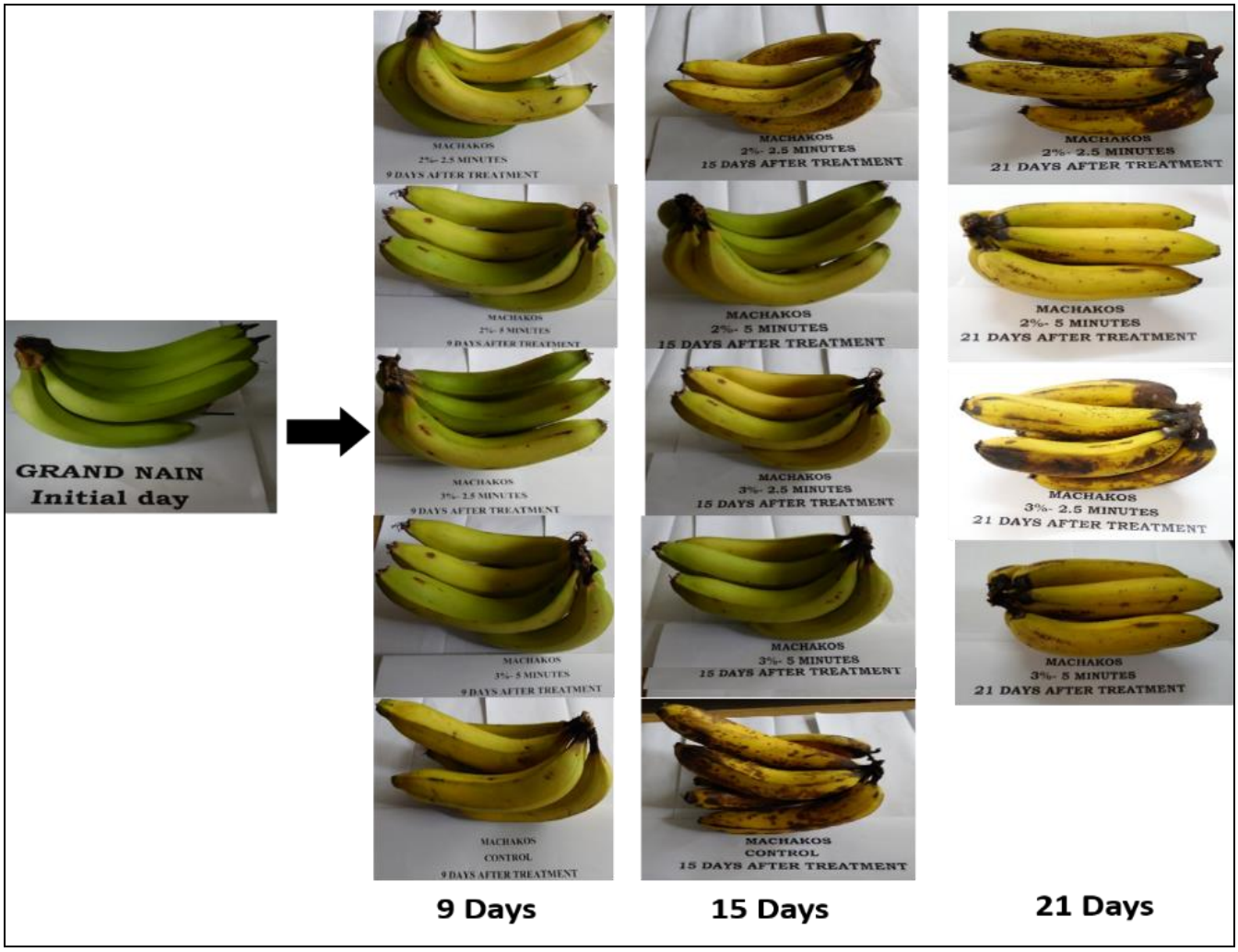


Figure 8: Progression of ripening in 'Grand nain' banana fruits post r d r d 2 d d r r 2 5 5 r d d d r d r r d

3.4.2. Ethylene production Levels

r d r d r d dr d d d d r d r r r r r r r r d r d *p* 5 r d d r rr d r r r d r d d r r d dr r d d *p* 5 r r r d r d r d r d r d r

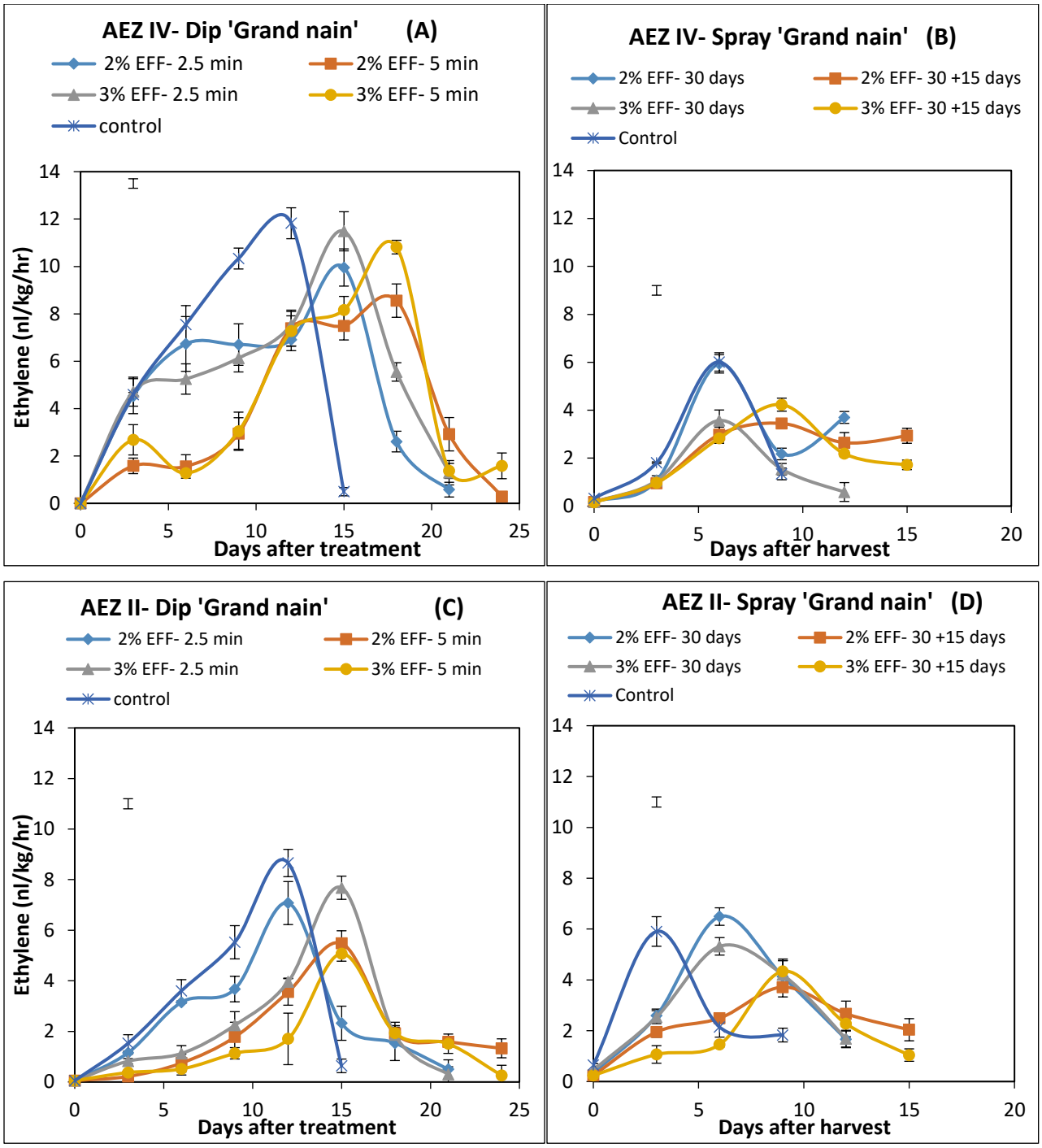


Figure 9: r d d r r r d r r d ‘Grand nain’ r r d r r r d r r r d r r d d *p* 5 r r r r *p* 5

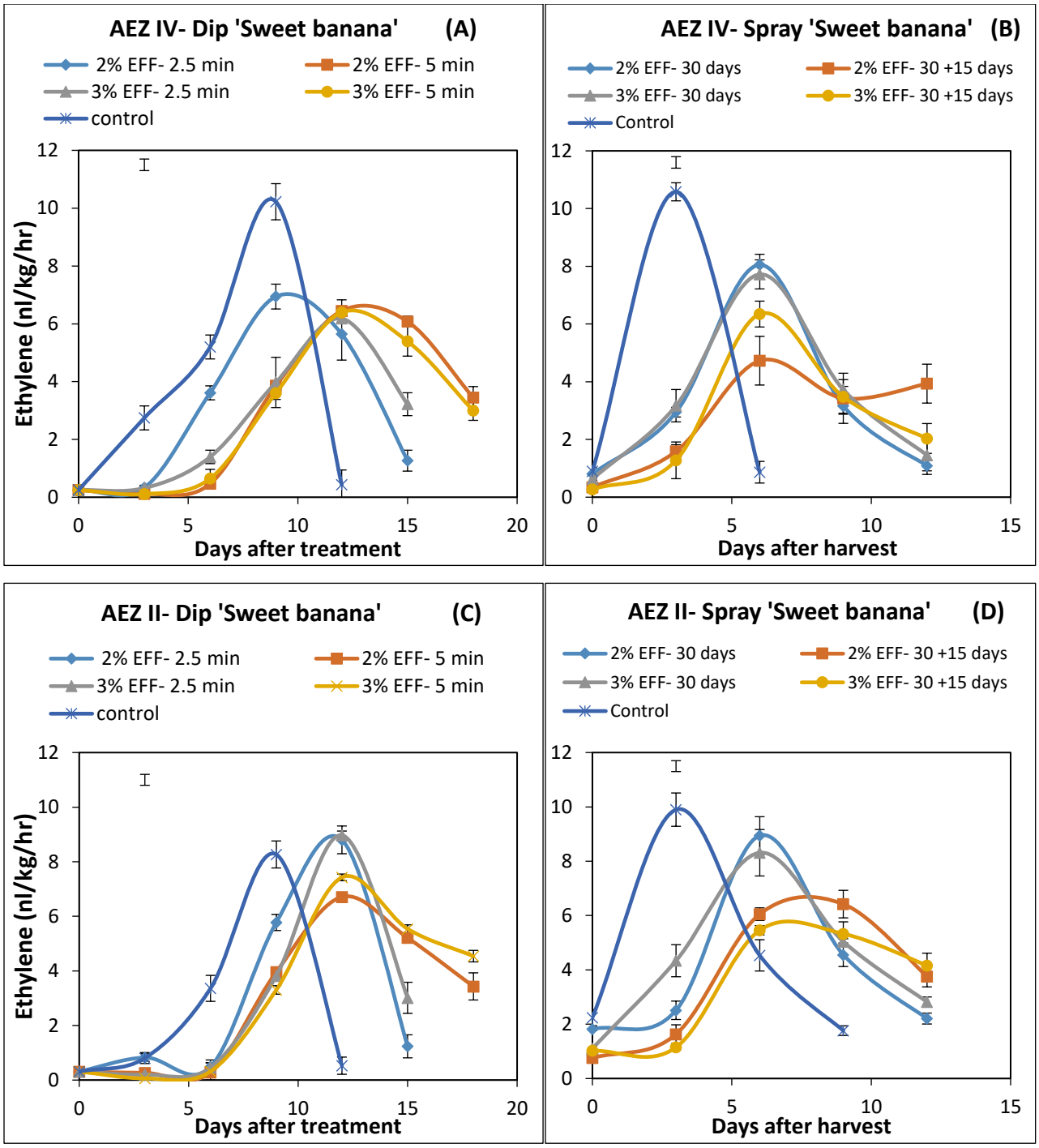


Figure 10: r d d r r r d r r d r r d r r r d r r r r r d r r r r r d r r r r r d d p 5 r r r r r p 5

3.4.3. Respiration rates

[illegible]

[illegible]

[illegible]

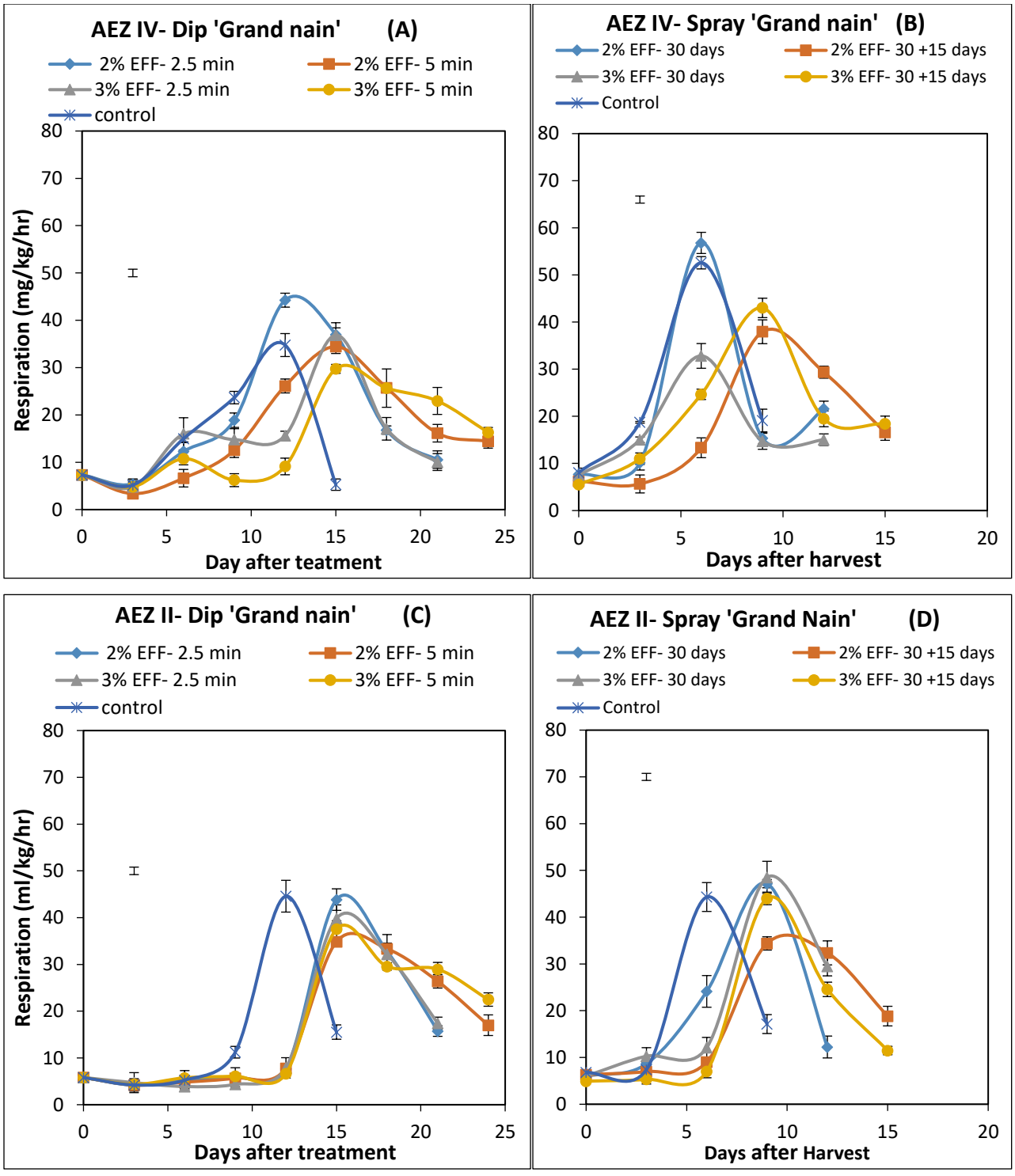


Figure 11: r d d r r r d r d r d ‘Grand nain’ banana r d r r r r d r r r d d *p* 5 r r r r *p* 5

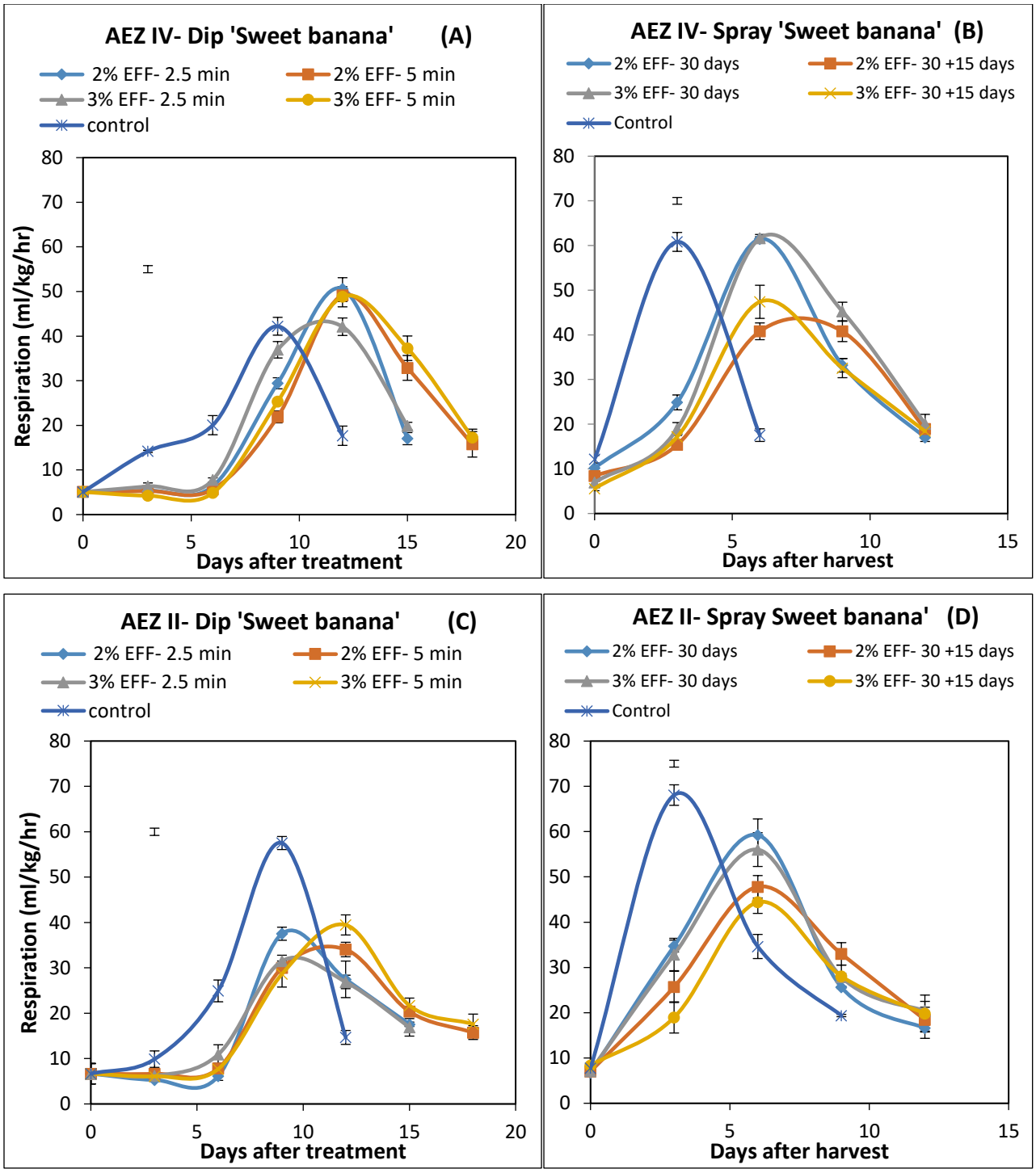

AEZ IV- Dip 'Sweet banana' (A)
2% EFF- 2.5 min
2% EFF- 5 min
3% EFF- 2.5 min
3% EFF- 5 min
control
Respiration (ml/kg/hr)
Days after treatment
AEZ IV- Spray 'Sweet banana' (B)
2% EFF- 30 days
2% EFF- 30 +15 days
3% EFF- 30 days
3% EFF- 30 +15 days
Control
Days after harvest
AEZ II- Dip 'Sweet banana' (C)
2% EFF- 2.5 min
2% EFF- 5 min
3% EFF- 2.5 min
3% EFF- 5 min
control
Respiration (ml/kg/hr)
Days after treatment
AEZ II- Spray Sweet banana' (D)
2% EFF- 30 days
2% EFF- 30 +15 days
3% EFF- 30 days
3% EFF- 30 +15 days
Control
Days after harvest

Figure 12: [illegible]

3.4.4. Cumulative weight loss (%)

r r d r r d r r d rr r r r d
d d r d 5 d 6 d r r d r d
r 2 r d d r r d
d d ‘Grand nain’ r r d d
r rd d r 5 d
d r r 5 r r r d
‘sweet b ’ r r d r r r dr r r d 6 r
6 r d ffect on weight loss with ‘sweet banana’ r r
2 d r r d ‘Grand nain’ r d r
r M d d d d
r 5 d 6

Table 5 cumulative weight loss of 'Grand nain' fruits from AEZ IV (Machakos County) and AEZ II (Meru

DAYS	Postharvest Dip					Preharvest spray				
Zone IV	**2%-A**	**2%-B**	**3%-A**	**3%-B**	**Ctrl**	**2%- S**	**2%-D**	**3%-S**	**3%-D**	**Ctrl**
0										
3	2 5	2 2	2 6	2	2	5 2		5 6	6	5 5
6	5 5	5	5	5	5 d			d		5
9			6	6		6	2 d	2	2 d	
12			2				5	5	6 2	
15	6d		6							
18	6	d		5d						
21		6	6	6 5						
24										
Zone II										
0										
3		6	5	5					6	
6		2			2	6 2	6 2	5 6	5	6 2d
9	6	6	5	6	6 2d	d				
12	5							2	2 5d	
15	6	5	6	5	2		2			
18	2		2 d	d						
21		2	5 2	5						
24										
Mean	**7.8**	**9.3**	**7.7**	**9.2**	**6**	**8.1**	**9.2**	**7.2**	**9.1**	**6.6**
M	2									
M	5									

d d r r d r *p* 5 r r 2 5 r 5 d r d 5 d r r r r r r M d d r d *p* 5 r r 2 5 r 5 d r d 5 d r r r r r r M d d r d

Table 6: cumulative weight loss of 'Sweet banana' fruits from AEZ IV (Machakos County) and AEZ II (Meru

DAYS	Postharvest Dip					Preharvest spray				
Zone IV	**2%-A**	**2%-B**	**3%-A**	**3%-B**	**Ctrl**	**2%- S**	**2%-D**	**3%-S**	**3%-D**	**Ctrl**
0										d
3			2		5	5 d	5 d	6	5 d	5
6	5	5 6	5 5	5 2	6 6			d		
9	6		d	6		6	6 6	5 6	5	
12					5	2			6	
15		2d		5 d						
18										
Zone II										
0										d
3		2 2	2		2	d	d		5 d	5 2
6	2	5	5		5					
9	6 6		5d		d	5	5		5	6
12	5d				2		6	5		
15	6	6	6							
18		2 2		2						
Mean	**6.8**	**8.8**	**6.9**	**8.9**	**6.3**	**10.5**	**9.6**	**9.4**	**9.5**	**6.7**
	2									
M										
M										
	6									

d d r r d r p 5 r r r d d r p 5 r r 2 5 r r 5 d r r r r r r M d d r d

3.4.5. Peel firmness

[illegible] *(p* [illegible]

[illegible] rand nain' variety (Figures 13 [illegible] firmness in 'sweet banana' fruits decreased at the end of storage from an initial of 39N to 2[illegible] two varieties, hexanal application was more effective in 'Grand nain' [illegible] AEZs in case of 'Grand nain' variety.

