STANDARDIZATION OF GROWTH REGULATORS FOR RACHIS ELONGATION IN CRIMSON SEEDLESS AND BERRY AND FLOWER THINNING IN RED GLOBE GRAPES (*Vitis vinfera* L.)

SUNITA PATIL

B. Sc. (Hort)

MASTER OF SCIENCE IN HORTICULTURE

(FRUIT SCIENCE)

DEPARTMENT OF FRUIT SCIENCE

COLLEGE OF HORTICULTURE VENKATARAMANNAGUDEM, WEST GODAVARI – 534 101

Dr. Y.S.R. HORTICULTURAL UNIVERSITY

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By

SUNITA PATIL

B. Sc. (Hort)

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DECLARATION

I, Ms. SUNITA PATIL hereby declare that the thesis entitled **"STANDARDIZATION OF GROWTH REGULATORS FOR RACHIS ELONGATION IN CRIMSON SEEDLESS AND BERRY AND FLOWER THINNING IN RED GLOBE GRAPES (V*itis vinfera* L)"** submitted to Dr.Y.S.R. Horticultural University, Venkataramannagudem for the degree of Master of Science in Horticulture (Fruit Science) is the result of original research work done by me. I declare that no material contained in the thesis has been published earlier in any manner.

Place: Venkataramannagudem
Date:

Name: SUNITA PATIL
ID. No: VHM/15-30

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Place: Venkataramannagudem
Date:

(SUNITA PATIL)

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LIST OF SYMBOLS AND ABBREVIATIONS

%	:	Per cent
&	:	And
/	:	Per
@	:	At the rate of
^{0}C	:	Degree centigrade
CD	:	Critical difference
Cm	:	Centimeter
cm^3	:	Cubic centimeter
CuSO4	:	Copper Sulphate
cv.	:	Cultivar
DNOC	:	Dinitro-Ortho-Cresol
Dist	:	District
Dr. Y.S.R.H.U	:	Dr. Y.S.R. Horticultural University
et al.	:	And his co workers
Etc	:	And so on
Fig.	:	Figure
G	:	Gram
GA_3	:	Gibberllic acid
g^{-1}	:	Per gram
H_2CN_2	:	Hydrogen Cyanamide
i.e.	:	That is
ICAR	:	Indian Council of Agricultural Research
IIHR	:	Indian Institute of Horticultural Research
L	:	Litre
µL	:	Microliter
Mg	:	Milligram
mg g^{-1}	:	Milligram per gram
Ml	:	Millilitre

ml Lt^{-1}	:	Milliliter per litre
Mm	:	Millimeter
mM	:	Millimolar
MT	:	Manual Thinning
No.	:	Number
NS	:	Non-significant
pH	:	Puissance de hydrogen
Ppb	:	Parts per billion
Ppm	:	Parts per million
RH	:	Relative humidity
SE m±	:	Standard error of mean
Viz.,	:	Namely
var.	:	Variety
vars.	:	Varieties

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ABSTRACT

A research trial was undertaken during the year 2016-17 at experimental vineyard ICAR-Indian Institute of Horticultural Research located at Hessaraghatta, Bengaluru on "Standardization of growth regulators for rachis elongation in Crimson Seedless and berry/flower thinning in Red Globe grapes (*Vitis vinfera* L)". The field experiment was laid out in Randomized Block Design (RBD) comprising a total of four treatments and replicated seven times in experiment -I and seven treatments and replicated four times in experiment-II.

The first experiment was conducted to standardize concentration of GA_3 for rachis elongation of Crimson Seedless grapes. Three different concentrations of GA_3 {*viz.*, 5 ppm (T_1), 7.5 ppm (T_2) and 10 ppm (T_3)} were sprayed during pre-bloom stage and compared with unsprayed control (T_4).Among different treatments, pre-bloom spray of GA_3 @5 ppm produced less compact bunches with highest total length of rachis(124.91 cm), average bunch weight (507.49 g), berry weight (4.92 g); berry length (25.85 mm); TSS (18.5^{0}B), sugar acid ratio(83.82); total sugars (18.2g/100 g) and with least bunch compactness (0.94). Among different treatments, pre-bloom spray of GA_3 @7.5 ppm could increase anthocyanin concentration (247.9

g/100g) compared to other treatments. However, the bunches sprayed with 7.5 ppm and 10 ppm GA_3 produced good quality bunches with average berry weight and TSS was less. Because of severe coiling of rachis at 7.5 ppm and 10 ppm GA_3 spraying, the bunches were too straggly compared to spraying of 5 ppm GA_3. The control bunches without GA_3 spray produced very compact clusters (2.6) with less average bunch weight (433 g), berry weight (3.98 g), berry diameter (16.87 mm) and berry length (22.76 mm).