[illegible] in 'Grand nain' variety [illegible] 'Grand nain' [illegible] In 'sweet banana' variety, no significant differences were observed between the single and d[illegible]. 'Sweet banana' fruits sprayed with hexanal [illegible]

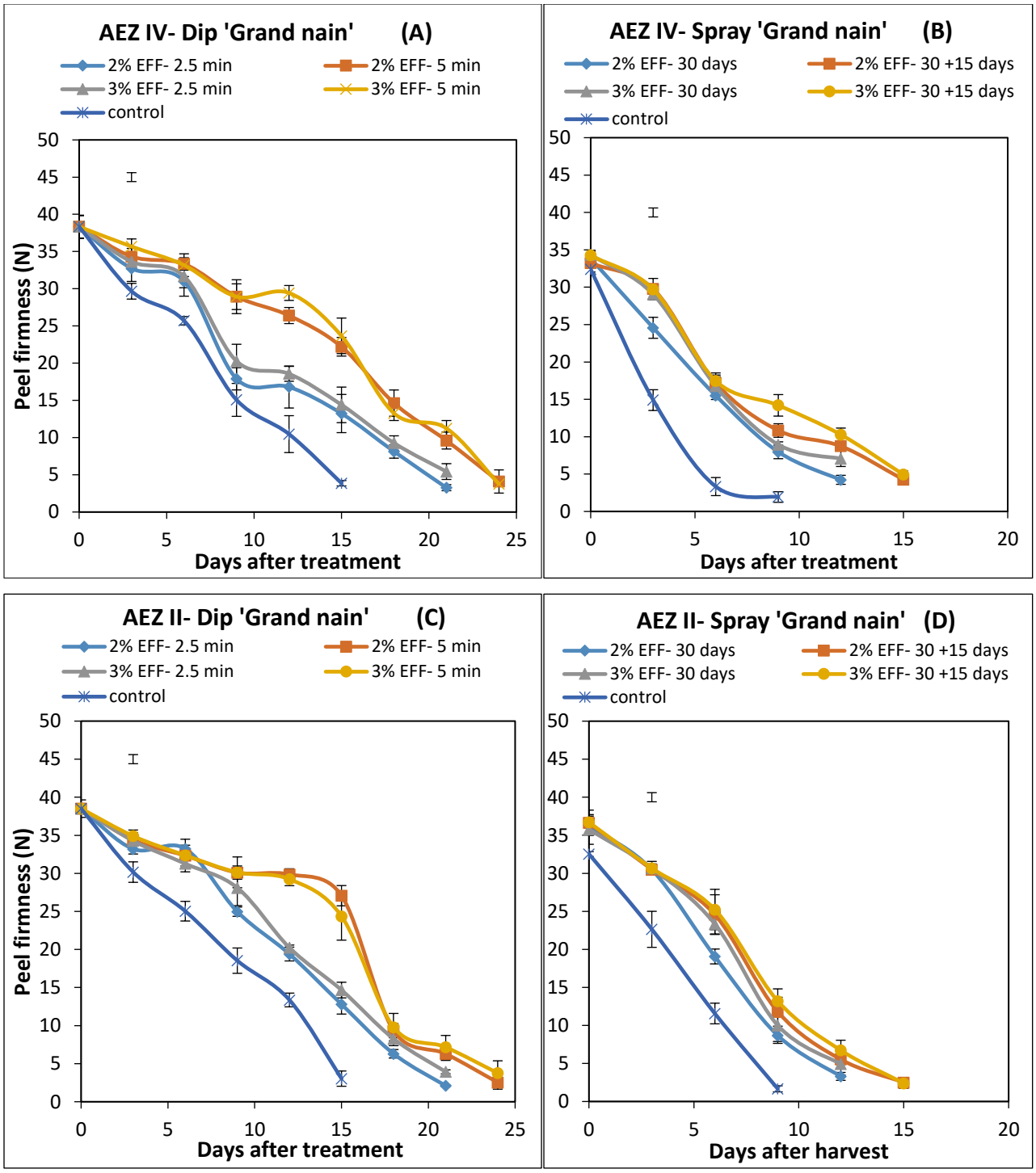


Figure 13: r d d r r r ‘Grand nain’ r r d r r d p 5 r r r p 5

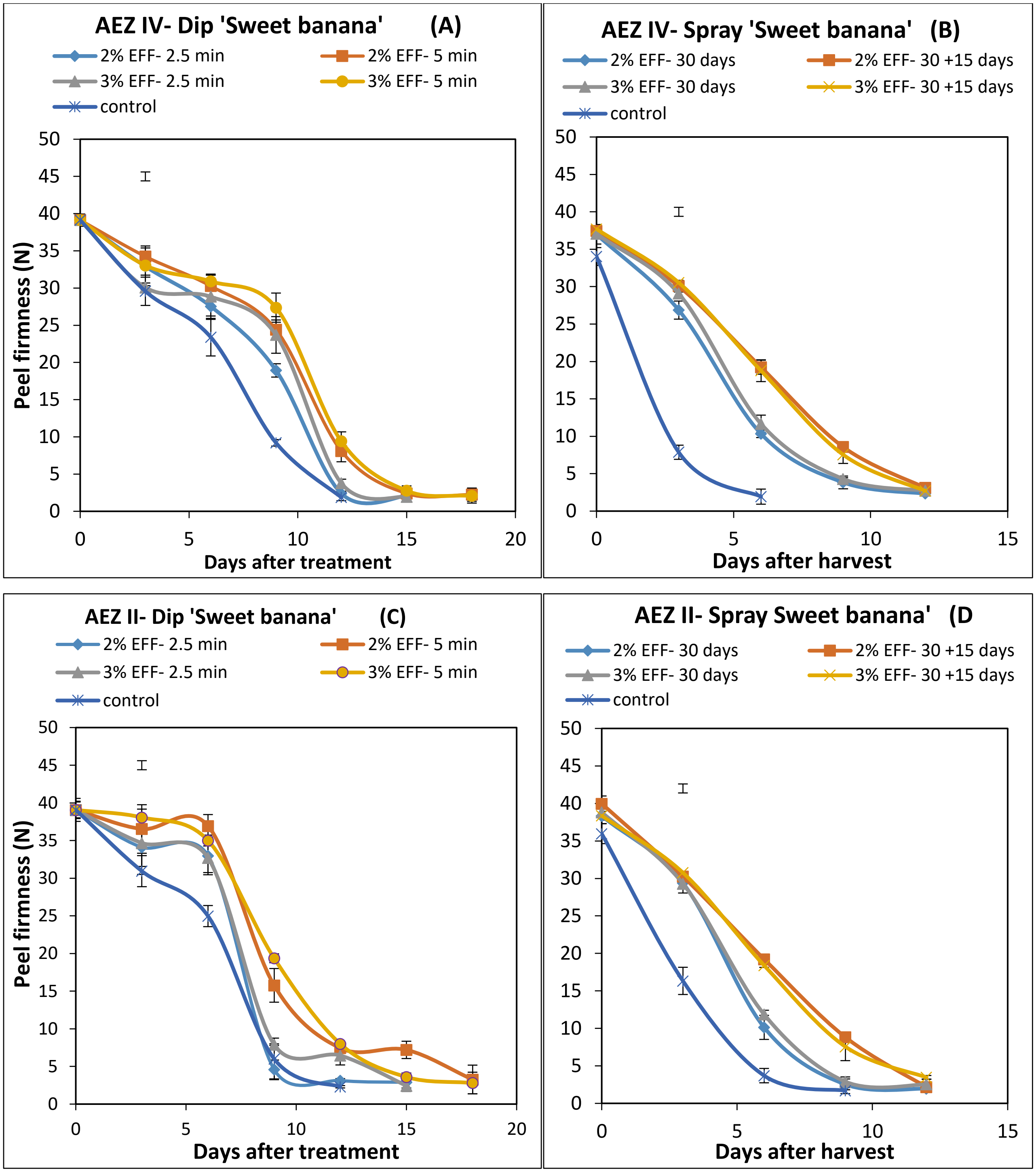


Figure 14: r d d r r r 'Sweet banana' r r d r r r r d r r r d p 5 r r r r p 5

3.4.6. Pulp firmness

[illegible]

[illegible]

[illegible] the hand, the controls in ‘sweet banana’ had lost [illegible]

[illegible] ‘Grand nain’ [illegible] was observed in ‘sweet banan’ [illegible] ngle spray and controls in ‘sweet banana’ [illegible] controls in ‘sweet banana’ variety.

Table 7: [illegible] 'Grand nain' fruits from AEZ IV (Machakos County) and AEZ II (Meru County).

DAYS	Postharvest Dip					Preharvest spray				
Zone IV	**2%-A**	**2%-B**	**3%-A**	**3%-B**	**Ctrl**	**2%- S**	**2%-D**	**3%-S**	**3%-D**	**Ctrl**
0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
18	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Zone II	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
18	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
24		[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	
Mean	**12.7**	**12.8**	**12.7**	**13**	**12.5**	**8.0**	**9.2**	**9.5**	**8.9**	**7.6**
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	

[illegible]

[illegible]

[illegible]

Table 8: [illegible] 'Sweet banana' fruits from AEZ IV (Machakos County) and AEZ II (Meru County).

DAYS	Postharvest Dip					Preharvest spray				
Zone IV	**2%-A**	**2%-B**	**3%-A**	**3%-B**	**Ctrl**	**2%- S**	**2%-D**	**3%-S**	**3%-D**	**Ctrl**
0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
18		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Zone II	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
18		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Mean	**14.8**	**14.6**	**15.4**	**15.7**	**13.3**	**10.6**	**13.4**	**11.7**	**14.2**	**9.9**
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]	

[illegible]

3.4.7. Peel color

Table 9: [illegible] of 'Grand nain' fruits from AEZ IV [illegible]

DAYS	Postharvest Dip					Preharvest spray				
Zone IV	**2%-A**	**2%-B**	**3%-A**	**3%-B**	**Ctrl**	**2%- S**	**2%-D**	**3%-S**	**3%-D**	**Ctrl**
0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
18	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Zone II	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
18	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Mean	**104.5**	**106.9**	**106.2**	**106.8**	**104.8**	**97.2**	**97.6**	**98.3**	**97.0**	**92.6**
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

[illegible]

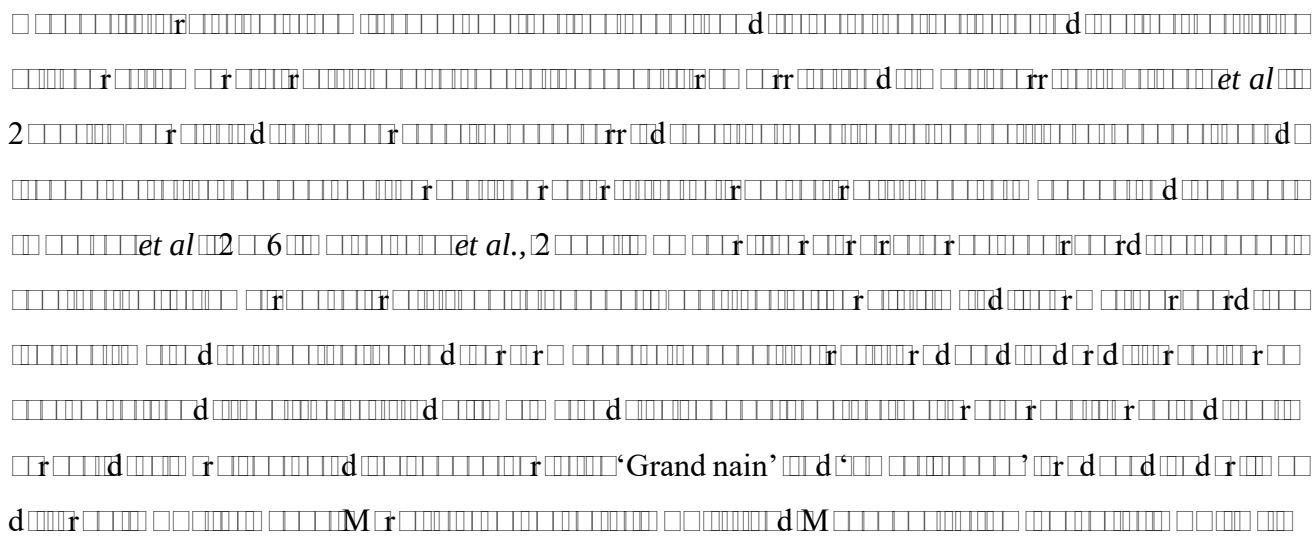
[illegible]

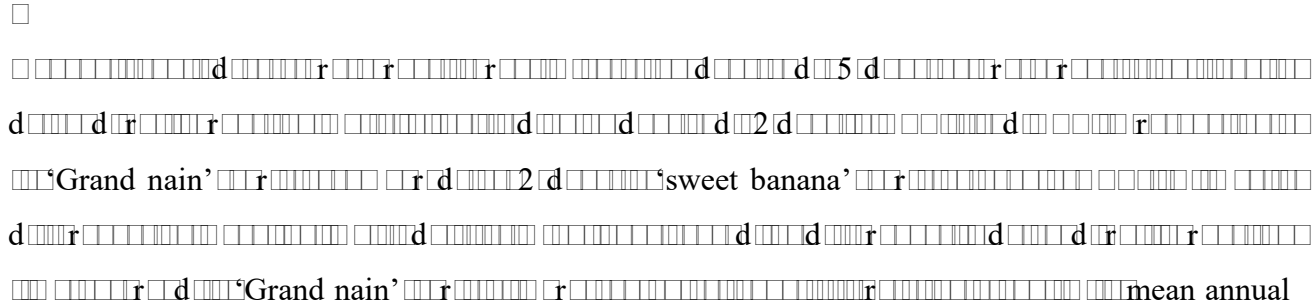
Table 10: [illegible] changes of ‘Sweet banana’ fruits from AEZ IV (Machakos County) and AEZ II (Meru County).

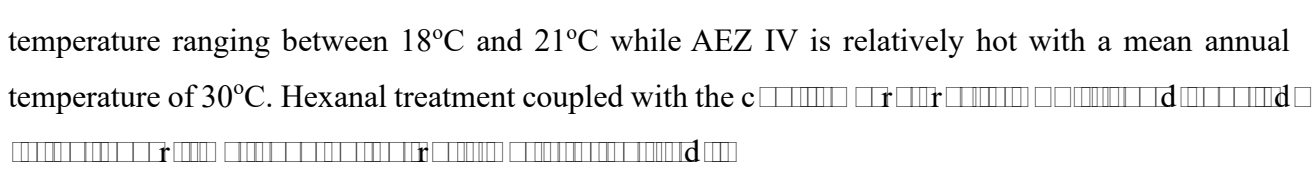
DAYS	**Postharvest Dip**					**Preharvest spray**				
Zone IV	**2%-A**	**2%-B**	**3%-A**	**3%-B**	**Ctrl**	**2%- S**	**2%-D**	**3%-S**	**3%-D**	**Ctrl**
0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
15	[illegible]	[illegible]	[illegible]	[illegible]						
18		[illegible]		[illegible]						
Zone II										
0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
15	[illegible]	[illegible]	[illegible]	[illegible]						
18		[illegible]		[illegible]						
Mean	**105.2**	**104.1**	**105.6**	**104.2**	**101.4**	**97**	**100.1**	**97.4**	**99.1**	**92.6**
[illegible]										
[illegible]										
[illegible]										
[illegible]										
[illegible]										

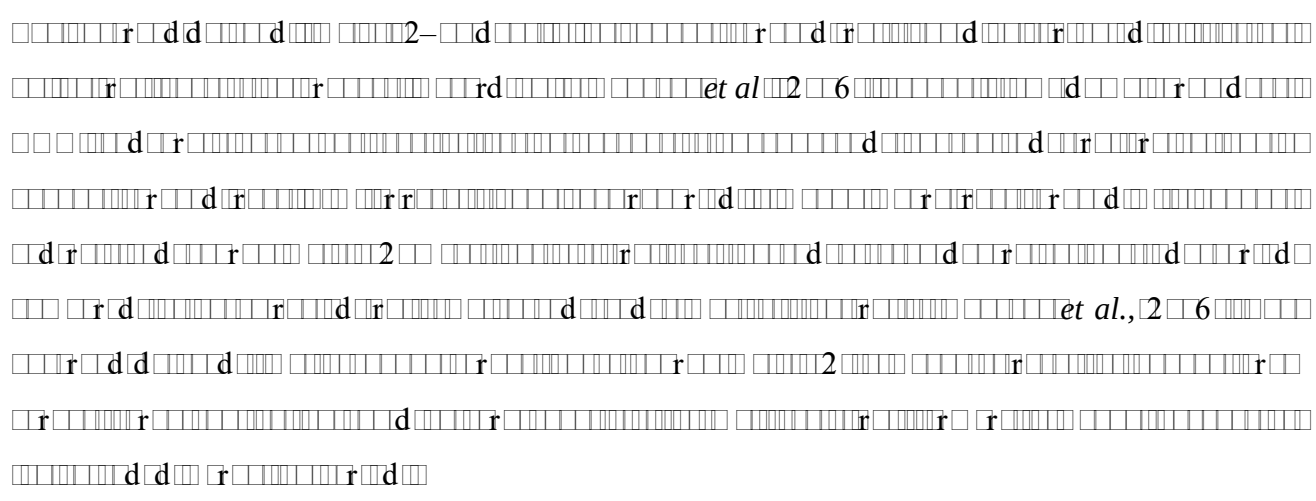
[illegible]

3.5. Discussion









rvest dip treated ‘sweet banana’ fruits

harvest dip treatment for 5 minutes extended fruits’ shelf life by 6 and 9 days in ‘Grand

nain' and 'sweet banana' varieties respe[illegible] harvest spray treated 'Grand nain' fruits had a shelf life of 3 and 6 days incase of single and double [illegible] harvest sprayed 'sweet banana' fruits had a shelf [illegible] 2 [illegible]'s pre harvest spray treated fruits [illegible]

CHAPTER 4

4.0 Effects of Hexanal Treatments on the Post-Harvest Quality Characteristics Banana Fruits

4.1 Abstract

4.1. Introduction

before the attainment of physiological maturity, the fruits don’t ripen fully and

4.2. Materials and methods

4.2.1. Fruit Samples

The experiments were conducted in two successive seasons, July to November 2016 and January to April 2017.

4.2.2. Measurement of biochemical attributes of banana

4.2.2.1. Total Soluble Solids (TSS/ºBrix)

$$\%\ \boldsymbol{Brix\ (dry\ weight\ basis)} = \left(\frac{\%\ \boldsymbol{Brix\ in\ wet\ weight\ basis} * \mathbf{100}}{\mathbf{100} - \boldsymbol{Moisture\ content}}\right)$$

4.2.2.2. Total Titratable Acidity (TTA)

$$\boldsymbol{TTA\ (dry\ weight\ basis)} = \left(\frac{\boldsymbol{TTA\ value\ in\ wet\ weight\ basis} * \mathbf{100}}{\mathbf{100} - \boldsymbol{Moisture\ content}}\right)$$

4.2.2.3. Ascorbic acid content

$$\textbf{Ascorbic acid}, \left(\frac{\textbf{mg}}{\textbf{100ml}}\right) = \left(\frac{\textbf{Peak area from graphs}}{\textbf{y}}\right) * \left(\frac{\textbf{Dilution volume}}{\textbf{Sample weight (g)}}\right) * \left(\frac{\textbf{100}}{\textbf{1000}}\right)$$

$$\textbf{Ascorbic acid (dry weight basis)} = \left(\frac{\textbf{Ascorbic acid value in wet weight basis} * \textbf{100}}{\textbf{100} - \textbf{Moisture content}}\right)$$

4.2.2.4. Determination of simple sugars (Glucose, fructose and Sucrose) contents

$$Amount\ of\ Carbohydrate\ present\ in\ sample\ (\%\ mg) = \frac{Sugar\ value\ from\ graph\ (mg)}{Aliquot\ sample\ used}\ X \frac{Total\ volume\ of\ extract\ (ml)}{Weight\ of\ sample\ (mg\ or\ ml)}\ X\ 100$$

$$Sugar\ value\ (dry\ weight\ basis) = \left(\frac{Sugar\ value\ in\ wet\ weight\ basis * 100}{100 - Moisture\ content}\right)$$

4.2.2.5. Sensory quality evaluation

[illegible] *et al.* ([illegible]

4.2.3. Statistical analyses

[illegible] $p \leq .05$ using [illegible]isher's protected test. [illegible]

4.3. Results

4.3.1. Total soluble solids (^{0}Brix)

TSS levels. Overall, 'sweet banana' had higher TSS levels compared to 'Grand nain' fruits in both

harvest dip mode of application (season 1), TSS levels in 'Grand nain' fruits increased from

'Grand nain' dip treated fruits, TSS

later compared to the untreated fruits. A similar trend was observed in 'sweet banana' dip treated

end stage (day 18), which occurred 6 days earlier than in dip treated 'Grand nain' fruits.

Brix in 'Grand nain' spray treated fruits in AEZ IV and AEZ II, respectively at the

harvest. In the 'sweet banana'

'sweet banana', sprayed fruits attained almost the same T

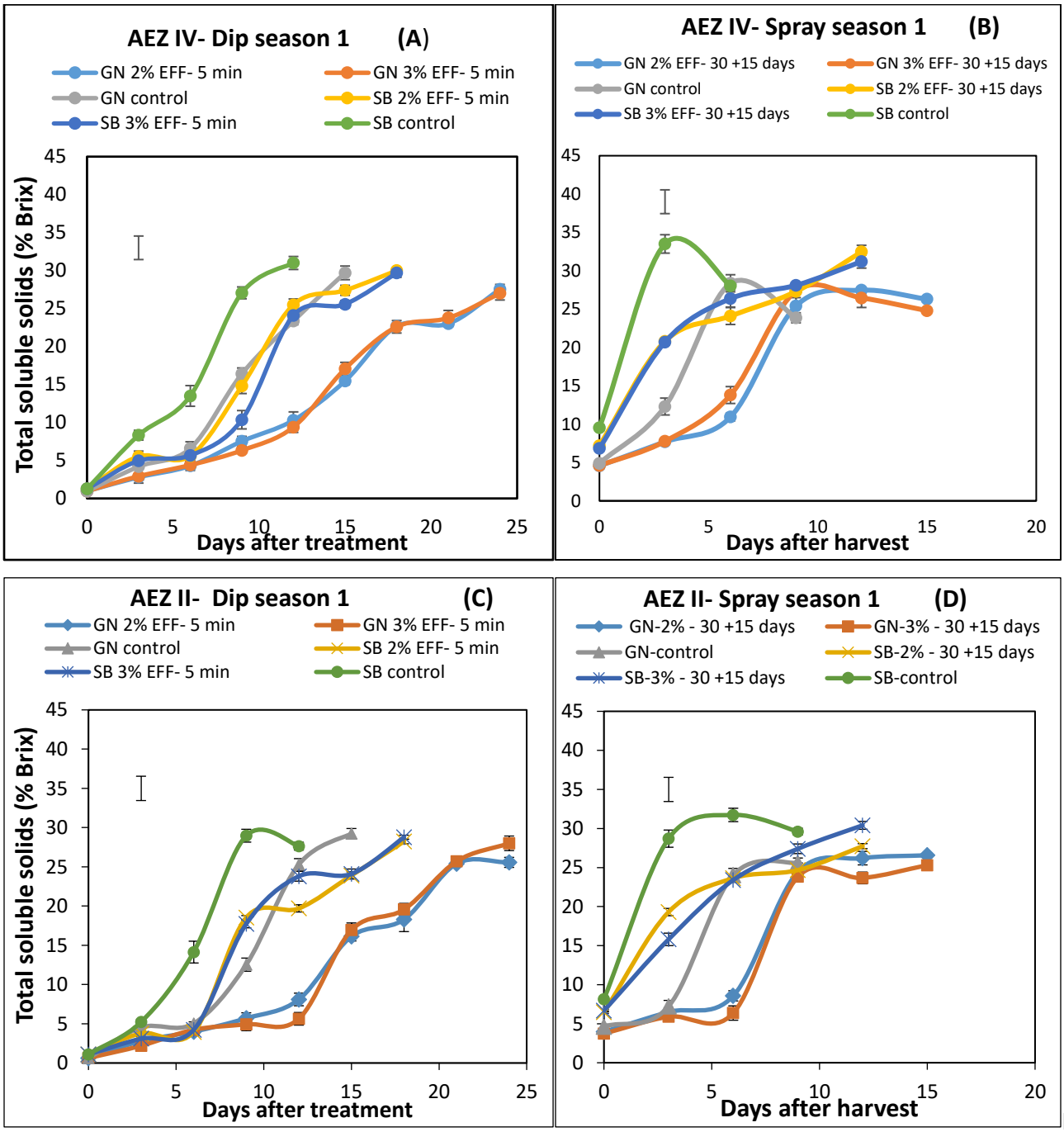


Figure 15: soluble solids in 'Grand nain' (GN) and 'Sweet banana'

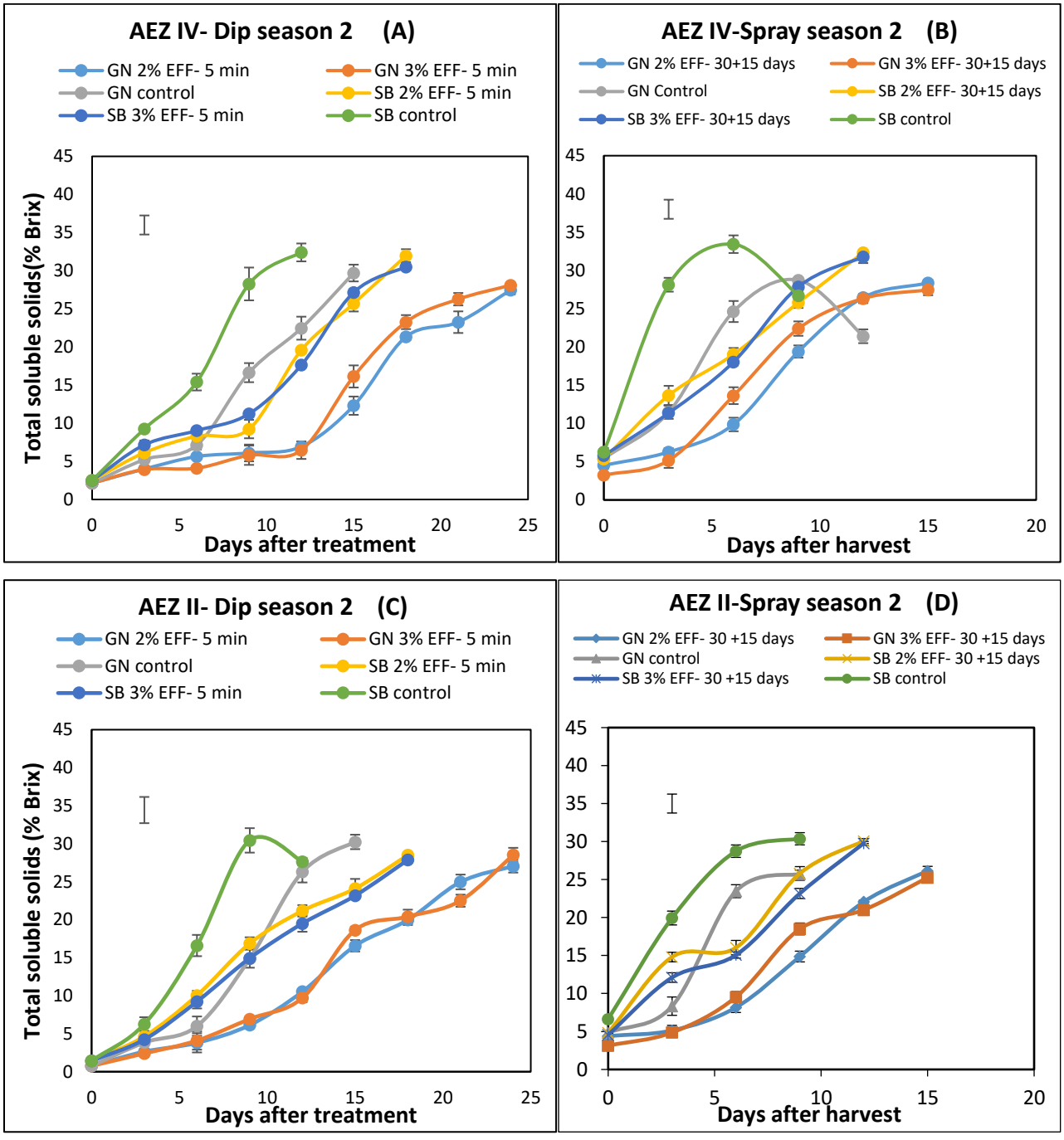


Figure 16: [illegible] ‘Grand nain’(GN) and ‘Sweet banana’ [illegible] 2 [illegible]

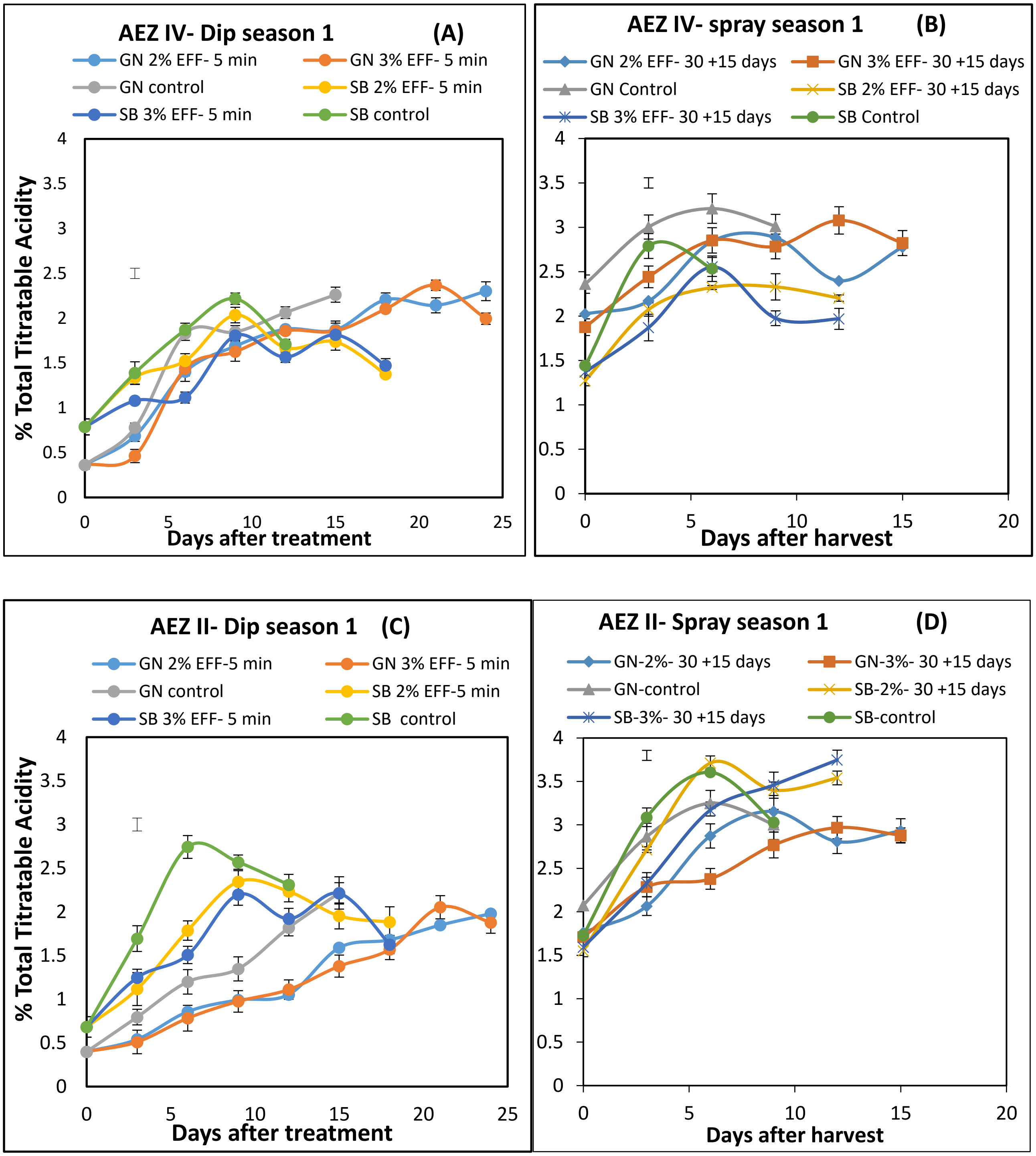


Figure 17: [illegible] 'Grand nain' [illegible] and 'Sweet banana' [illegible] *p* [illegible] 5 [illegible] *p* [illegible] 5 [illegible]

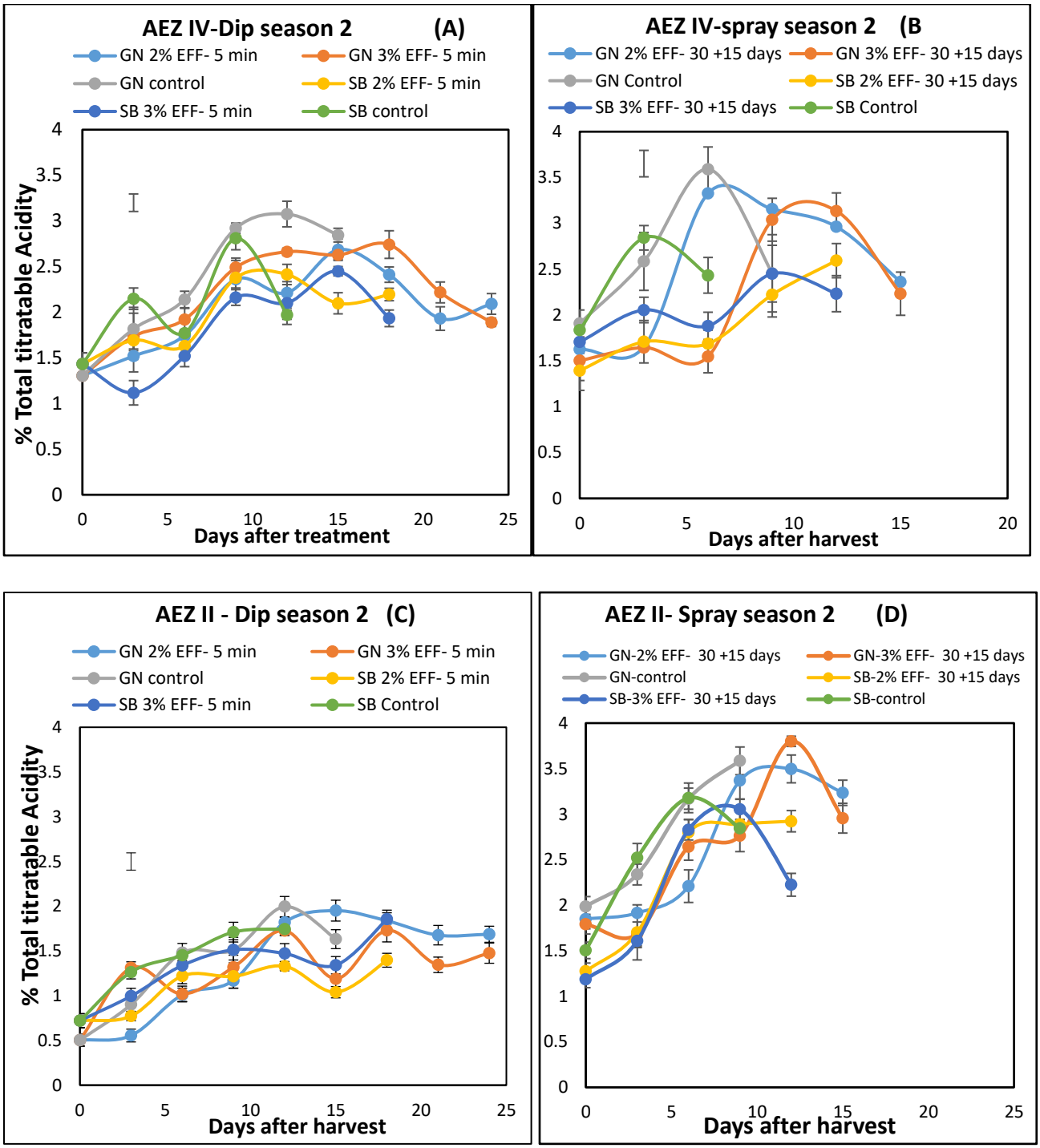


Figure 18: r d d r r r d r d ‘Grand nain’ and ‘Sweet banana’ r r d 2 r r r r d r r r d p 5 r r r r p 5

4.3.3. Ascorbic acid (vitamin C)

significant differences between them in ‘Grand nain’ var‘sweet banana’, c‘Grand nain’ fruits pared to ‘sweet banana’ irrespective of t in the untreated control (‘Grand nain’ by the end of storage (day 24) in the ‘Grand nain’ variety. In the ‘sweet banana’ variety, the ascorbic In the untreated ‘Grand nain’ fruits, vitamin C levels decreased irrespective of variety and AEZ. By day 24 of storage, ‘Grand nain’ fruits treated with 2 % hexana

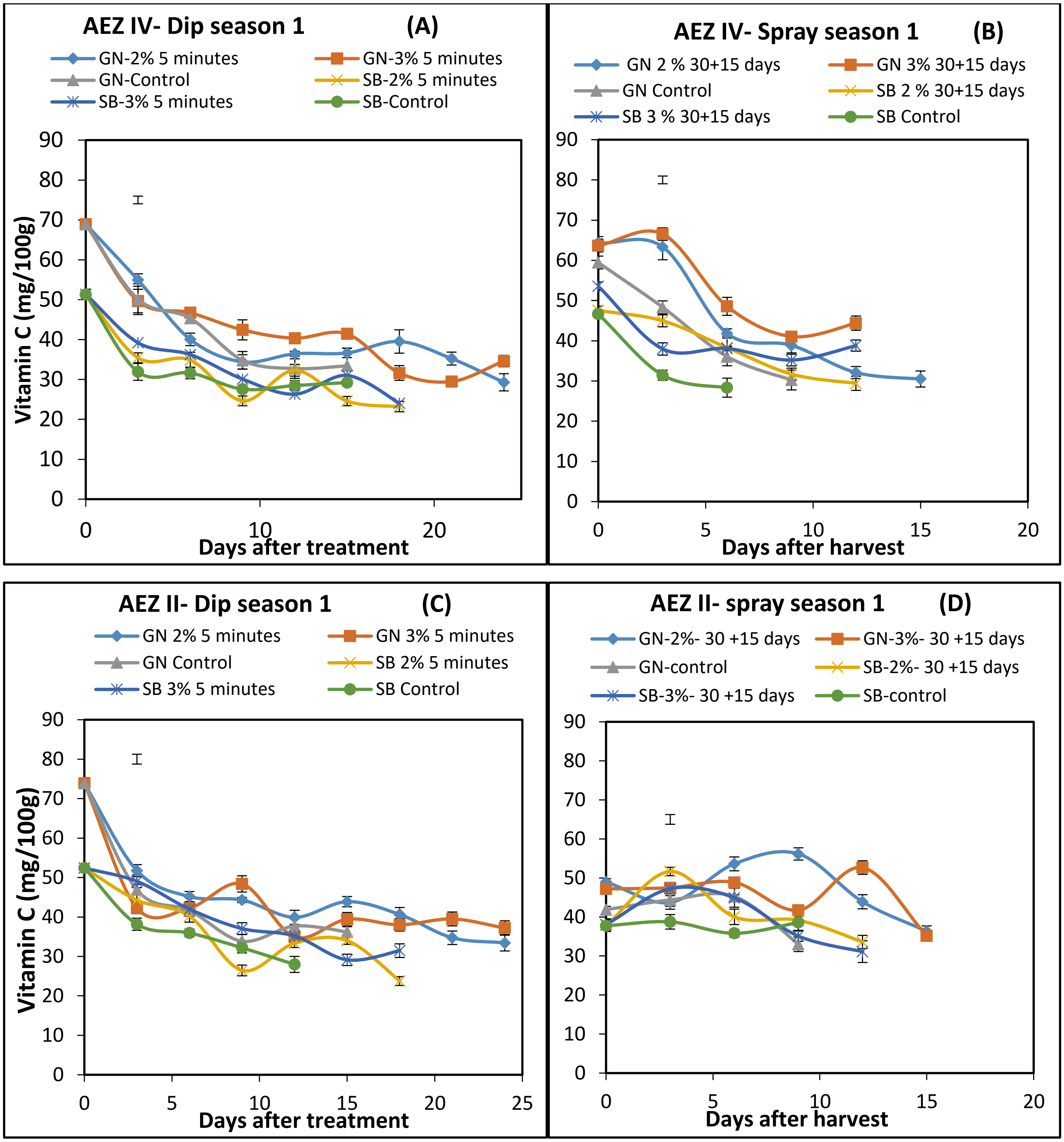


Figure 19: [illegible] 'Grand nain' [illegible] and 'Sweet banana' [illegible] p [illegible] 5 [illegible] p [illegible] 5 [illegible]

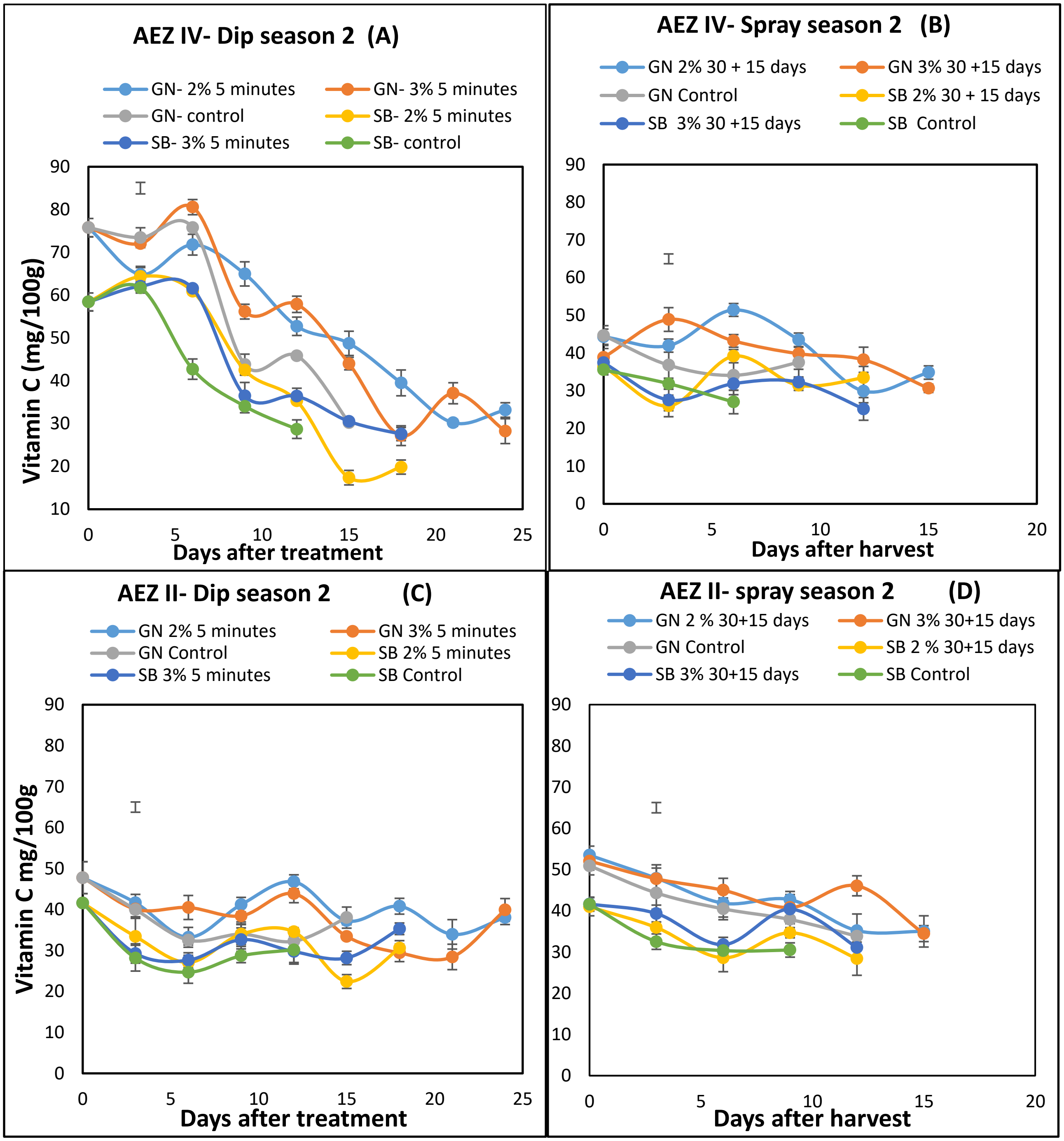


Figure 20: [illegible] 'Grand nain' [illegible] and 'Sweet banana' [illegible] 2 [illegible] p [illegible] 5 [illegible] p [illegible] 5 [illegible]

4.3.4. Changes in simple Sugars

4.3.4.1. Fructose

[illegible] g/100g (day 3) occurred in the untreated ‘Grand nain’ and ‘sweet banana’ fruits [illegible] ‘sweet banana’ peaked high (148.6 [illegible]

[illegible] compared to the untreated ones. In the untreated ‘Grand nain’ fruits, fructose levels increased [illegible]

[illegible] n the ‘sweet banana’ variety. The fructose levels increased rapidly to [illegible] in the hexanal treated fruits assumed a similar trend to that in ‘Grand nain’ variety with levels of [illegible]

Table 11A: [illegible] of 'r[illegible]d nain' [illegible]

M[illegible]	[illegible]r[illegible]			[illegible] r[illegible]r[illegible]		
[illegible]	[illegible]	[illegible]r[illegible]	2[illegible]	[illegible]	[illegible]r[illegible]	2[illegible]	[illegible]
[illegible]	[illegible]	5[illegible]	5[illegible]	5[illegible]	[illegible]5[illegible]	[illegible]	26[illegible]
	[illegible]	[illegible]5[illegible]	[illegible]	[illegible]	5[illegible]	[illegible]	[illegible]
	6[illegible]	[illegible]	25[illegible]	[illegible]	2[illegible]2[illegible]	65[illegible]	[illegible]
	[illegible]	[illegible]5d[illegible]	56[illegible]	5[illegible]		[illegible]5[illegible]	[illegible]62[illegible]
	[illegible]2[illegible]	2[illegible]	[illegible]	6[illegible]		[illegible]2[illegible]	26[illegible]
	[illegible]5[illegible]	[illegible]5[illegible]	62[illegible]	[illegible]		[illegible]2[illegible]	[illegible]5[illegible]
	[illegible]		[illegible]	[illegible]22[illegible]d[illegible]			
	2[illegible]		2[illegible]5[illegible]	[illegible]			
	2[illegible]		2[illegible]6[illegible]	[illegible]			
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	6[illegible]	6[illegible]	6[illegible]	[illegible]	[illegible]2[illegible]	[illegible]
	[illegible]	[illegible]2[illegible]	[illegible]	[illegible]	5[illegible]d[illegible]	2[illegible]	2[illegible]5[illegible]
	6[illegible]	26[illegible]	22[illegible]	[illegible]5[illegible]	[illegible]225[illegible]	[illegible]6[illegible]	[illegible]2[illegible]
	[illegible]2[illegible]	[illegible]52[illegible]	2[illegible]2[illegible]	[illegible]	[illegible]22[illegible]	[illegible]	[illegible]
	[illegible]5[illegible]	[illegible]6[illegible]	[illegible]6[illegible]	5[illegible]		2[illegible]d[illegible]	[illegible]d[illegible]
	[illegible]	[illegible]	62[illegible]	[illegible]		[illegible]6[illegible]	[illegible]6[illegible]
	2[illegible]	[illegible]	[illegible]2[illegible]	[illegible]2[illegible]			
	2[illegible]	[illegible]	[illegible]6d[illegible]	[illegible]2[illegible]			
		[illegible]	[illegible]	[illegible]			
	Mean	**82.4**	**75.4**	**74.2**	**96.4**	**83.8**	**92.6**
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]M[illegible]	2[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]M[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]6[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible] d[illegible] d[illegible] r[illegible] r[illegible] d[illegible] r[illegible] *p*[illegible]5[illegible] [illegible] r[illegible] r[illegible] d[illegible] d[illegible] r[illegible] *p*[illegible]5[illegible] r[illegible] [illegible] r[illegible]M[illegible] d[illegible] [illegible] d[illegible] r[illegible] r d[illegible]

Table 11B: [illegible] 'Sweet banana' [illegible]

M d [illegible]	[illegible] r [illegible]			[illegible] r [illegible]		
[illegible]	[illegible]	[illegible] r [illegible]	2 [illegible]	[illegible]	[illegible] r [illegible]	2 [illegible]	[illegible]
[illegible]	[illegible]	5 5 [illegible]	5 5 [illegible]	5 5 [illegible]	5 5 [illegible]	2 [illegible]	[illegible] 5 [illegible]
	[illegible]	[illegible]	[illegible]	[illegible] 2 [illegible]	6 [illegible]	2 2 [illegible]	2 5 [illegible]
	6 [illegible]	5 2d [illegible]	[illegible]	[illegible] 6 [illegible]	2 2 [illegible]	6 [illegible]	[illegible]
	[illegible]	[illegible]	22 2 [illegible]	2 6 [illegible]		[illegible] 2 [illegible]	[illegible] 2 [illegible]
	2 [illegible]	[illegible]	[illegible] d [illegible]	[illegible] 2 d [illegible]		[illegible]	[illegible]
	5 [illegible]		[illegible] 2 [illegible]	[illegible] 2 [illegible]			
	[illegible]		[illegible] 5 [illegible]	[illegible] 5 5 [illegible]			
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] 5 [illegible]
	[illegible]	[illegible]	[illegible]	[illegible] 6 [illegible]	[illegible] 6 [illegible]	66 6d [illegible]	[illegible]
	6 [illegible]	5 [illegible]	2 [illegible]	[illegible]	[illegible] 6 [illegible]	52 [illegible]	5 [illegible]
	[illegible]	[illegible]	6 [illegible]	[illegible]	[illegible] 2d [illegible]	[illegible] 6 [illegible]	[illegible] d [illegible]
	2 [illegible]	[illegible]	[illegible]	[illegible] 6 [illegible]		[illegible] 2 [illegible]	[illegible]
	5 [illegible]		[illegible] 2 [illegible]	[illegible] 6 [illegible]			
[illegible]	[illegible]		[illegible]	[illegible] 6d [illegible]			
	Mean	**77.3**	**59.3**	**65.9**	**98.6**	**68.3**	**70.5**
	[illegible] [illegible]	[illegible] 2 [illegible]					
	[illegible] M [illegible]	[illegible] 6 [illegible]					
	[illegible] M [illegible]	6 2 [illegible]					
	[illegible] [illegible]	[illegible] 6 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible] d [illegible] d [illegible] r [illegible] r [illegible] [illegible] d [illegible] r [illegible] *p* [illegible] 5 [illegible] [illegible] r [illegible] r [illegible] [illegible] d [illegible] d [illegible] r [illegible] *p* [illegible] 5 [illegible] r [illegible] [illegible] r [illegible] M [illegible] d [illegible] d [illegible] r [illegible] r d [illegible]

4.3.4.2. Glucose

[illegible] r [illegible] d [illegible] r r d [illegible] r [illegible] r [illegible] d [illegible] r [illegible] r [illegible] 2 [illegible] d [illegible] [illegible] r [illegible] r [illegible] r d [illegible] r [illegible] d r [illegible] r d [illegible] r [illegible] r d [illegible] r [illegible] r [illegible] *p* [illegible] 5 [illegible] d [illegible] r [illegible] [illegible] d [illegible] d [illegible] r [illegible] r [illegible] r [illegible] r [illegible] d [illegible] r [illegible] *p* [illegible] 5 [illegible] d [illegible] r [illegible] [illegible] r d [illegible] r [illegible] d [illegible] r d [illegible] r [illegible] d [illegible] r [illegible] d [illegible] r [illegible] [illegible] d [illegible] r [illegible] [illegible] r [illegible]

'sweet banana' fruits had significantly high levels of glucose compared to 'Grand nain' variety [illegible] 2 [illegible] d [illegible]

[illegible]
day 3 in the untreated 'Grand nain' fruits, compared to approximate [illegible]
[illegible]
in 'sweet banana' variety, glucose levels i[illegible]
[illegible]
of storage in the preharvest sprayed AEZ IV fruits. Unexpectedly, the untreated control 'Grand nain' [illegible]

Table 12A: [illegible] 'Grand nain' [illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Mean	**83.5**	**73.9**	**87.0**	**131.3**	**100.7**	**97.1**
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

Table 12B: [illegible] g/100g) of 'Sweet banana' from AEZ IV (Machakos County) and AEZ II (Meru County).