The second experiment was conducted to standardize flower thinning chemicals in Red Globe to improve the bunch and berry quality parameters. Different organic and inorganic chemicals *viz.*, 0.5 % Olive oil (T_1); 0.3% Caffeine (T_2); 0.1 % Hydrogen Cyanamide (T_3); 0.1 % Dinitro Ortho Cresolate (T_4); 0.5 % Copper Sulphate (T_5) were sprayed during full bloom stage and were controlled with manual berry thinning at 8-10 mm stage (T_6) and untreated control (T_7). Among different treatments, spraying of olive oil could increase rachis length (122.73 cm), least bunch compactness (0.91) was observed and $CuSO_4$ (1.09) also could produce less compact bunches. However the average bunch weight, berry diameter and berry length was highest on vines sprayed with caffeine and olive oil. Bunch compactness was highest in control (2.56) vines and least bunch weight (599.38 g) was also recorded on control vines. Among different treatments manual berry thinning at 8-10 mm stage could produce highest TSS and total sugars. Though the treatments like $CuSO_4$ and Hydrogen Cyanamide could produce loose clusters with good bunch weight, scorching of rachis was observed indicating their toxicity. Among the treatments studied the bunches treated with olive oil and caffeine could produce good quality bunches.

Chapter I

Introduction

Chapter I

INTRODUCTION

Grape (*Vitis vinifera* L.) is one of the important commercial fruit crop in India. Though it is originated in temperate regions, it is well acclimatized to tropical and subtropical regions of India. In India, it is grown in wide range of tropical and subtropical areas from north to south, but the most important grape producing states are Maharashtra, Karnataka, Andhra Pradesh and West Bengal. In India, Grape is grown in an area of about 0.125 million hectares with a production of around 24.83 million tonnes with productivity of 21.8 MT/ha (NHB, 2015-16). In Andhra Pradesh, it is cultivated in nearly 0.400 ha with a production of 89000 MT (NHB, 2014).

It is cherished as fresh fruit as raw or they can be used for processing to several value added products *viz.*, wine, jam, juice, jelly, seed extract, raisins, vinegar, and grapes seed oil. It is one of the important crops which earn lot of foreign exchange through export of fresh grapes. For table purpose bunch should be loose but well filled, berries should be attractive, and have less acid but high sugar content i.e high sugar: acid ratio and good flavor. For obtaining good quality of table grapes, one has to follow good canopy management practices and judicious use of growth regulators in addition to nutrient and water management. Growth regulators are used in seedless grape varieties for improving bunch and berry quality.

Though Thompson Seedless is the internationally accepted table grape variety across the globe, in recent years many new green and colored varieties are finding place in export market. The important varieties are Crimson Seedless, Fantasy Seedless, Red Globe, Autumn Royal etc. In India, major area under grape cultivation comprises of Thompson Seedless and its clonal selections like Tas-A-Ganesh, Sonaka and Manik Chaman and its cultivation is mainly concentrated in Maharashtra and Northern Karnataka regions. However, the area under colored grape varieties is steadily increasing in mild tropical climatic regions of Bangalore and surrounding districts. The important cultivars grown there are Flame Seedless, Sharad Seedless

and its clonal selections, Red Globe, Crimson Seedless etc. Though most of the cultural practices are similar to that of standard Thompson Seedless cultivar, their response is different for growth regulator application and canopy management practices.

Two important varieties *viz.*, Crimson Seedless and Red Globe are gaining importance in recent years owing to their superior quality with respect to bunch and berry parameters and extended shelf life. Red Globe was introduced from the University of California, USA in the year 1985. The vines are moderate in vigour but tend to produce more number of bunches with variable sizes. The berries are very bold, attain 22-25 mm dia., spherical and having few soft seeds. Pulp is very firm and fleshy, skin is light red thick, often peelable. It is a mid-late maturing variety. Light coloured fruits are more attractive and fetch better price. Red Globe berries will be attractive when they turn to wine red colour and extra bold in size. This variety doesn't require GA_3 for rachis elongation. But, it needs rigorous flower or berry thinning as increased fruit set reduces individual berry size. Application of very little dose of GA_3 for flower thinning results in coiling of rachis and affects the bunch quality very badly. Hence, there is a need to find alternate and safe chemicals for flower or berry thinning.

Crimson Seedless is a late season grape variety, developed by cross between Emperor × C33-199 at USDA, Fresno, California. The vines are very vigorous. Berries are attractive bright red seedless with very firm flesh. It also has very good shelf life because of its tough thick skin. Bunches are medium in size, conical with a shoulder and well filled to slightly compact. It is late ripening variety and takes not less than 130 days from pruning. The fruits are acidic and usually harvested at sugar:acid ratio of more than 25 for Indian markets. The fruits can be stored up to 18-20 weeks. The bunches are too compact and there is a need to increase rachis length through very mild dose of GA_3. Higher concentration of GA_3 causes coiling of clusters and affects bunch quality. Hence, there is a need to standardize the concentration of GA_3 to increase length of rachis.

To achieve production of good quality grapes improved crop regulation techniques like rachis elongation and flower or berry thinning by using growth

regulators need to be standardized in these varieties. Hence this study is proposed with the following objectives.

1. To evaluate different concentration of GA_3 for rachis elongation in Crimson Seedless grapes.
2. To evaluate different chemicals and their concentration for flower/berry thinning in Red Globe grapes.
3. To improve the overall bunch and berry quality parameters of Crimson Seedless and Red Globe grapes.

Plate 1.1 Grape cultivars Crimson Seedless and Red globe used in experimrent I &II.

Chapter II

Review of Literature

Chapter II

REVIEW OF LITERATURE

Though Indian table grape industry hovers around white/green Seedless varieties, *viz*. Thompson Seedless and its mutants Tas-A-Ganesh and Sonaka in export scenario, in recent past many of the colored varieties are also finding place in export market particularly to Middle East and Gulf countries. Some of those varieties are Sharad Seedless (syn: Kishmish Cherney), Flame Seedless, Crimson Seedless, Red Globe *etc.* In mild tropical climate of South interior Karnataka, cultivation of coloured grape varieties is gaining strong impetus as this region is best owed with climate which produced good quality grapes.

Two varieties *viz.* Crimson Seedless and Red Globe are gaining importance in recent years owing to their superior quality with respect to crispy pulp, attractive color and good shelf life. Crimson Seedless is a late season, attractive crimson color grape cultivar with very firm berries. It also has very good shelf life. The bunch is too compact and there is a need to increase rachis length through very mild dose of GA_3. Higher concentration of GA_3 causes coiling of clusters and affects bunch quality. Hence, there is a need to standardize the concentration of GA_3 to increase length of rachis. Red globe is a variety with moderate vigour, but tend to produce more number of bunches with variable sizes. However, systematic research findings are lacking in colored Seedless varieties for rachis elongation. Hence, one of the objectives of this study was to standardize different concentration of GA_3 for rachis elongation in Crimson Seedless grapes. Similarly, in cultivation of colored Seedless grape varieties, significant input cost comes under use of growth hormones like GA_3 and manual labors for berry thinning. Hence, another objective of this study was to standardize the time and concentration of berry thinning agents to produce good quality bunches. The literature pertaining to the present study is reviewed under the following main and sub headings:

2.1 EFFECT OF DIFFERENT CONCENTRATION OF GA_3 ON RACHIS ELONGATION IN GRAPE

2.1.1 Bunch characters

2.1.1.1 Total length of rachis

The increase in growth rate in terms of bunch length has been reported by many research workers which could be attributed to the application of Gibberellic acid and other regulating chemicals at different concentration and at different stages. The main reason for increase in bunch length could be elongation of cells in rachis thus resulting in increased rachis length, which consequently could have effect to the increased bunch length. The time and concentration of GA_3 application plays a major role and several workers have tried to standardize its application at different stages after panicle emergence. As early as , Jawanda *et al*. (1974) reported that cluster length and weight increased significantly with 50 ppm GA_3 application at 10 days before anthesis in 'Thompson Seedless' grapes. Application of GA_3 5-40 ppm at 75 % cap fall stage increased berry weight and berry volume with successive increase in GA_3 level. But, in another study, Patil *et al*. (1980) reported that 30 ppm GA_3 treatment at pin- head stage had maximum bunch length (21.9 cm) in Perlette cultivar. Gill *et al*. (1987) recorded increase in bunch length when GA_3 was applied at early bloom stage in Thompson Seedless cultivar. Bunch length was relatively more pronounced when 50 ppm GA_3 was applied at fruit-set stage.