[illegible]	[illegible]	[illegible]			[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
	[illegible]		[illegible]	[illegible]			
	[illegible]		[illegible]	[illegible]			
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
	[illegible]		[illegible]	[illegible]			
	[illegible]		[illegible]	[illegible]			
	Mean	**71.6**	**72.3**	**79.0**	**107.5**	**78.7**	**65.1**
	[illegible]	[illegible]					
	[illegible]	[illegible]					
	[illegible]	[illegible]					
	[illegible]	[illegible]					
	[illegible]	[illegible]					

[illegible]

4.3.4.3. Sucrose

In the untreated ‘sweet banana’ fruits (pos to 150 mg/100g (day 3) and 161mg/100g (day 6) in ‘sweet banana’ fruits from AEZ IV and

the ‘Grand nain’ variety which had sucrose levels increasing to a peak

Table 13A: [illegible] 'Grand nain' [illegible]

[illegible]	[illegible]	[illegible]			[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	146.0	126.5	127.9	97.3	99.8	105.2
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

Table 13B: [illegible] g/100g) of 'Sweet banana' from AEZ IV (Machakos County [illegible]

[illegible]		[illegible]			[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
	[illegible]		[illegible]	[illegible]			
	[illegible]		[illegible]	[illegible]			
[illegible]							
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
	[illegible]		[illegible]	[illegible]			
	[illegible]		[illegible]	[illegible]			
	Mean	**138.0**	**116.7**	**118.4**	**98.7**	**89.2**	**89.5**
	[illegible]	[illegible]					
	[illegible]	[illegible]					
	[illegible]	[illegible]					
	[illegible]	[illegible]					
	[illegible]	[illegible]					

[illegible]

4.3.5. Sensory quality evaluation

Generally, untreated control ‘Grand nain’ fruits from Meru County scored relatively higher for

ontrols in ‘Grand nain’ variety (Figure 2

In ‘sweet banana’ variety,

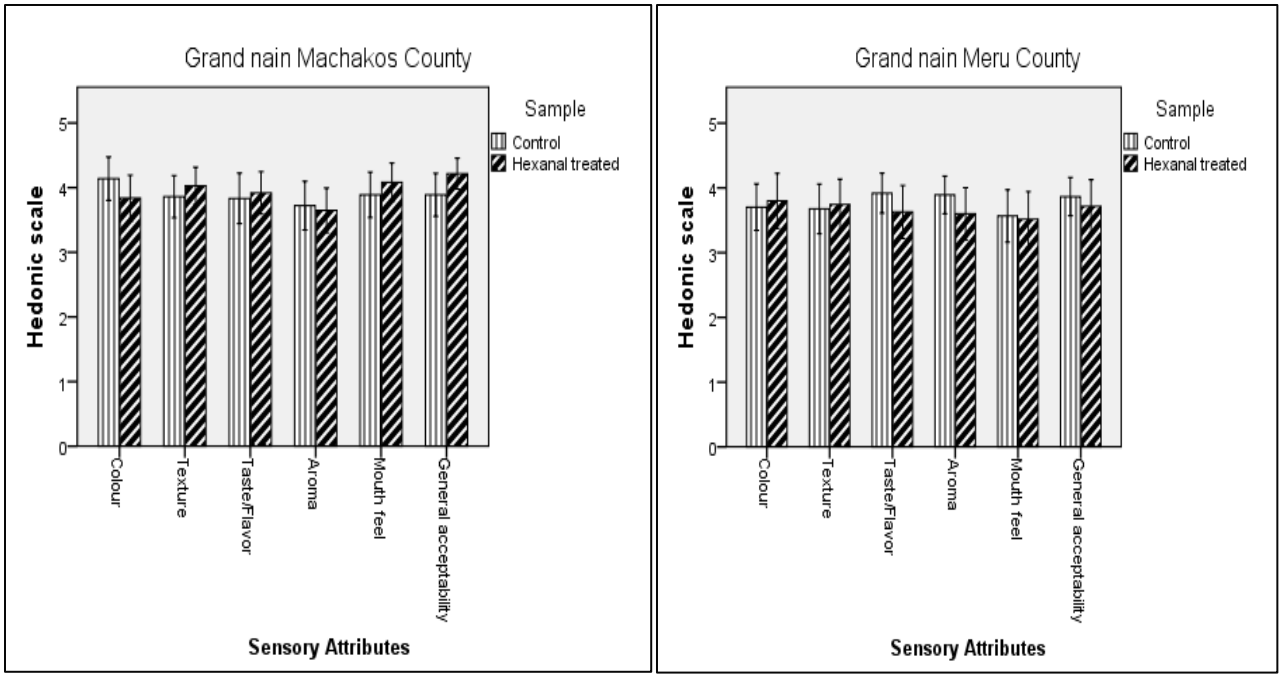


Figure 21: Hedonic scores for sensory quality attributes of 'Grand nain' bananas harvested from M r d M d r d r r r r r 5 d d r 2 d d r r r d 5 r r r r r r r

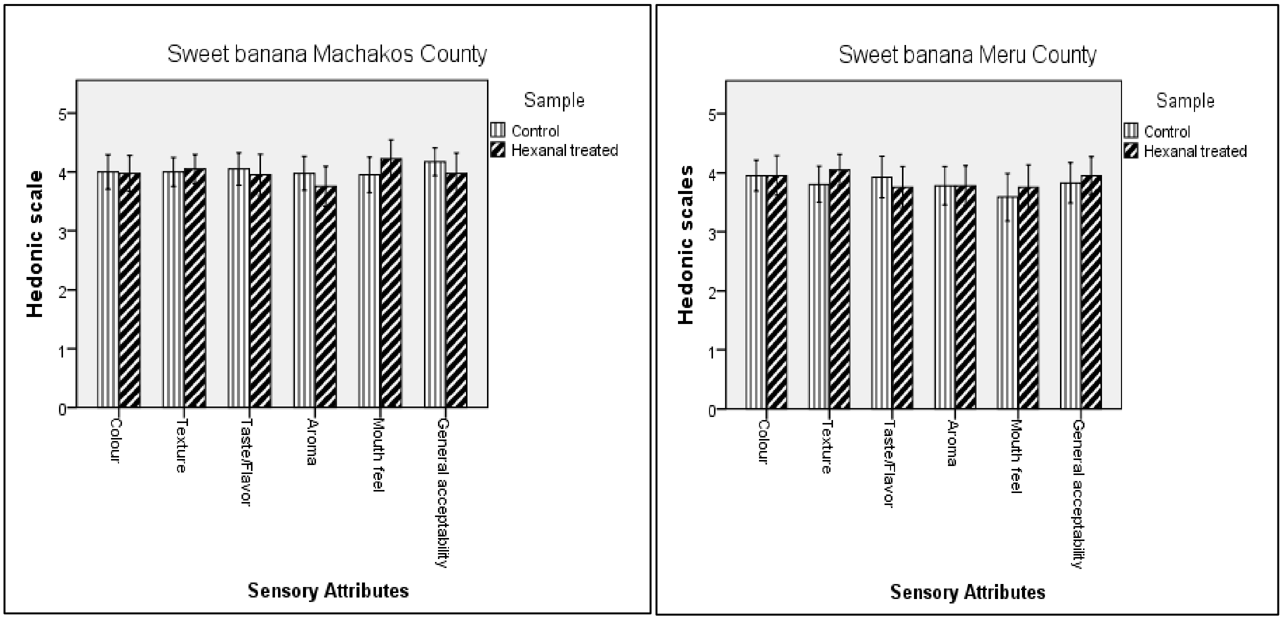


Figure 22: Hedonic scores for sensory quality attributes of 'sweet banana' variety harvested from [illegible]

4.4 Discussions

[illegible]

CHAPTER FIVE

5.0 The molecular basis of hexanal's mode of action in preserving the post-harvest shelf life of banana fruits

5.1 Abstract

'Grand nain' banana fruits were harvested from Meru

MaPG1 *MaPME* *MaXET1, MaPL1* *MaACO*

hexanal had higher levels of lycopene, β

5.3. Materials and methods

5.3.1. Plant material and post-harvest treatment

‘Grand nain’ were ob

s dipped in hexanal’s most effective concentration

5.3.1. Analysis of physical and physiological parameters

5.3.2. Extraction of total RNA

5.3.4. Transcriptome analysis/ Next generation sequencing (NGS)

as per the manufacturer's

5.3.5. Data analysis

5.3.5.1. Quantitative polymerase chain reaction (qPCR) analysis

5.3.5.2. Next generation sequencing analysis/ Bioinformatics analysis

than 20 (Q ≤ 2

Musa acuminata

p <0.05 and a log2fold ratio ≥ 1 as the threshold.

et al

5.4. Results

5.4.1. Changes in physical and physiological parameters

5.4.1.1. Rate of ethylene production

p

p

p

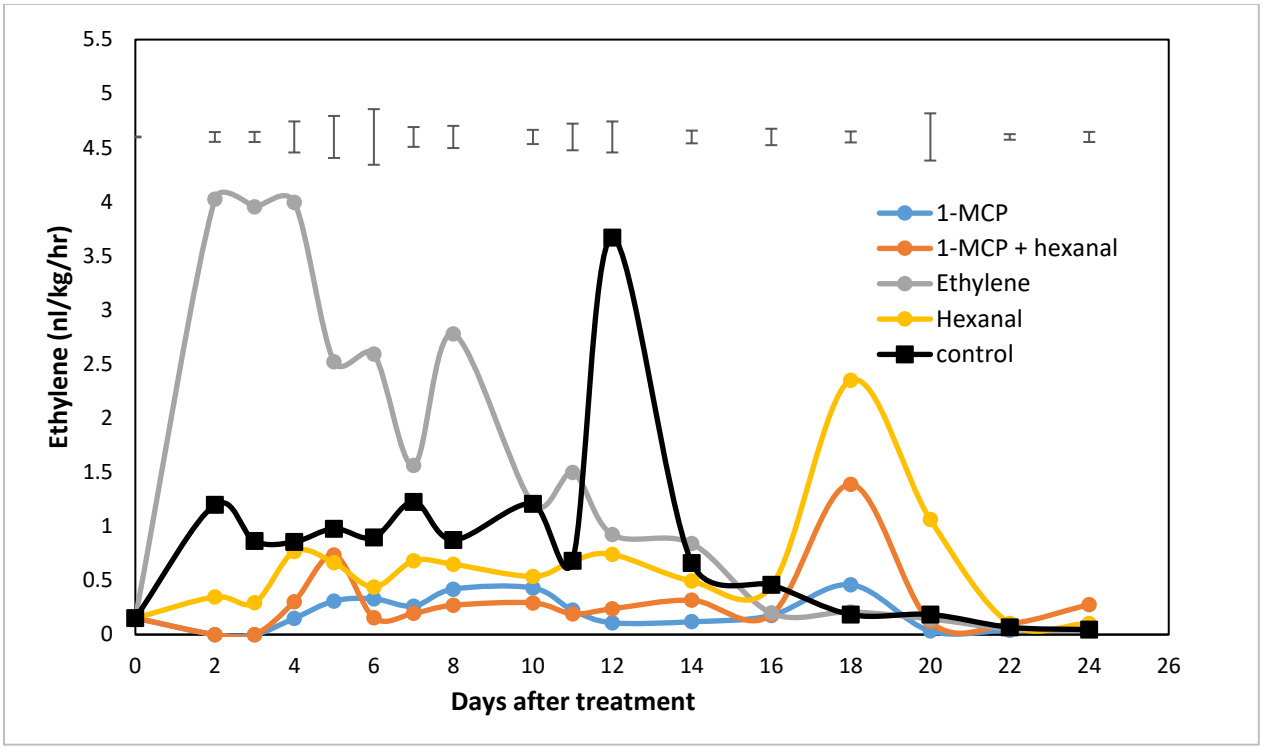


Figure 23: [illegible] on the rate of ethylene production in 'Grand nain' [illegible]

5.4.1.2. Rate of Respiration

[illegible]

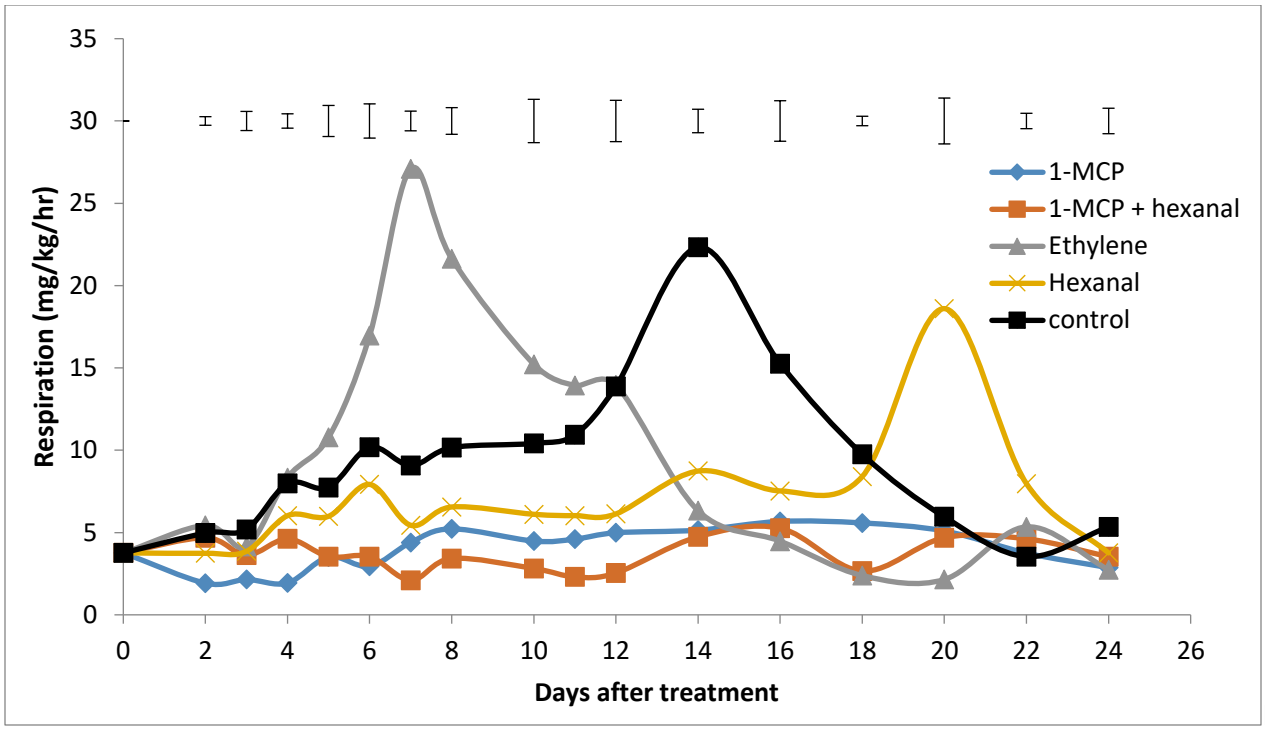


Figure 24: [illegible] compared to control on the rate of respiration in 'Grand nain' bananas. Top bars indicate least [illegible] *p* [illegible]

5.4.1.3. Changes in peel firmness

[illegible]

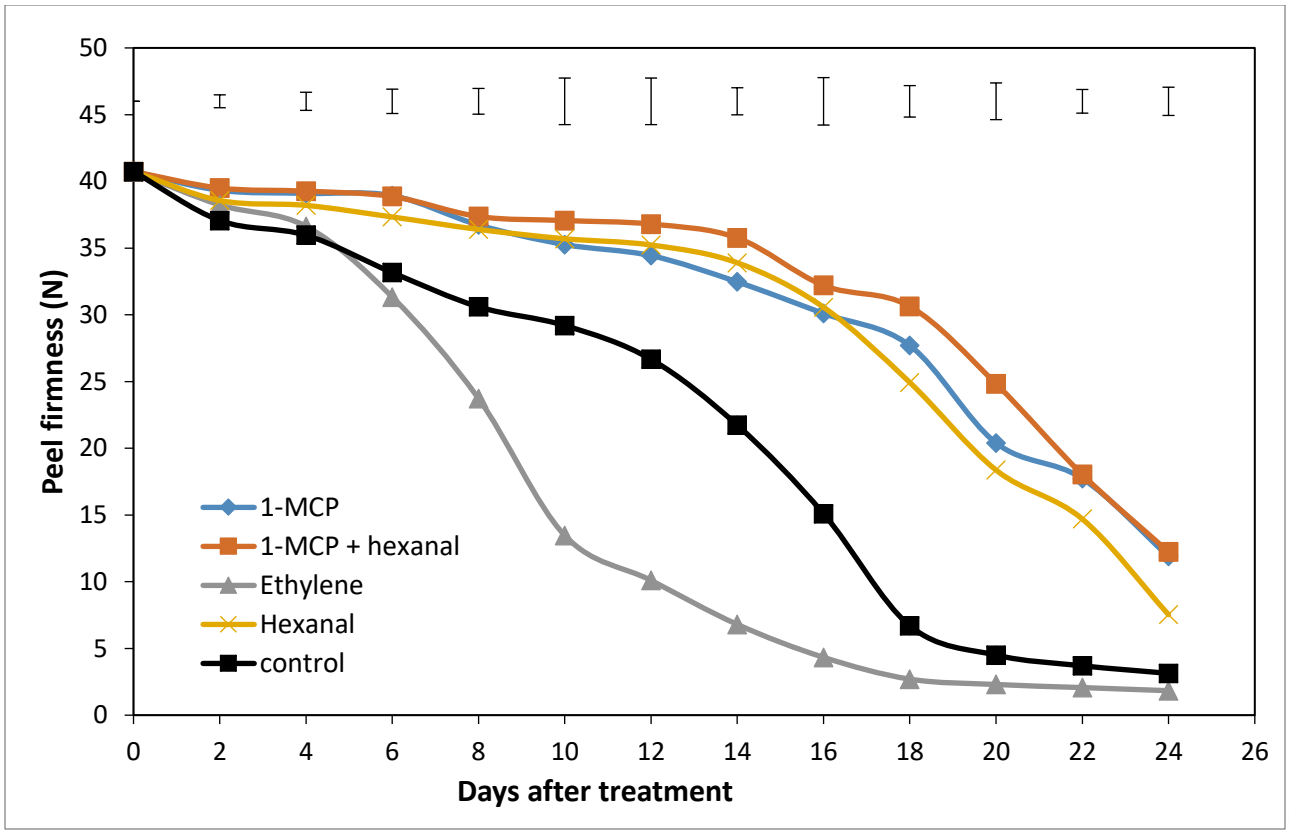


Figure 25: [illegible] in 'Grand nain' bananas. Top bars indicate least significant [illegible] p [illegible]

5.4.1.4. Changes in pulp firmness

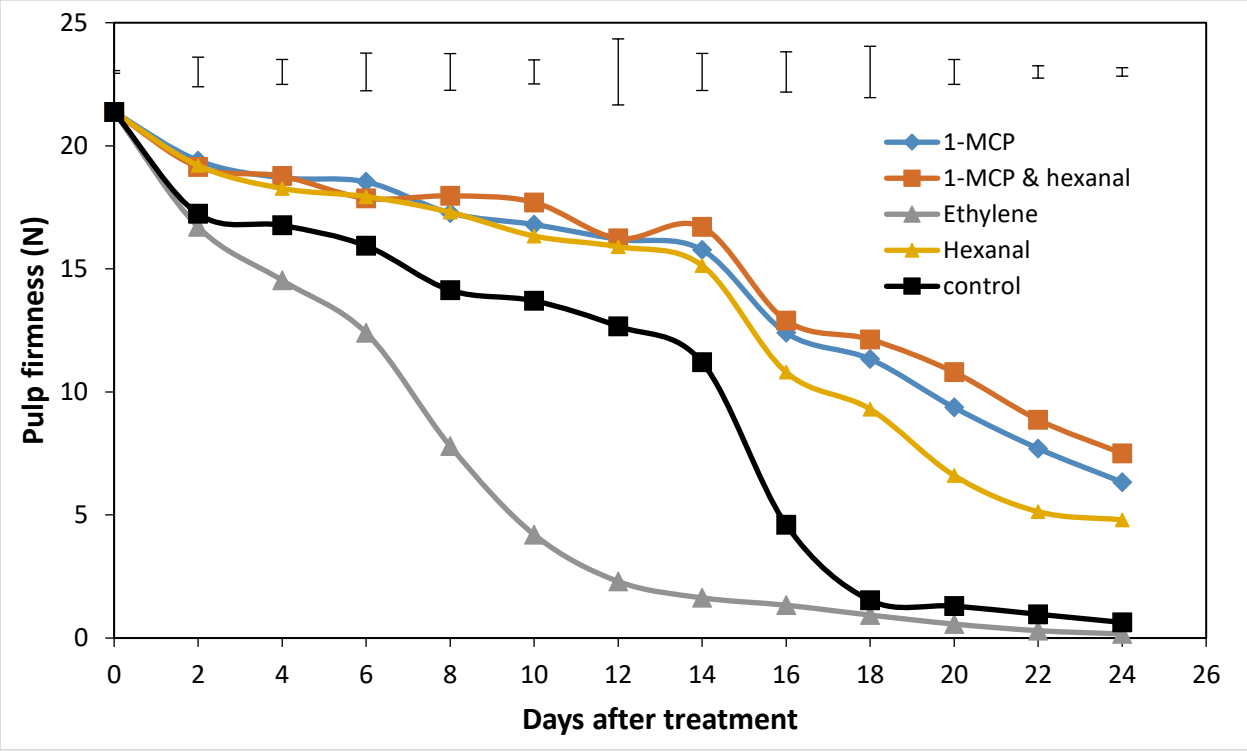


Figure 26: [illegible] in 'Grand nain' bananas. Top bars indicate least significant [illegible]

5.4.1.5. Changes in peel color

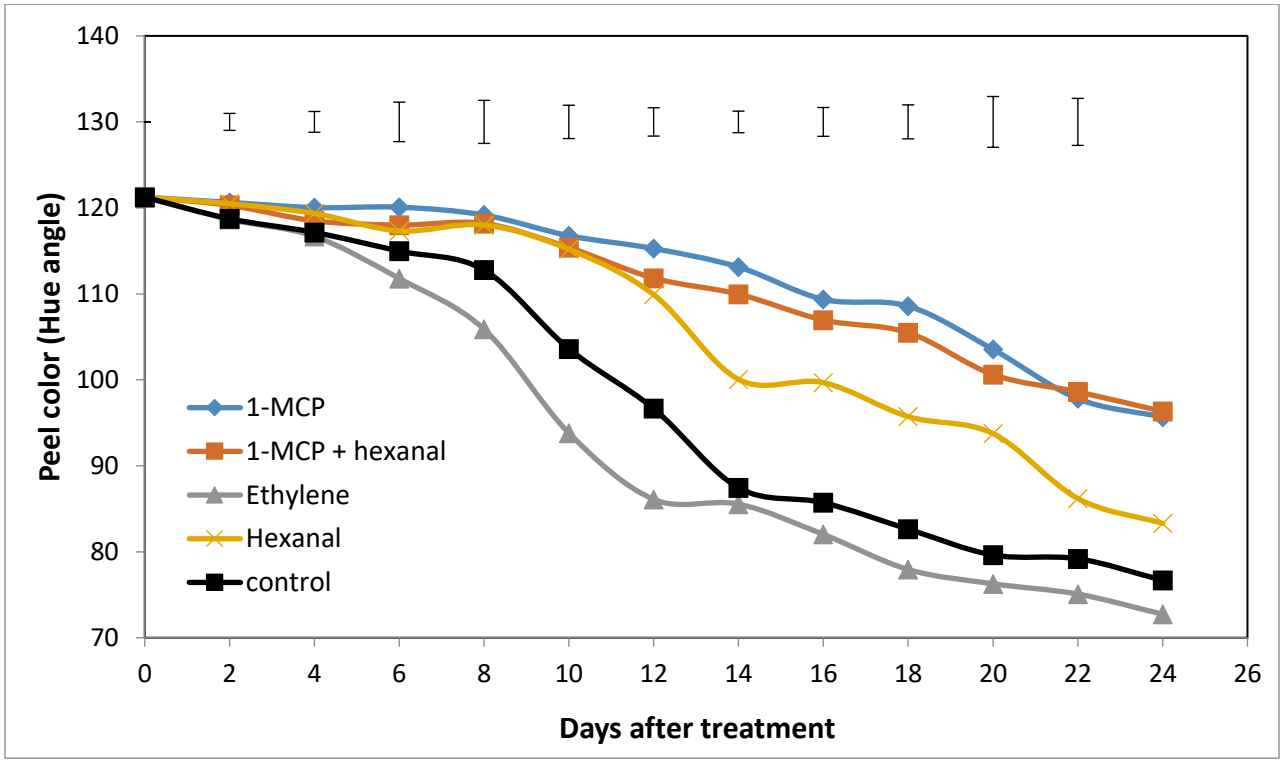


Figure 27: r in 'Grand nain' bananas. Top bars indicate least significant

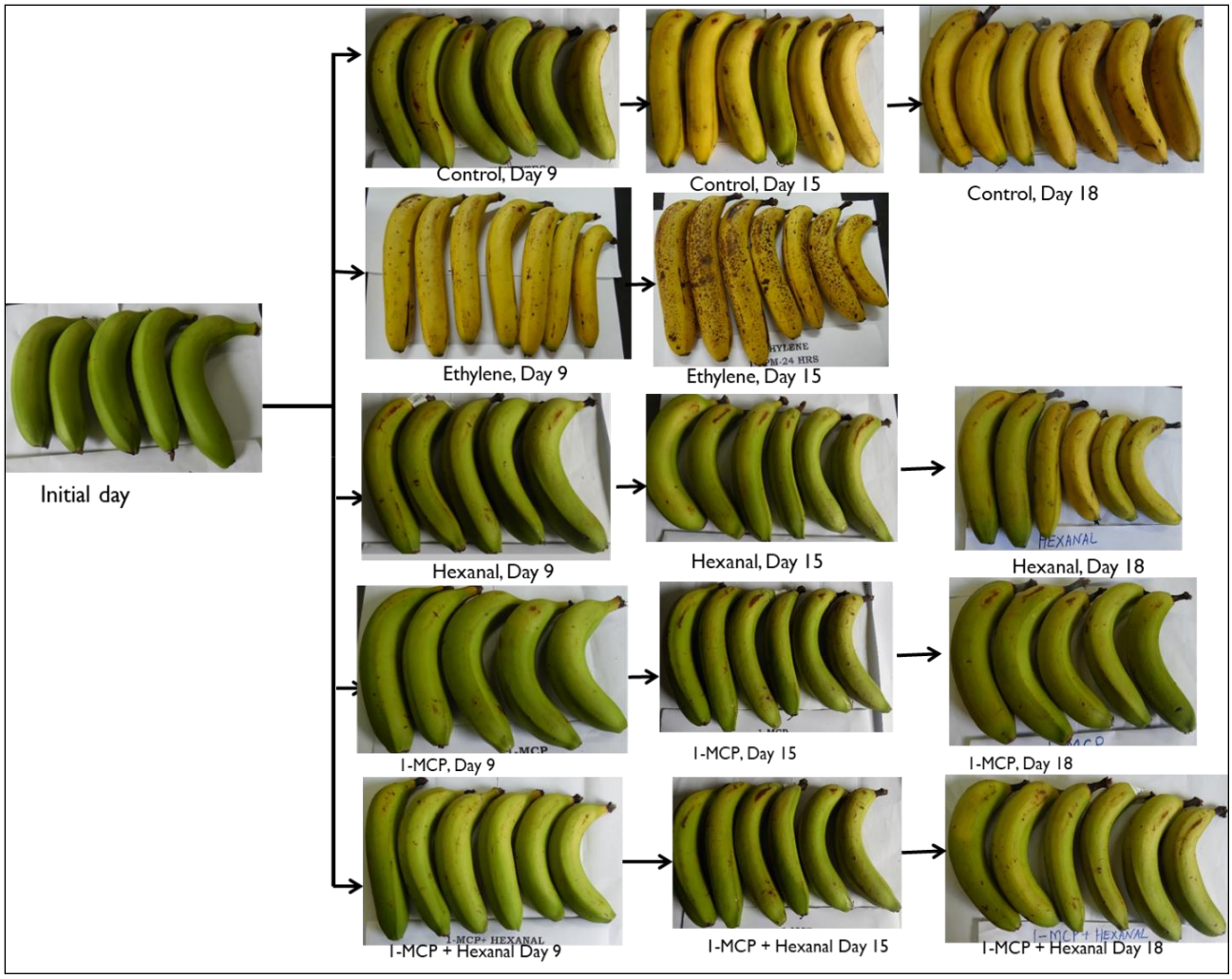


Figure 28: r r of ripening in 'Grand nain' banana fruits treated with hexanal, ethylene, 1 M d r r d d d d r r r d r

5.4.2. Quantitative polymerase chain reaction (qPCR) and Transcriptome analysis

5.4.2.1. Quality Check of the extracted RNA

r 2 r 5 d d 2 d 6 d d r d r d r r d 5 d r 2 d 6 d r r d r d r

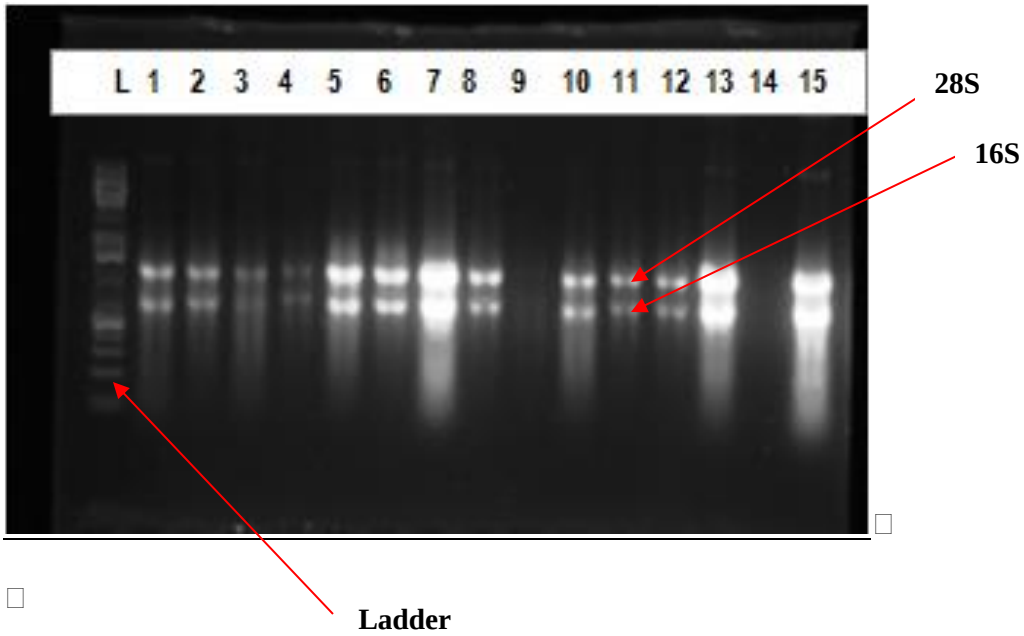


Figure 29: [illegible]

5.4.2.2 Quantitative PCR Results

i. Polygalacturonase gene (PG gene)

[illegible]

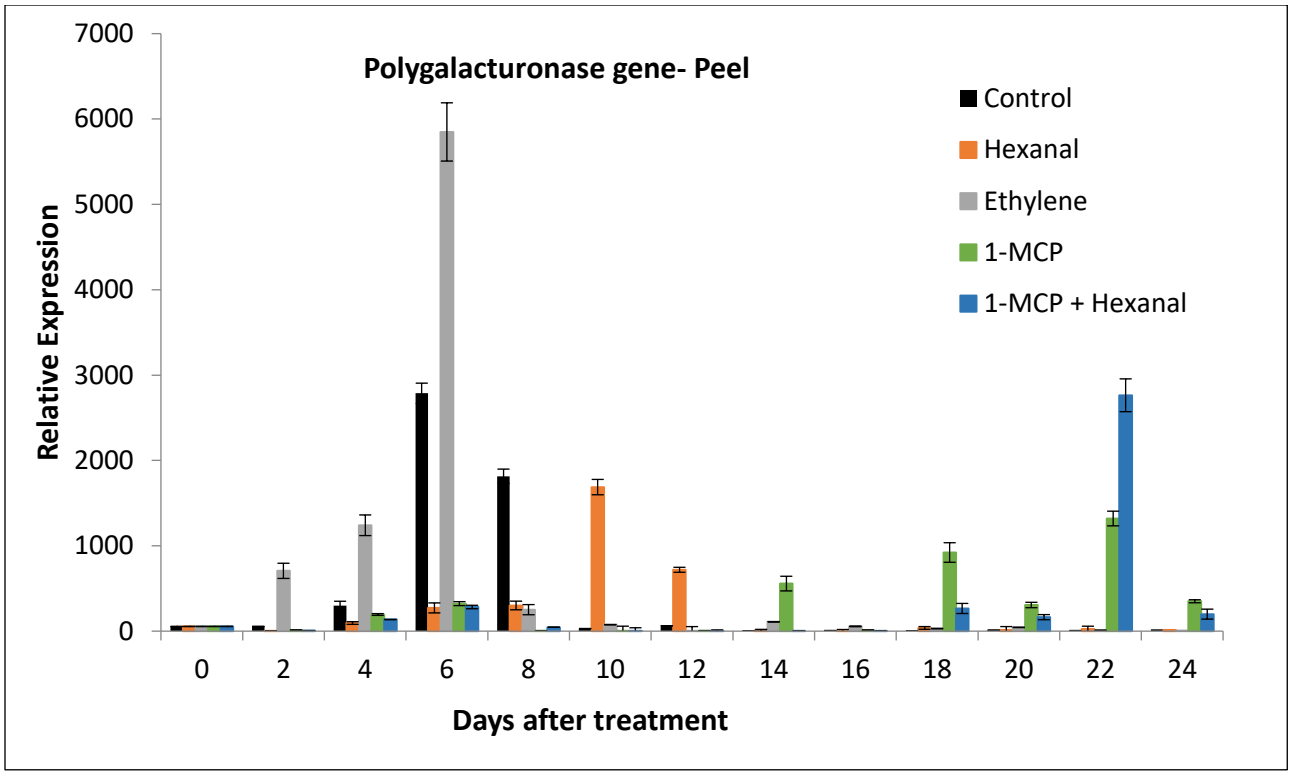

Polygalacturonase gene- Peel
Relative Expression
Days after treatment
Control
Hexanal
Ethylene
1-MCP
1-MCP + Hexanal
7000
6000
5000
4000
3000
2000
1000
0
0
2
4
6
8
10
12
14
16
18
20
22
24

Figure 30:

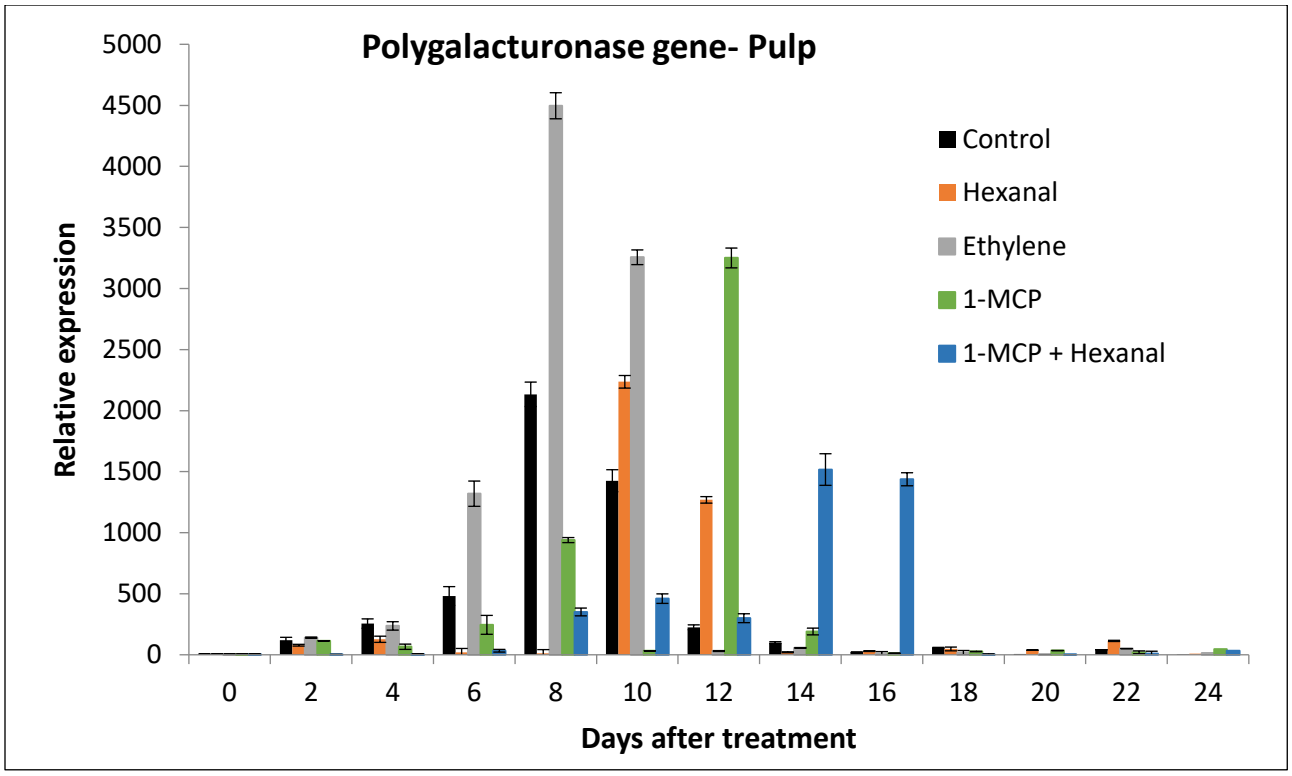


Figure 31:

ii. Pectate Lyase gene (PL gene)

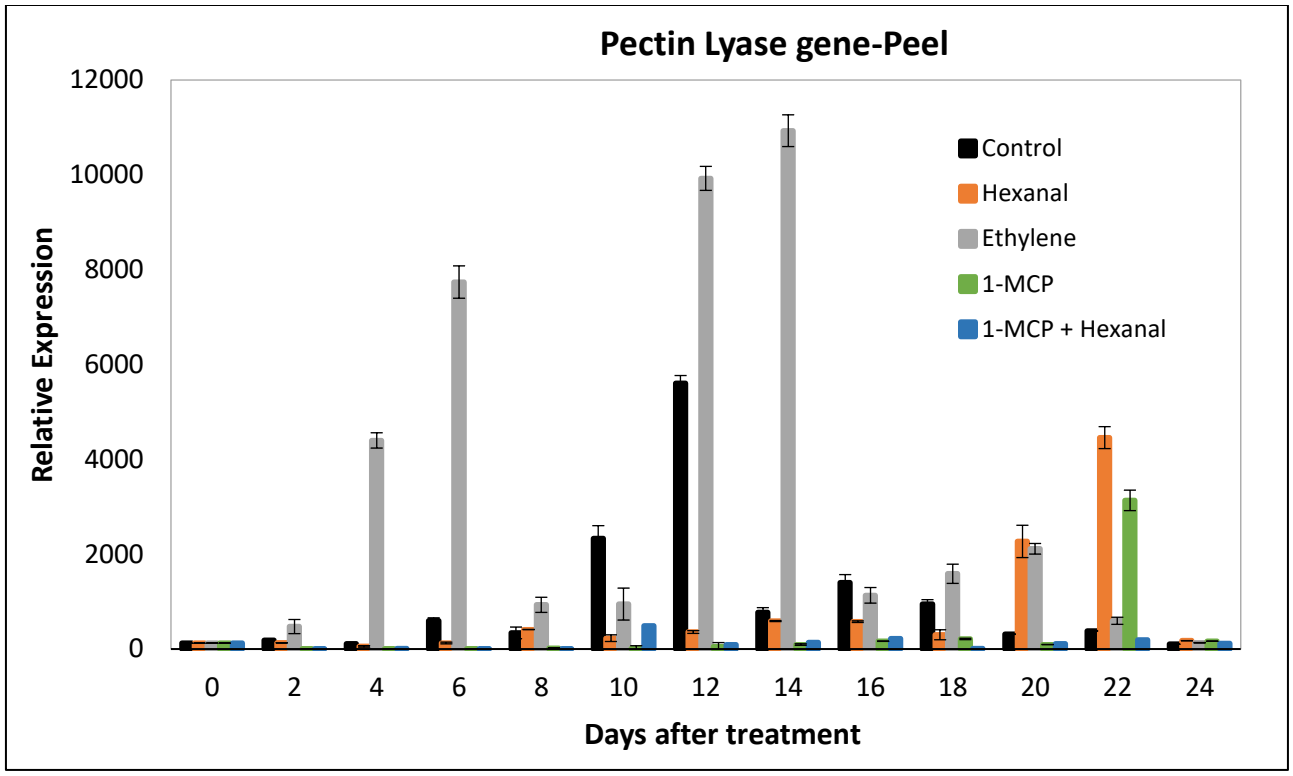

Pectin Lyase gene-Peel
Relative Expression
12000
10000
8000
6000
4000
2000
0
0
2
4
6
8
10
12
14
16
18
20
22
24
Days after treatment
Control
Hexanal
Ethylene
1-MCP
1-MCP + Hexanal

Figure 32:

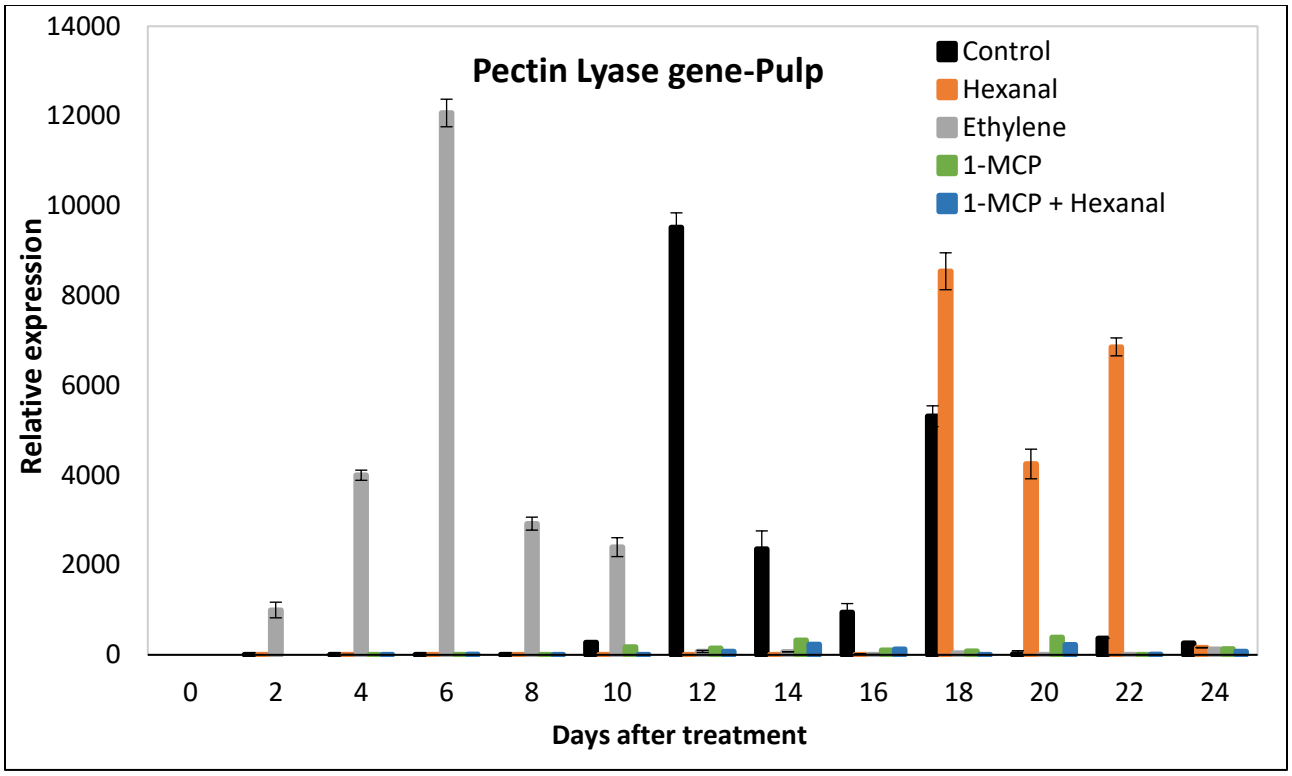


Figure 33: [illegible]

iii. Pectin methylesterase gene (PME gene)

[illegible]

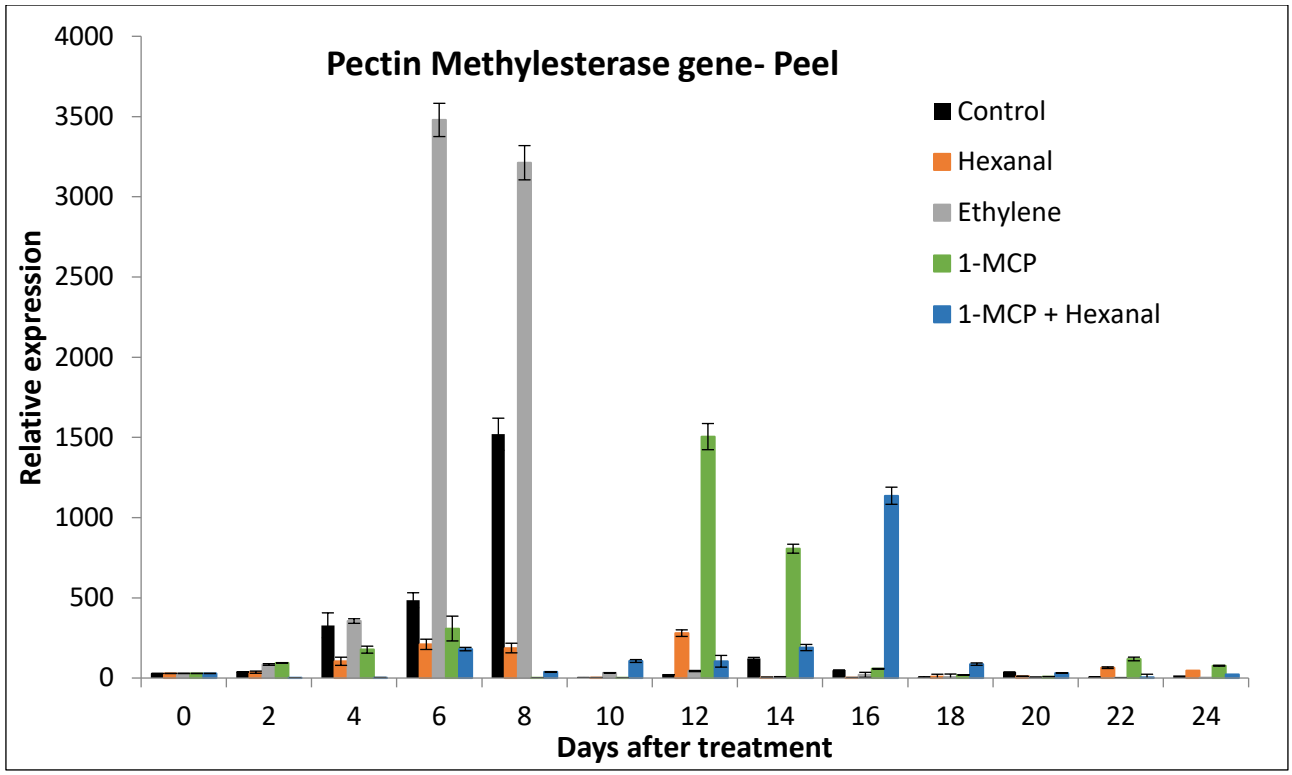

Pectin Methylesterase gene- Peel
Relative expression
Days after treatment
Control
Hexanal
Ethylene
1-MCP
1-MCP + Hexanal
4000
3500
3000
2500
2000
1500
1000
500
0
0
2
4
6
8
10
12
14
16
18
20
22
24

Figure 34: [illegible]

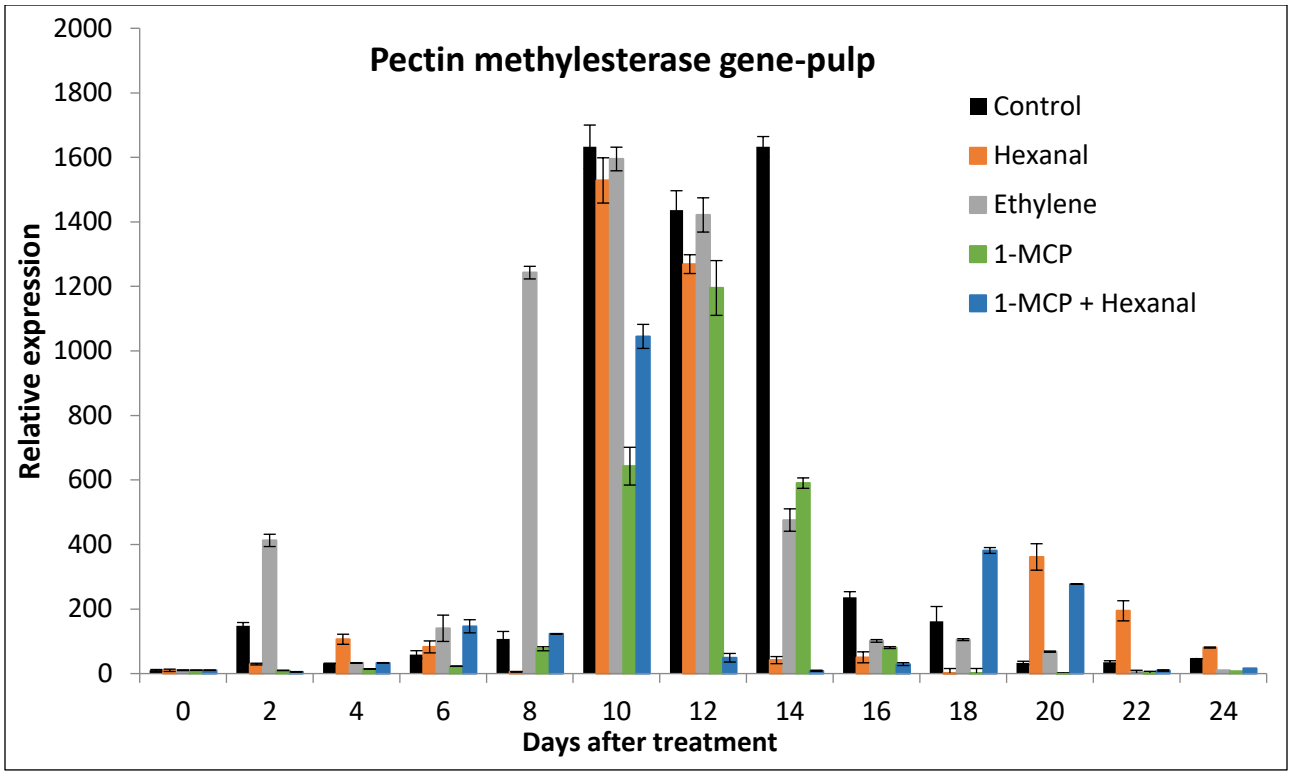


Figure 35: [illegible]

iv. Xyloglucan endotransglucosylase gene (XET gene)

[illegible]

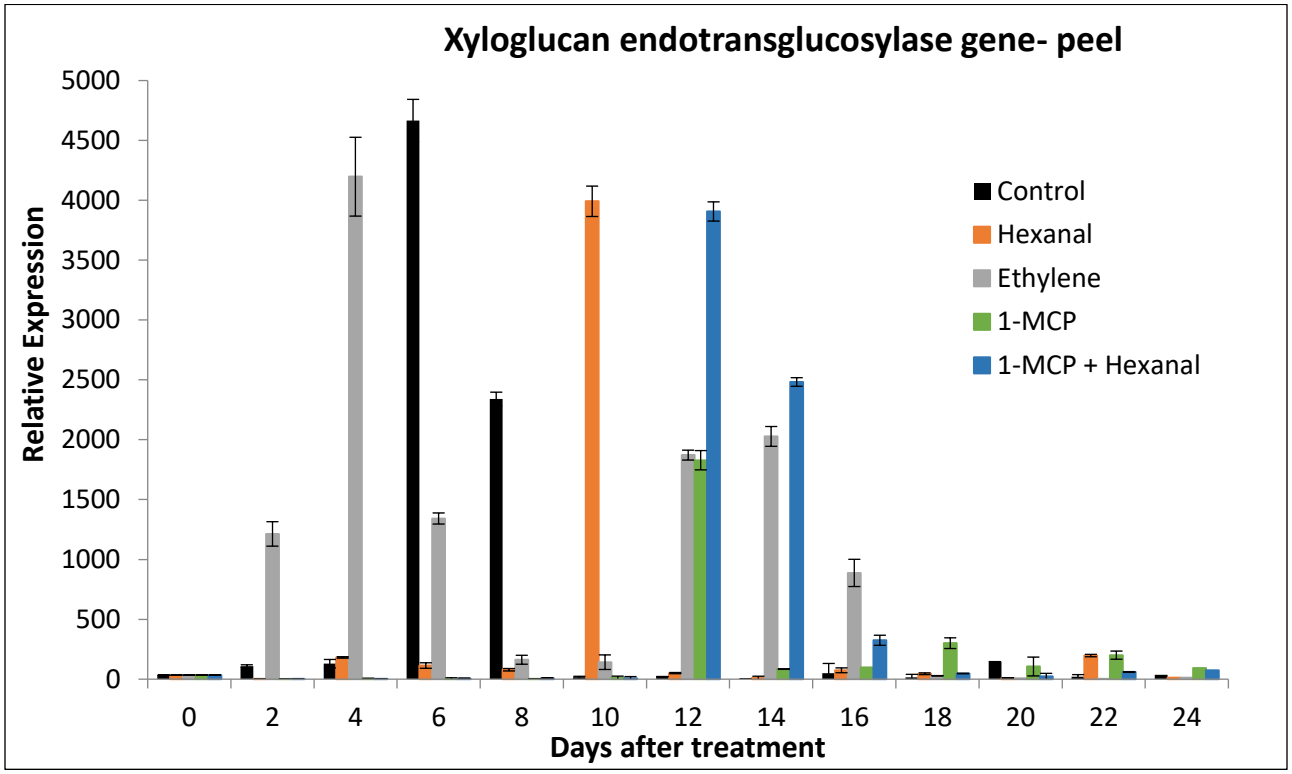

Xyloglucan endotransglucosylase gene- peel
Relative Expression
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
2
4
6
8
10
12
14
16
18
20
22
24
Days after treatment
Control
Hexanal
Ethylene
1-MCP
1-MCP + Hexanal

Figure 36:

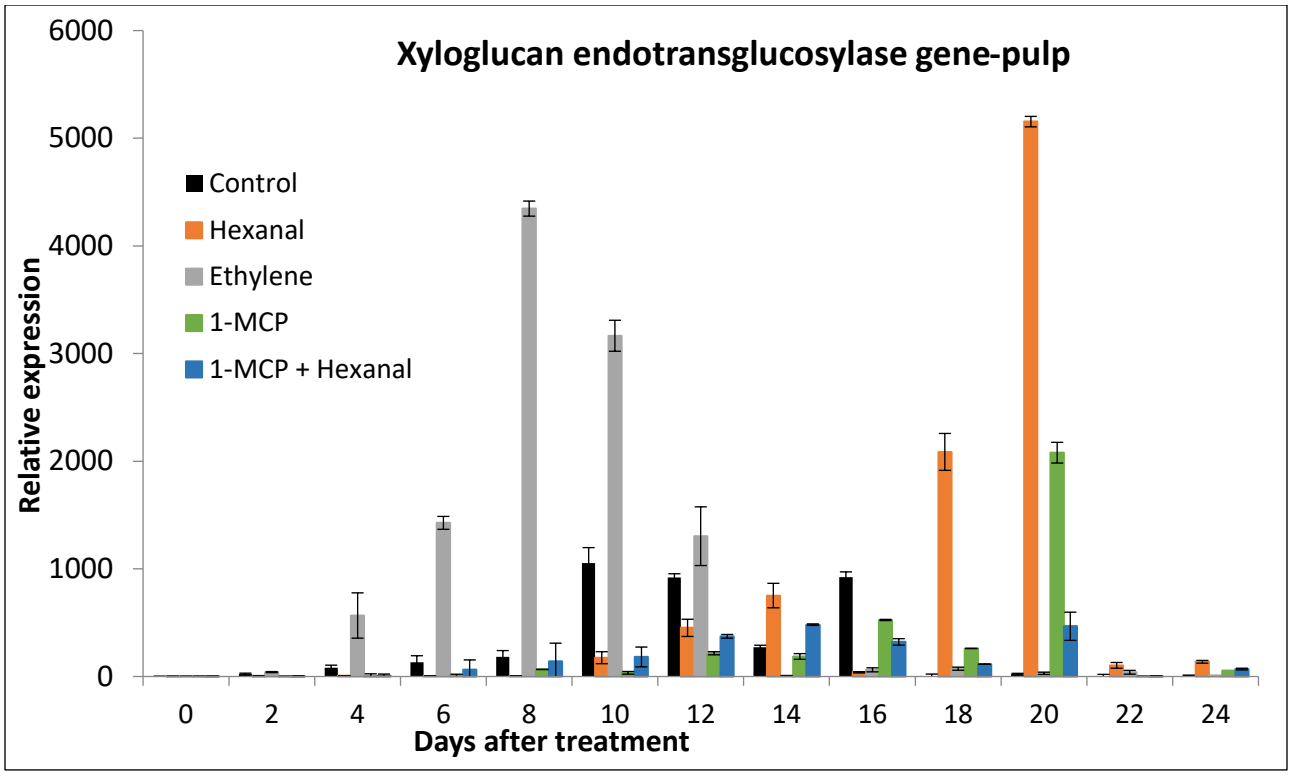


Figure 37: [illegible]

v. 1-Aminocyclopropane-1-Carboxylic Acid Oxidase gene (ACO gene)

[illegible]

[illegible]

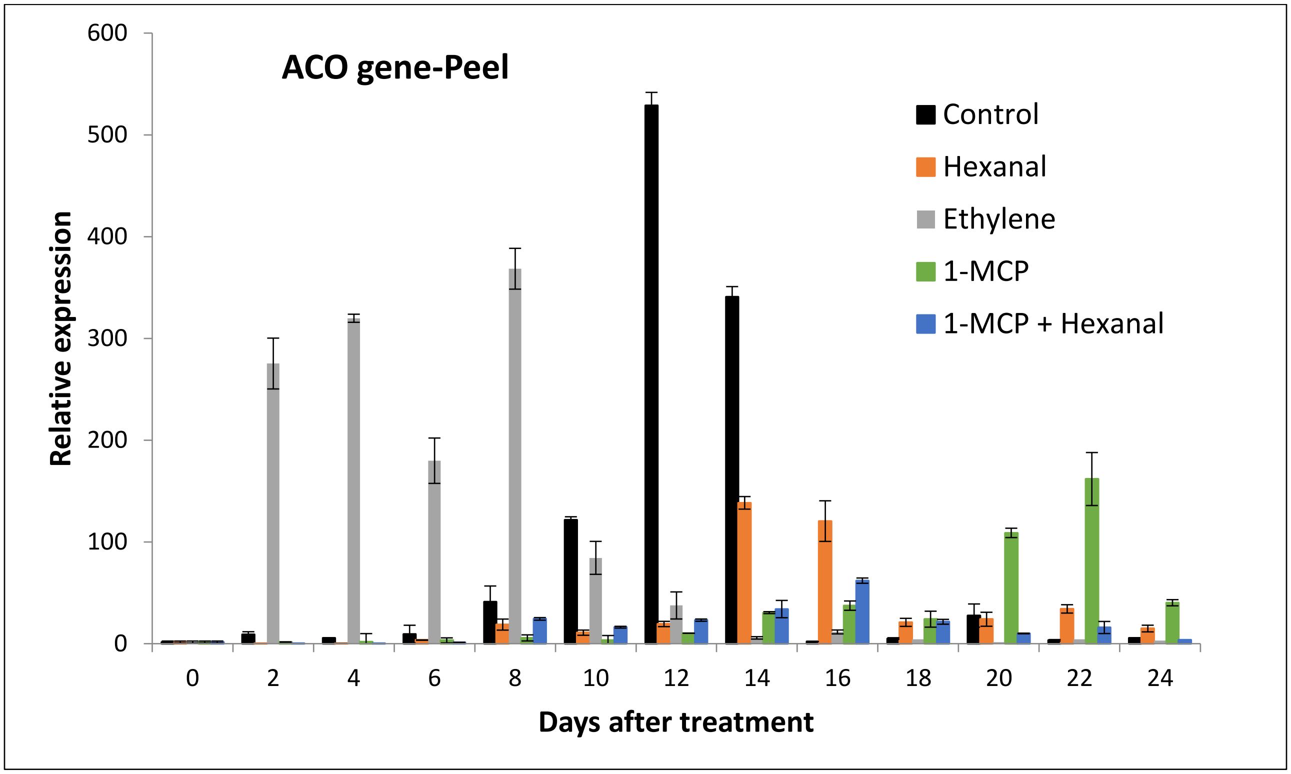

ACO gene-Peel
Relative expression
0
100
200
300
400
500
600
0
2
4
6
8
10
12
14
16
18
20
22
24
Days after treatment
Control
Hexanal
Ethylene
1-MCP
1-MCP + Hexanal

Figure 38: [illegible]

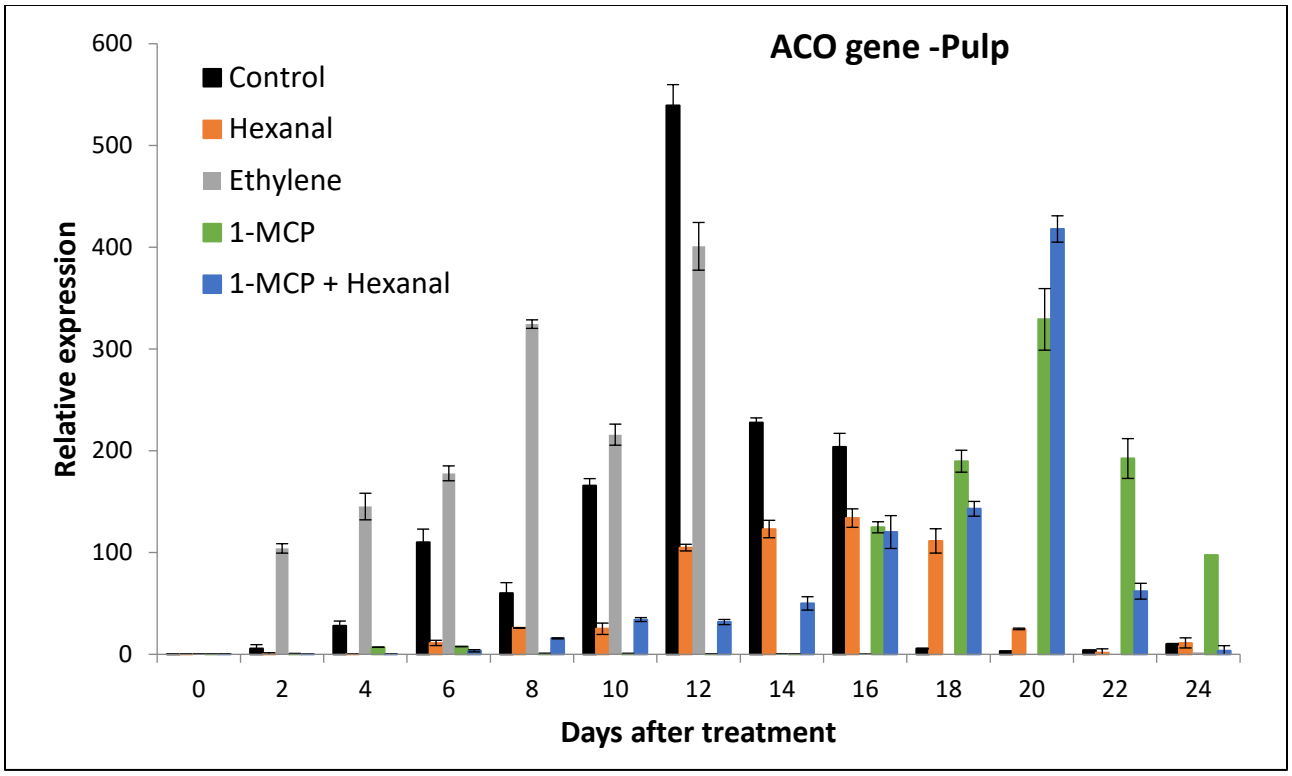


Figure 39: [illegible]

5.4.3. Next Generation sequencing / Transcriptome analysis

5.4.3.1. Quality control of the prepared libraries

[illegible]

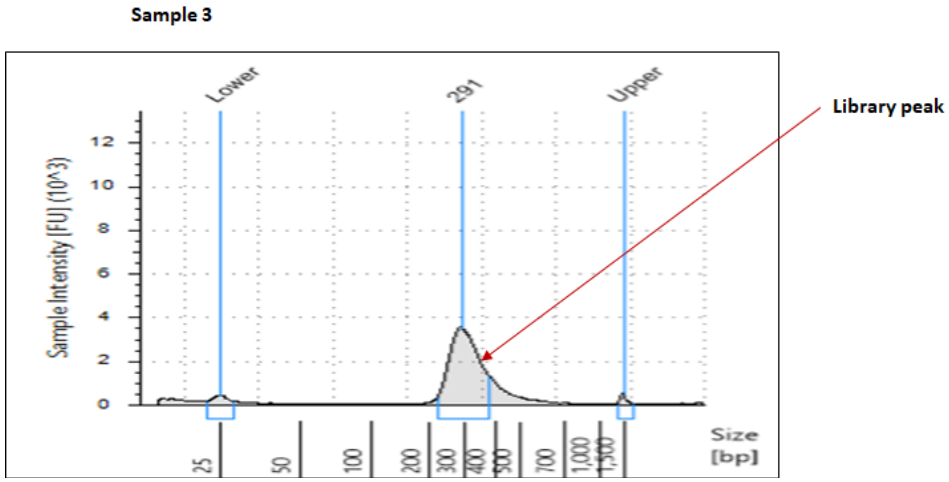


Figure 40: [illegible]

5.4.3.2. Differentially Expressed Genes (DEGs)

[illegible]

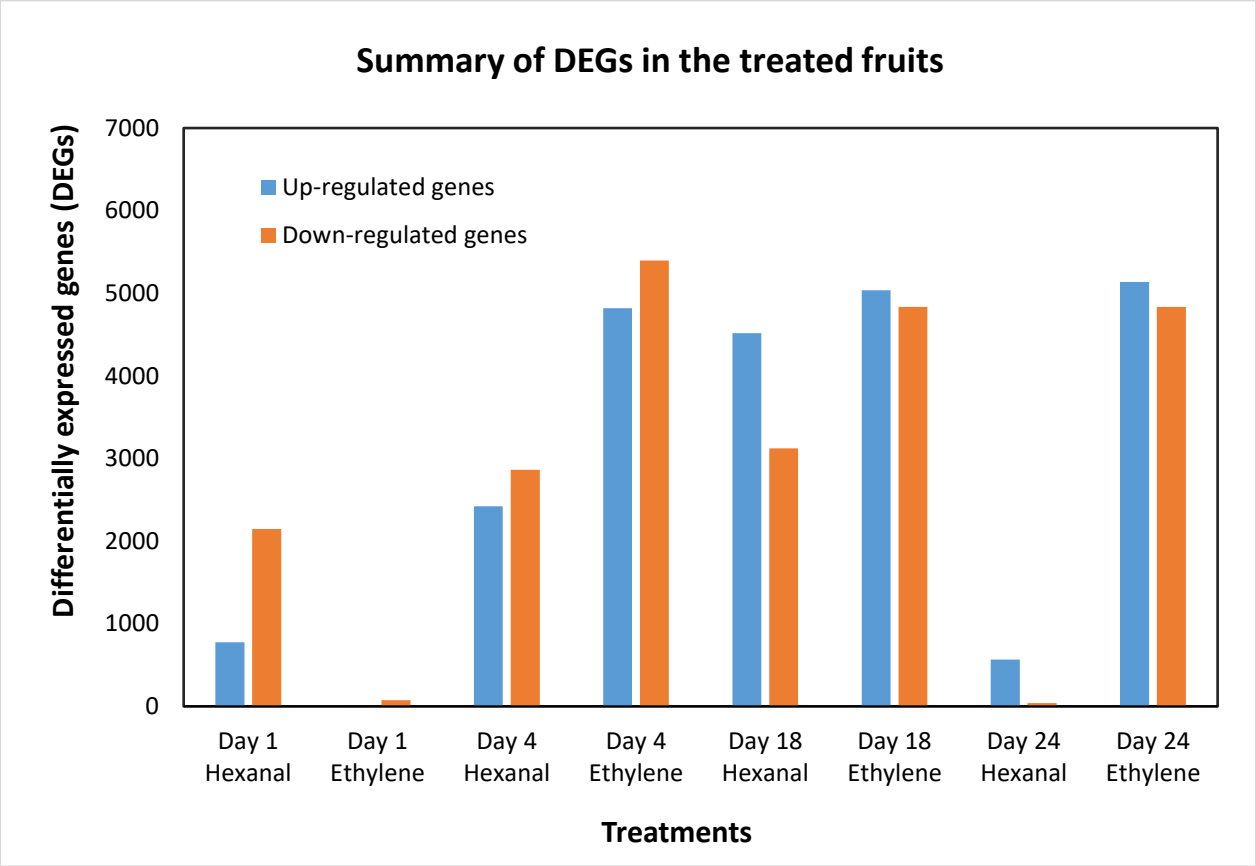

Summary of DEGs in the treated fruits
Differentially expressed genes (DEGs)
7000
6000
5000
4000
3000
2000
1000
0
Up-regulated genes
Down-regulated genes
Day 1 Hexanal
Day 1 Ethylene
Day 4 Hexanal
Day 4 Ethylene
Day 18 Hexanal
Day 18 Ethylene
Day 24 Hexanal
Day 24 Ethylene
Treatments

Figure 41:

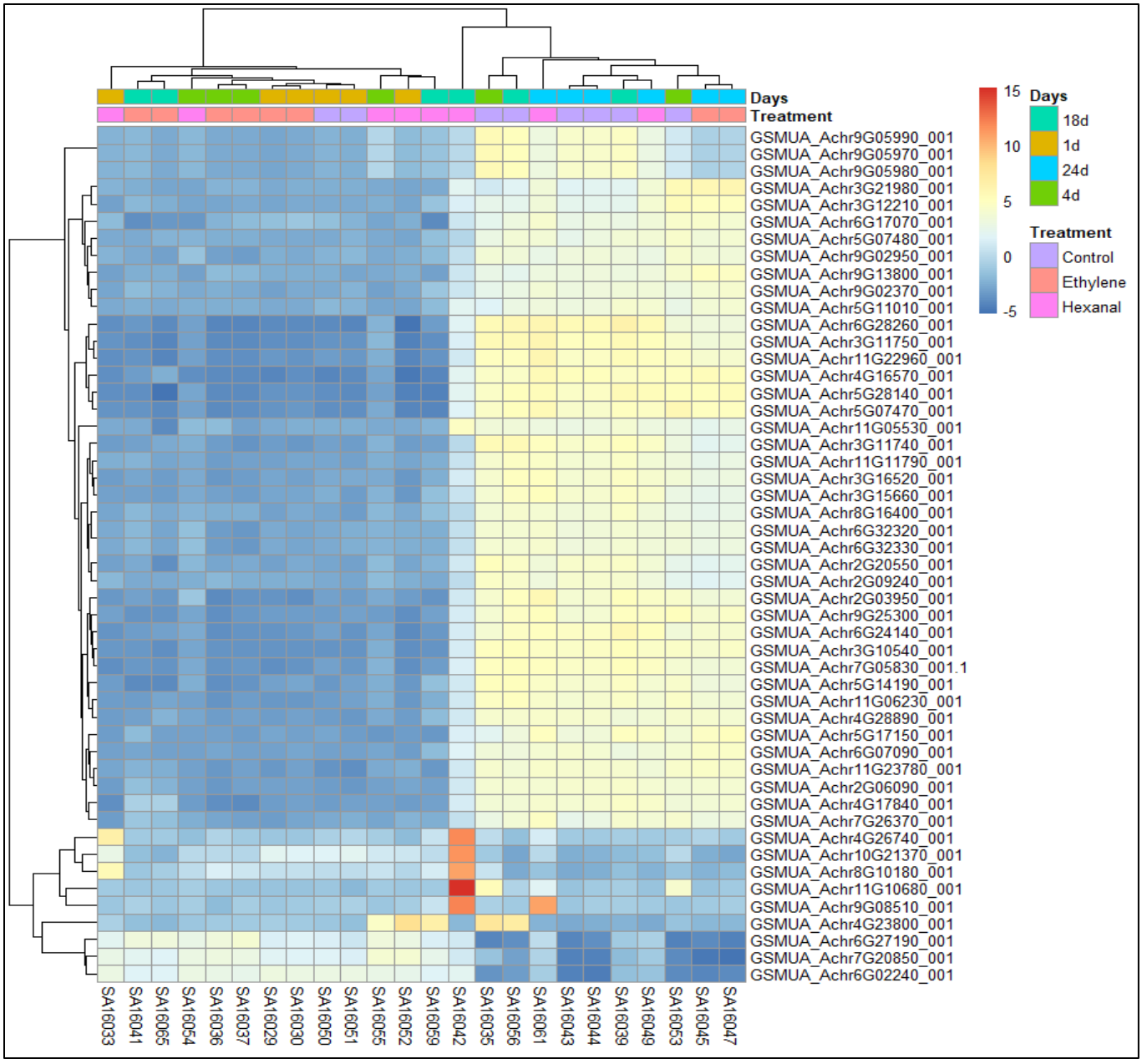

Days
Treatment
GSMUA_Achr9G05990_001
GSMUA_Achr9G05970_001
GSMUA_Achr9G05980_001
GSMUA_Achr3G21980_001
GSMUA_Achr3G12210_001
GSMUA_Achr6G17070_001
GSMUA_Achr5G07480_001
GSMUA_Achr9G02950_001
GSMUA_Achr9G13800_001
GSMUA_Achr9G02370_001
GSMUA_Achr5G11010_001
GSMUA_Achr6G28260_001
GSMUA_Achr3G11750_001
GSMUA_Achr11G22960_001
GSMUA_Achr4G16570_001
GSMUA_Achr5G28140_001
GSMUA_Achr5G07470_001
GSMUA_Achr11G05530_001
GSMUA_Achr3G11740_001
GSMUA_Achr11G11790_001
GSMUA_Achr3G16520_001
GSMUA_Achr3G15660_001
GSMUA_Achr8G16400_001
GSMUA_Achr6G32320_001
GSMUA_Achr6G32330_001
GSMUA_Achr2G20550_001
GSMUA_Achr2G09240_001
GSMUA_Achr2G03950_001
GSMUA_Achr9G25300_001
GSMUA_Achr6G24140_001
GSMUA_Achr3G10540_001
GSMUA_Achr7G05830_001.1
GSMUA_Achr5G14190_001
GSMUA_Achr11G06230_001
GSMUA_Achr4G28890_001
GSMUA_Achr5G17150_001
GSMUA_Achr6G07090_001
GSMUA_Achr11G23780_001
GSMUA_Achr2G06090_001
GSMUA_Achr4G17840_001
GSMUA_Achr7G26370_001
GSMUA_Achr4G26740_001
GSMUA_Achr10G21370_001
GSMUA_Achr8G10180_001
GSMUA_Achr11G10680_001
GSMUA_Achr9G08510_001
GSMUA_Achr4G23800_001
GSMUA_Achr6G27190_001
GSMUA_Achr7G20850_001
GSMUA_Achr6G02240_001
SA16033
SA16041
SA16065
SA16054
SA16036
SA16037
SA16029
SA16030
SA16050
SA16051
SA16055
SA16052
SA16059
SA16042
SA16035
SA16056
SA16061
SA16043
SA16044
SA16039
SA16049
SA16053
SA16045
SA16047
15
10
5
0
-5
Days
18d
1d
24d
4d
Treatment
Control
Ethylene
Hexanal

Figure 42: [illegible]

5.4.3.2.1 Differentially Expressed Genes (DEGs) at day one of storage

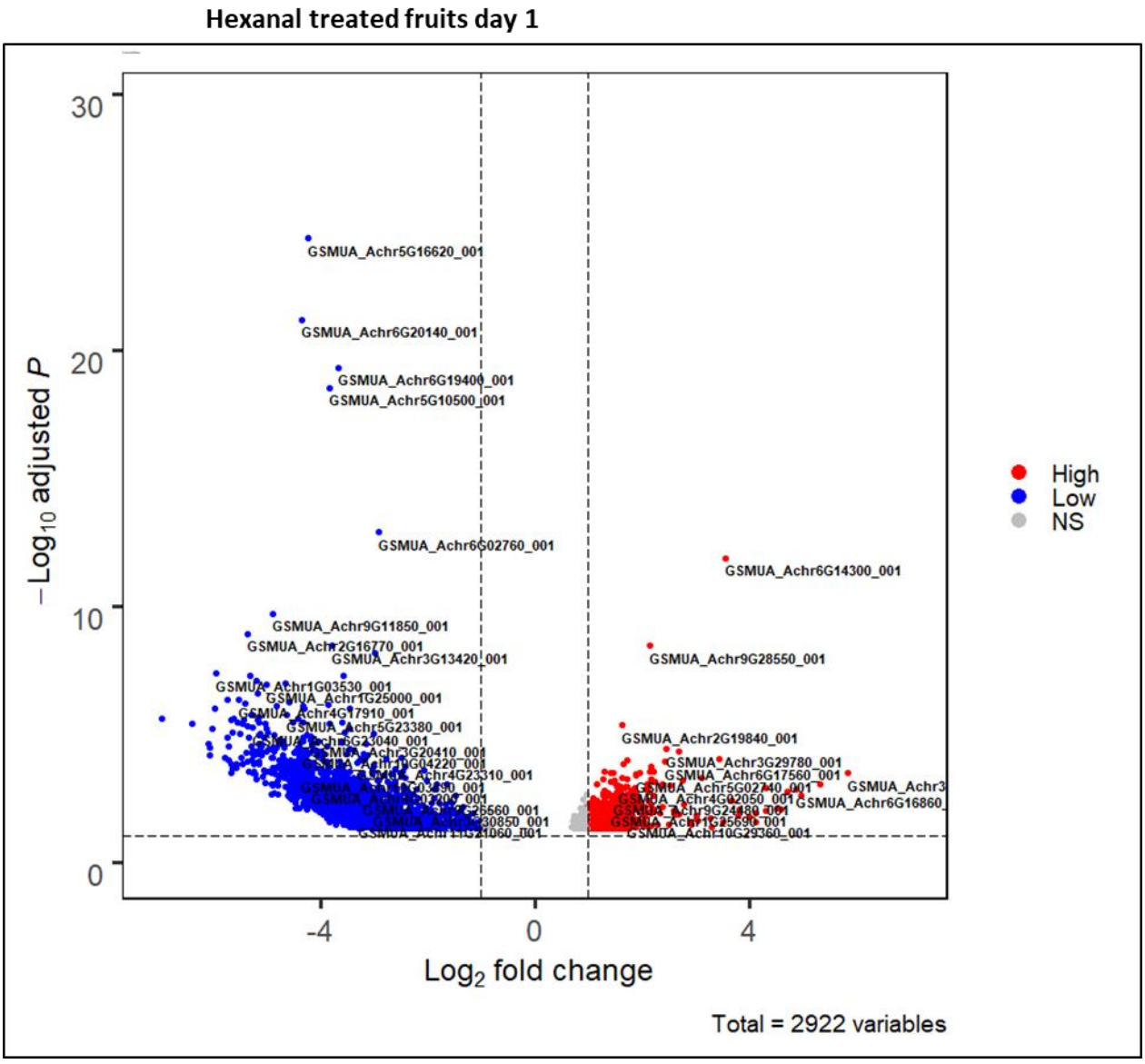


Figure 43: [illegible] log2fold ratio ≥ 1 at [illegible]

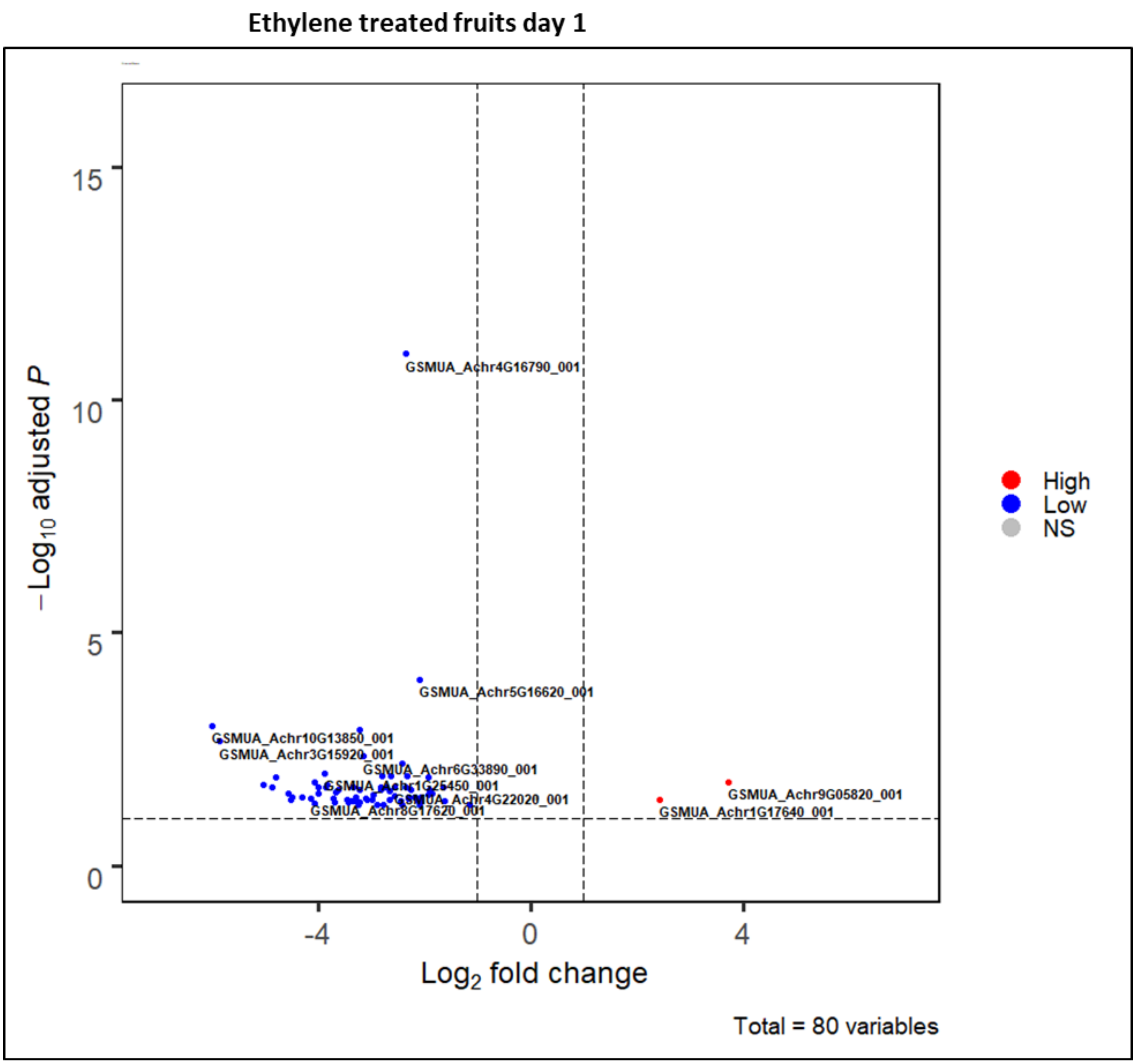


Figure 44: [illegible] 5 [illegible] log2fold ratio ≥ 1 at [illegible]

5.4.3.2.2 Differentially Expressed Genes (DEGs) at day 4 of storage

[illegible]

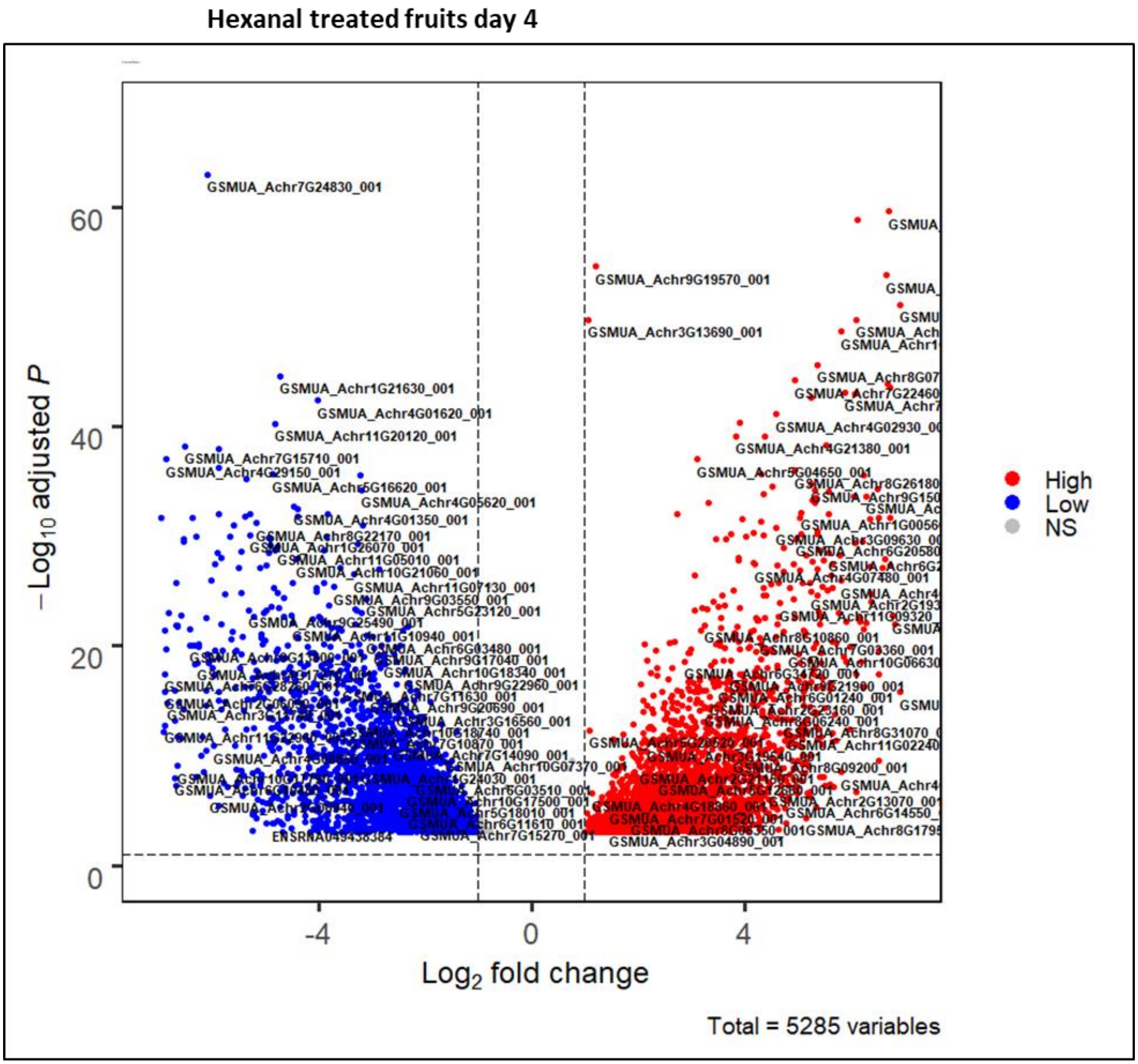


Figure 45: [illegible] log2fold ratio ≥ 1 at day 4 of storage in the hexanal treated fruits

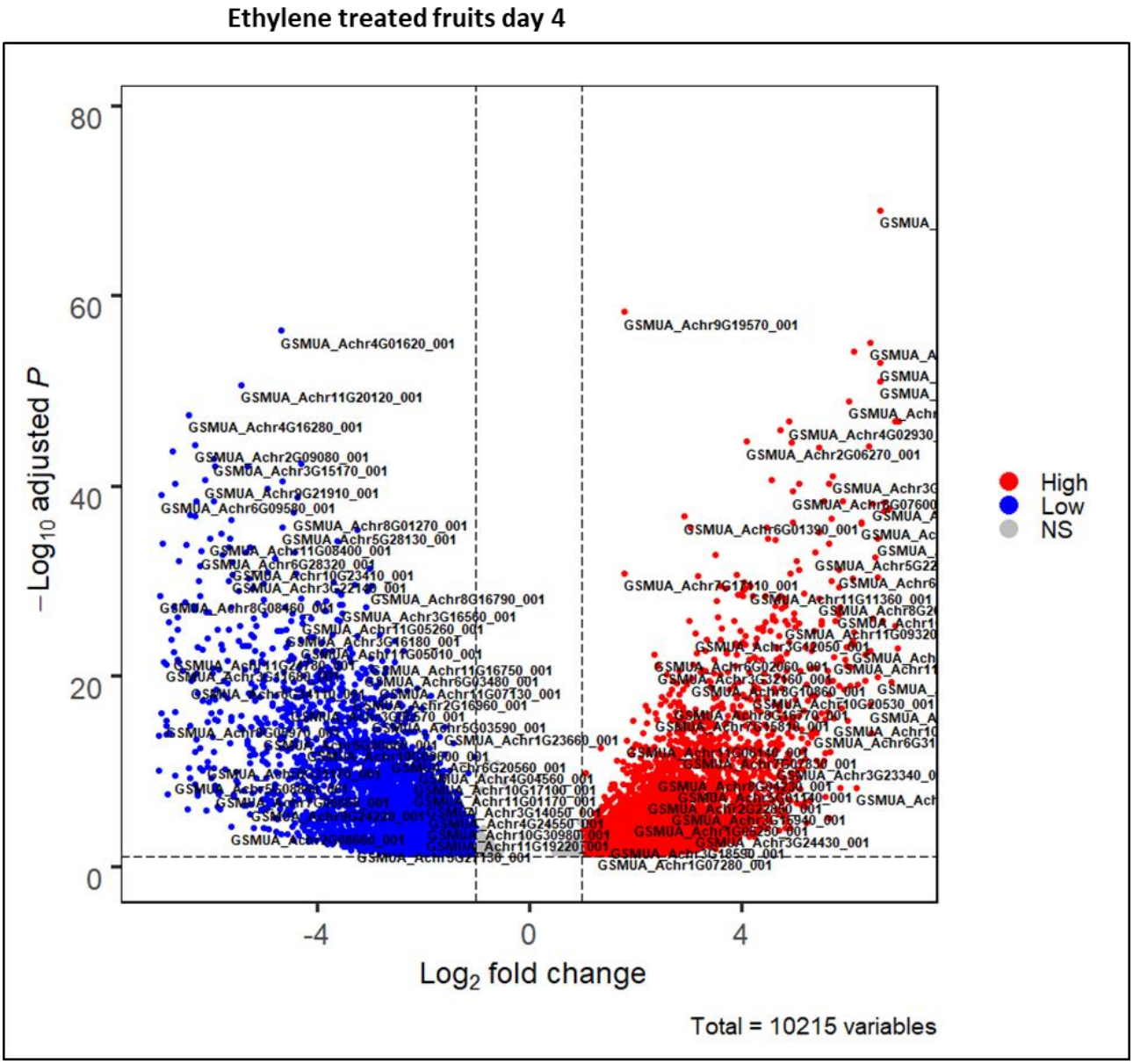
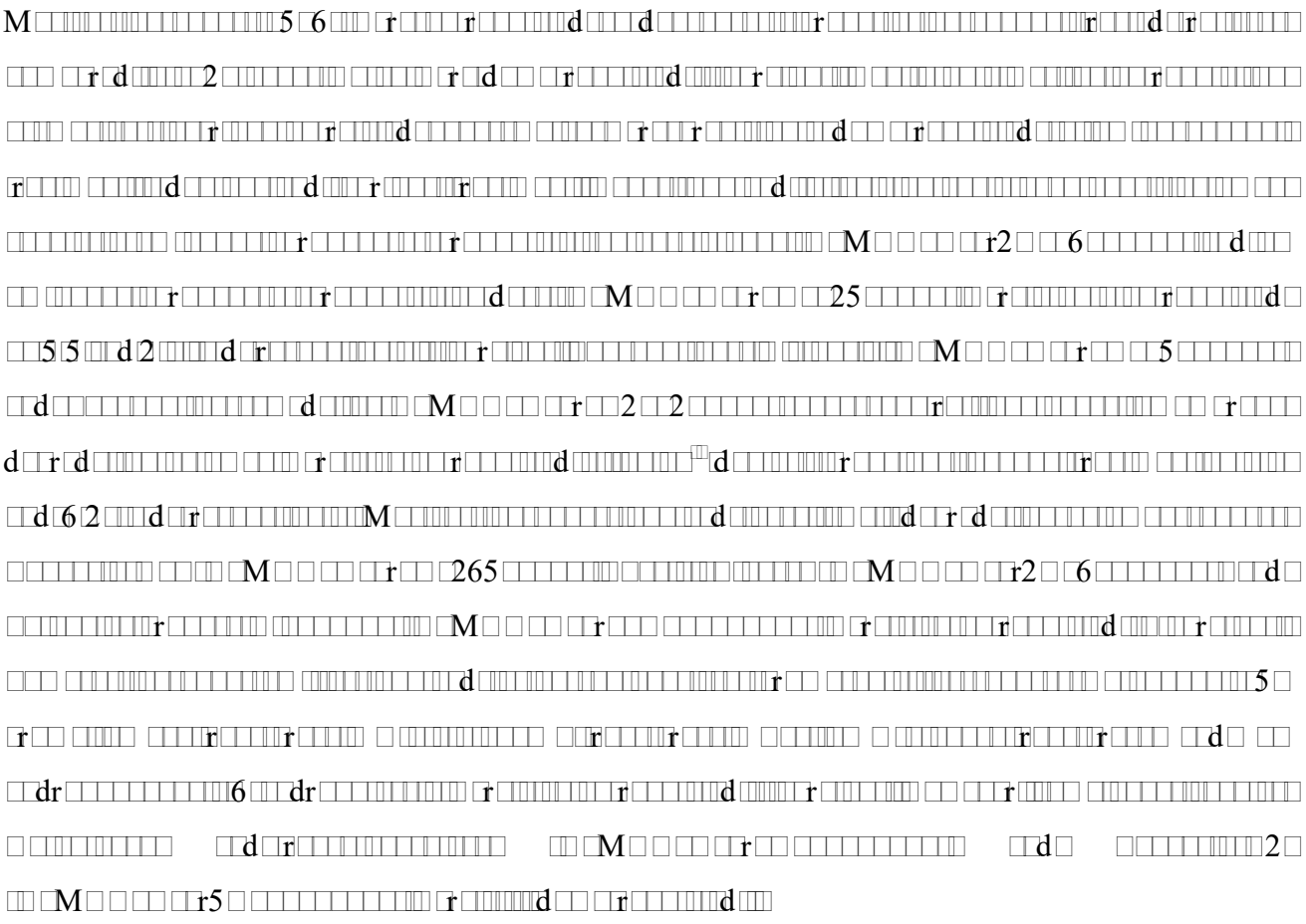
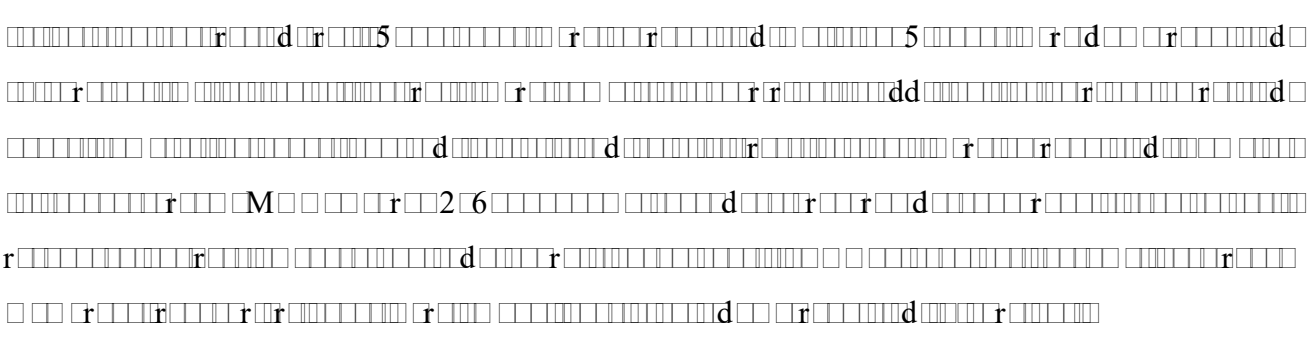


Figure 46: [illegible] log2fold ratio ≥ 1 at day 4 of storage in the ethylene treated fruits

5.4.3.2.3 Differentially Expressed Genes (DEGs) at day 18 of storage





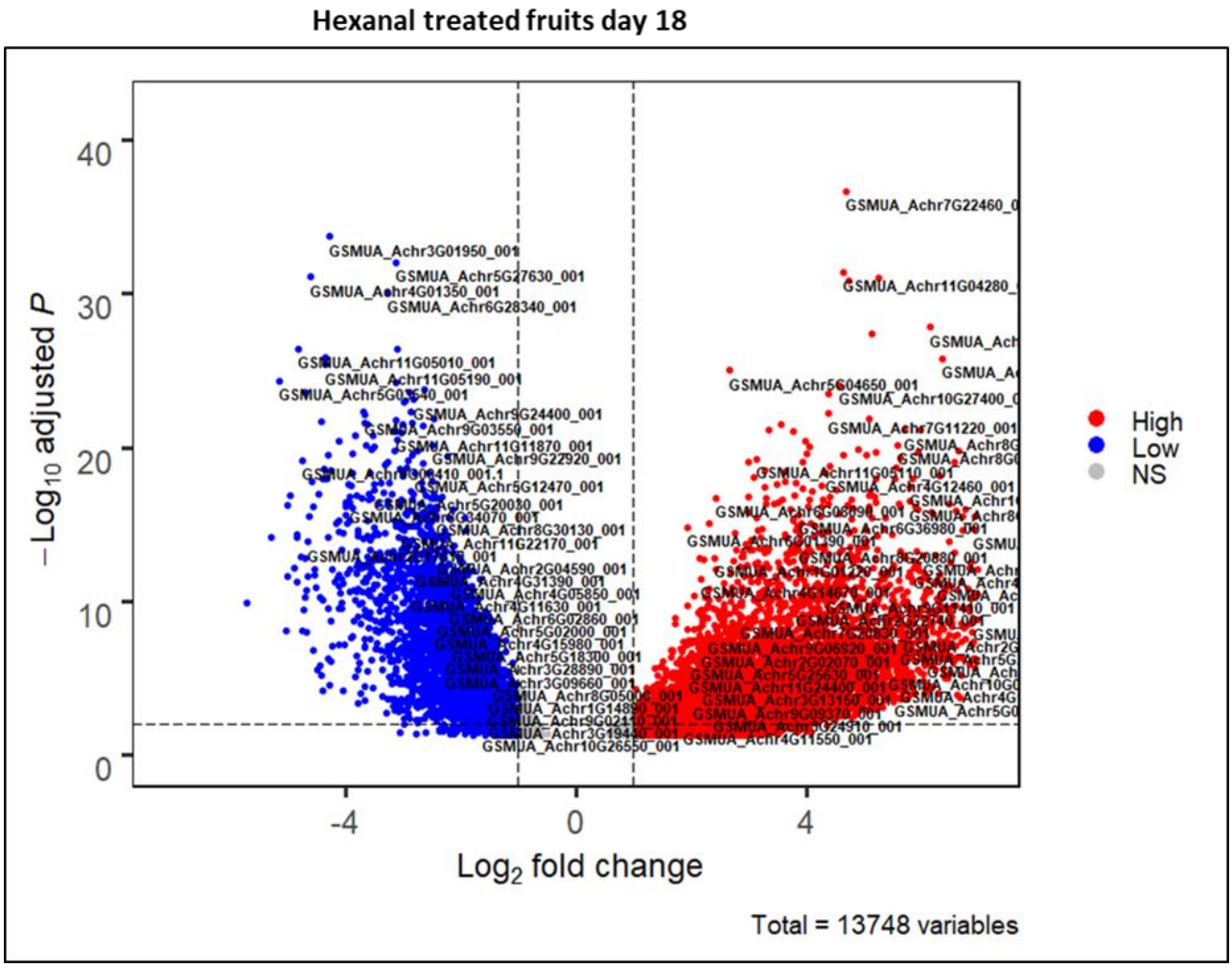


Figure 47: d d r r d 5 d log2fold ratio ≥ 1 at day 18 of storage in the hexanal treated fruits

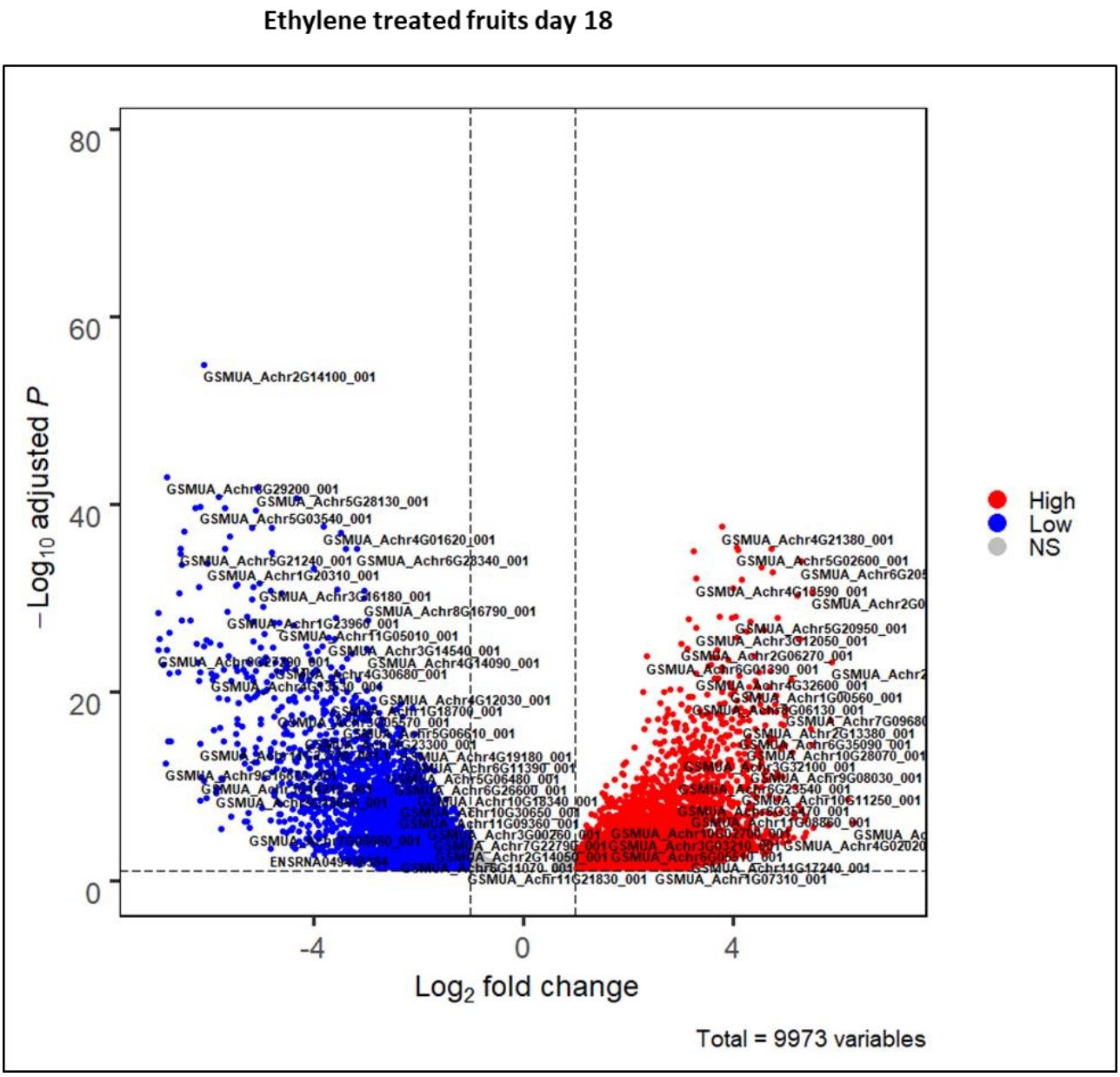


Figure 48: [illegible] log2fold ratio ≥ 1 at day of 18 storage in the ethylene treated fruits

5.4.3.2.4 Differentially Expressed Genes (DEGs) at day 24 of storage in the Hexanal treated fruits

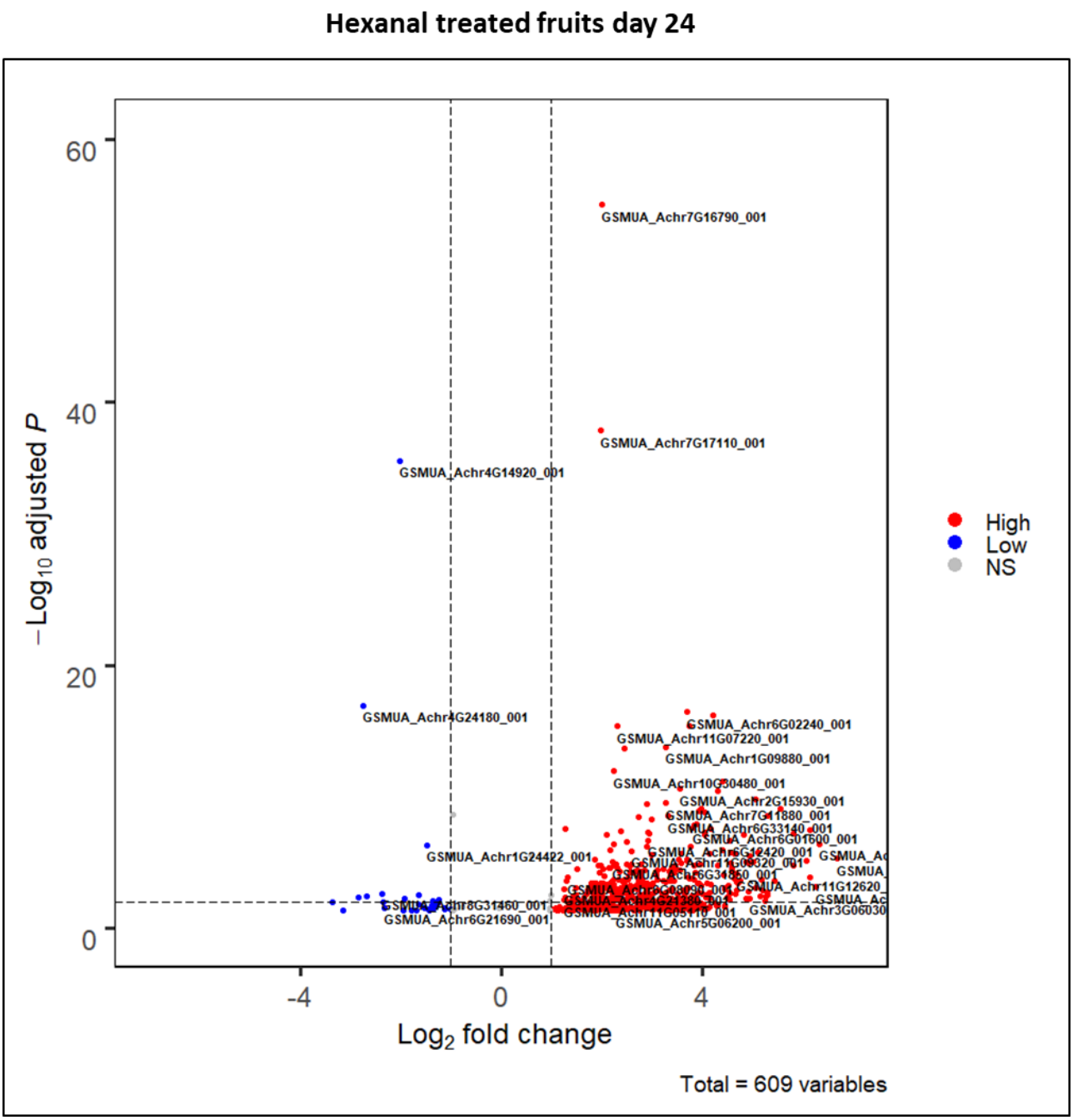


Figure 49: [illegible] log2fold ratio ≥ 1 at day 2 [illegible]

5.5. Discussion

et al.

et al

et al

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□

□□□□□□□ □□□□□□□□

CHAPTER SIX

6.0 GENERAL DISCUSSION, CONCLUSION AND RECOMMENDATIONS

6.1 General Discussion

grown in the country and plays a key role in Kenya's economy and food security that is in tandem with 2030 vision of the country. However, bananas' full potenti

exanal treatment coupled with the c

enhance the fruits' post

d objective, sought to elucidate the molecular basis of hexanal's mode of action in del

REFERENCES

Léchaudel, M. and J. Joas. 2006. “Quality and maturation of mango fruits of cv. Cogshall i r to harvest date and carbon supply.” Australia Journal of Agriculture and Research, 57:419 26

d 2 r r d r quantitative PCR and the 2−ΔΔ d M d 25 2

rd M d 2 r r d r d r r 25 2 5– 2 2

r d d 2 dr d r d d r M d r d 26

rd 2 r 5 r d r r r d r 2

r M M r M M 2 d r r r 6 6

M d M r 2 d r r r d r 5 66

M M d M d 2 2 dr d d r M r r 55 62

M r dr M r rd d 2 2 d r d r d r r 5 2 5 2

M M M r M r d r r r r d d d d M 2

atmosphere storage on the shelf life of banana ‘Sucrier’.

65–66

2

r

6 26

26

M

2

5 6 6

5

2 265–2

2

–2

2

5 2 2

M –M

2

Prunus avium

25 2 2

2 66 66

2

study on the ripening process of ‘Namwa’ banana.

5 6

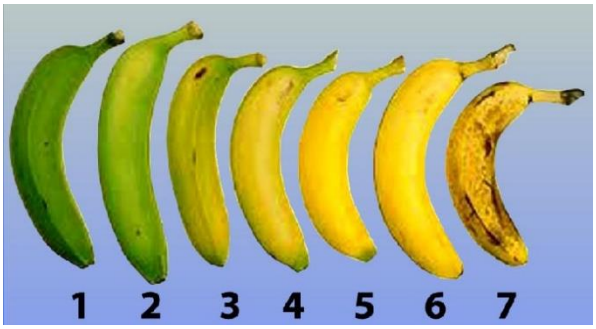
6 –

M 2 M

25 26

APPENDICES

Appendix 1 Banana ripening chart



Appendix 2. Sensory evaluation questionnaire for banana fruits

Name……Gender…… Age

□
□

□□□ □□□ □□□ □□□

□□M□□□□ □□□□□	□□□□□□	□□□□□□□□	□□□□□□□□□□□□□□	□□□M□□	M□□□□□□□□□	□□□□□□□□ □□□□□□□□□□□□□□
□□□□□□	□	□	□	□	□	□
□□□2□	□	□	□	□	□	□

□

□□□ □□□ □□2□□

□□ □□□□□□□□□□□□r□□□□
2□ □□□□□□□□□□□d□r□□□□□□
□□ □□□□r□□□□□□□□r d□□□□□□
□□ □□□□□□□d□r□□□□□□
5□ □□□□□□□□r□□ □□□□□□□□□
□

□□M□□□□ □□□□□	□□□□□□	□□□□□□□□	□□□□□□□□□□□□□□	□□□M□□	M□□□□□□□□□	□□□□□□□□ □□□□□□□□□□□□□□
□□□□□□	□	□	□	□	□	□
□□□2□	□	□	□	□	□	□

□

□
□

□

□

□

□

Appendix 3. ANOVA for peel color field

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
[illegible]	[illegible]	5[illegible]6.56[illegible]	[illegible]2[illegible]	[illegible]5[illegible]	[illegible]
[illegible]	[illegible]	5[illegible]6[illegible]	5[illegible]6[illegible]	2[illegible]6[illegible]	[illegible]
[illegible]	[illegible]	[illegible]5[illegible]5[illegible]	[illegible]5[illegible]5[illegible]	5[illegible]	[illegible]
[illegible]	[illegible]	[illegible]2[illegible]6[illegible]	[illegible]2[illegible]	[illegible]5[illegible]	[illegible]
[illegible]	[illegible]	2[illegible]6[illegible]	5[illegible]	2[illegible]2[illegible]	[illegible]65[illegible]
[illegible]	[illegible]	62[illegible]	[illegible]5[illegible]6[illegible]	[illegible]5[illegible]	[illegible]6[illegible]
[illegible]	[illegible]	5[illegible]	5[illegible]	2[illegible]22[illegible]	[illegible]
[illegible]	[illegible]	[illegible]6[illegible]	[illegible]5[illegible]6[illegible]	[illegible]	[illegible]2[illegible]	[illegible]
[illegible]	[illegible]	5[illegible]	6[illegible]	2[illegible]6[illegible]	[illegible]
[illegible]	[illegible]	26[illegible]2[illegible]	[illegible]26[illegible]2[illegible]	[illegible]2[illegible]26[illegible]	[illegible]
[illegible]	[illegible]	6[illegible]6[illegible]	[illegible]	[illegible]66[illegible]	[illegible]622[illegible]
[illegible]	[illegible]	[illegible]2[illegible]	26[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]6[illegible]6[illegible]	5[illegible]55[illegible]	2[illegible]	[illegible]2[illegible]
[illegible]	[illegible]	[illegible]5[illegible]	55[illegible]66[illegible]	2[illegible]	[illegible]
[illegible]	2[illegible]	[illegible]25[illegible]	[illegible]6[illegible]	[illegible]6[illegible]	[illegible]6[illegible]
[illegible]	[illegible]5[illegible]	[illegible]6[illegible]	26[illegible]6[illegible]	[illegible]	[illegible]
Total	**533**	**47965.63**	[illegible]	[illegible]	[illegible]

Appendix 4. ANOVA for ethylene production levels

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
Total	**650**	**5159.97**			

Appendix 5. ANOVA for respiration rate

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
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□□□□□□□	65□□	□55□□5□□□2□			

Appendix 6. ANOVA for cumulative weight loss

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
M d				2	
r		5 5	66 2		6
r		6	6		
		2	2	5 5	5
M d r		2	2		
r r		5	22	6	
M d		6	6	2 5	
r		2			52
r					
M d r		2	2		6
r r		6 5		5	
d	2 2	5 2	6 62		
Total	**1259**	**45766.03**			

Appendix 7. ANOVA for peel firmness

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
d		5 5 25	5 5	5	
r		256 2	6 2 6		
r		55 6	55 6	52 26	
				5	
	5	5 2	5 66	5	
d r		22	22	6 5	
r r		52 2	6		
d		26 2 6	26 2 6	2 2	
r		6	5	2 6	5
r					
d r		5	5	56 6	
r r		2	52	6 6	
d r	5	255	5 562	252 6	
r r		62	2 2	2	
d	5	22 5 2		2	
r		5 55	655	6	
r	5	6 6 5	6 2	5	
M r		2 2	55	5 5	

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
Total	**665**	**111816.33**	[illegible]	[illegible]	[illegible]

Appendix 8. ANOVA for pulp firmness

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	[illegible]	[illegible]		[illegible]	

Appendix 9. ANOVA for peel color

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]		
Total	**659**	**143291.74**			

Appendix 10. ANOVA for Total soluble solids

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]		
Total	**395**	**43078.86**			

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Appendix 11. ANOVA for Total titratable acidity

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
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Total	**434**	**25.3513**			

Appendix 12. ANOVA for Vitamin C

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
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Appendix 13. ANOVA for fructose

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
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□r□□□□ □□□□□□	5□	26□□□□□□□	52□□□□□	□2□□□	□□□□□□
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□□□□	□□	2□□□□2□	2□□□□2□	□□□□□	□□□□□□
□□□□□□□□□□□□□□□d□□□□r□□□□□	□□	□66□□□	□66□□□	5□□□	□□□25□
□r□□□□ □□□□□□□□r□□□□□	5□	□□□□□2□	2□2□□□	2□□□	□□□□□□
□□□□□□□□□□□□□□□d□□□ □□□	□□	□5□□□□	□5□□□□	□□□□□	□□□□□□
□r□□□□ □□□□□□□ □□□	5□	□□6□□□	□□□□□□□	2□6□	□□□26□
□□r□□□□□□□ □□□	□□	55□□□	55□□□	□□□□	□□□□□□
□□□□□□□□□□□□□□□d□□□□r□□□□□□□ □□□	□□	5□□□□□□	5□□□□□	□6□	□□□□6□
□r□□□□ □□□□□□□□r□□□□□□□ □□□	5□	□□□□□□□□	262□□□	□6□	□□□□□□
□□□□d□□□□	□□□□	2□□□□□□□□	□2□□□		□□
Total	**434**	**131733.7**			

Appendix 14. ANOVA for glucose

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr□
□□□□□□□□□□□□□□□d□□	□□	□26□5□	□26□5□	□□□2□	□□□□□□
□r□□□□ □□□□□□	5□	□□□□6□	□□□□□□	5□□□□	□□□□□□
□□□□	□□	□□□6□	□□□6□	□□□□□	□□□□□□
□□r□□□□□	□□	□□6□□	□□6□□	5□6□□	□□□□□□
□□□□□□□□□□□□□□□d□□□ □□□	□□	2□5□	2□5□	□□□□□	□□□□□□
□r□□□□ □□□□□□□ □□□	5□	2□□6□	□□5□	□□2□□	□□□□5□
□□□□□□□□□□□□□□□d□□□□r□□□□□	□□	6□□□	6□□□	□□□5□	□55□□
□r□□□□ □□□□□□□ r□□□□□	5□	□2□□□	□□□□□□	□□□□□	□52□□
□□□□□r□□□□□	□□	52□□	52□□	□□□□	□5□□□
□□□□□□□□□□□□□□□d□□□ □□□□□r□□□□□	□□	65□	65□	□□□□□	□□□□□□
□r□□□□ □□□□□□□ □□□□r□□□□□	5□	□6□□□	□2□□	□□□□□	□□□6□□
□□□□d□□□□	□□2□	6□□2□□□	□□□5□		□□
Total	**431**	**762042**			