Verma *et al*. (1991) reported that application of 20 ppm Gibberellic acid at pre bloom and again at full bloom stages resulted in highest bunch length (26.50 cm) in Thompson Seedless grape. Lakshmanan *et al*. (1992) showed highest bunch length in three Seedless cultivars *viz*. Thompson Seedless, Tas-A-Ganesh and Arkavathi when these were treated with 50 ppm GA_3 at calyptra fall stage and pea stage.

Though GA_3 application is a common practice in Thompson Seedless grapes all over the world to improve bunch and berry characters, many research workers have initiated their work in this direction on other grape varieties. Similarly, Mohamed Farooq and Hulamani (2000) showed highest bunch length of Arkavati grapes when the bunch were treated with 75 ppm GA_3 at full bloom stage. Ahmad *et*

al. (2005) observed maximum bunch length in Perlette grapes treated with girdling in combination with bunch dipping in GA_3 at 40 ppm.

Gowda *et al*. (2006) reported significant effects of different concentration of GA_3 when applied at different stages of cluster development. Selvaraju *et al*. (2007) recorded maximum bunch length, breadth, weight and bunch compactness with 20ppm GA_3 at pre bloom stage along with clipping of 30 % of the inflorescence at pea stage. In contrast, Casanova *et al*.(2009) recorded significant increase in bunch weight, length and width by 80 ppm GA_3, irrespective of the date of treatment in 'Emperatriz Seedless' grape, In some varieties like BRS Clara, along with application of GA_3 for two times, cluster thinning could produce rachis length of desired size as reported by Formolo *et al*. (2010).

Magdalena *et al*. (2011) found that mixture of Gibberellic acid ($50mgL^{-1}$) and NOA (0.2 %) were shown to have a significant effect on bunch length irrespective of method of application in 'Einset Seedless' grape. In a similar study, Dimovska *et al*. (2014) observed significant increase of bunch length, width and weight with double application of GA_3 at 7-10 days before blooming and 7-10 days after blooming in 'Flame Seedless' grapes .

2.1.1.2 Number of berries per bunch

One of the important export standards of Indian grapes to different countries is number of berries per bunch. Though it is achieved through manual thinning, application of GA_3 at higher concentration could reduce fruit set by flower thinning. This chemical thinning will help to achieve desired number of berries per bunch with less input of manual labours for berry thinning. Asano *et al*. (2001) studied that the number of berries per bunch was greater when cytokinin was supplemented than single Gibberellin at 25, 50 and 100 ppm.

Taleb *et al*. (2010) evaluated the influence of GA_3 application on the fruit quality and productivity of cane pruned Thompson Seedless with different combination of treatments and no statistical differences were observed between all the treatments, even though, the highest berry number (66.5) was obtained by the naturally treated grapevine, while the lowest number (60.5) was obtained by the girdle treated grapevines.

Similarly, Dimovska *et al*. (2011) studied the different concentration of GA_3 (5, 10 and 20 mg L^{-1}) applied during the three different periods of the vine growing (before blooming, after blooming and before veraison) in two different Seedless cultivars *viz.* 'Thompson Seedless'and 'Belgrade', addition of gibberellic acid at concentration of 20 mg L^{-1} increased the cluster mass and number of berries significantly.

Taleb and Salameh (2012) found that GA_3 (50 ppm) in combination with girdling (at berry set stage) developed heavier bunches with increased number of berries in 'Black Magic'.

2.1.1.3 Bunch compactness

In their studies on effect of soil application of chelated Fe, Zn and Mn as well as foliar spray of GA_3 and ascorbic acid on improving the vegetative growth and productivity of Flame Seedless grapes under Calcareous soil conditions, Emad *et al*. (2015) revealed that untreated control has excessive compact cluster (12.9 and 13.26 berries /cm in both seasons) compared with all treatment that have 8.31 to 9.09 and 8.29 to 9.13 berries /cm in both years and concluded that right concentration of GA_3 can reduce cluster compactness ratio.

2.1.1.4 Bunch weight

Effect of Gibberellic acid on bunch weight is one of the most striking responses of grapes. The increase in bunch weight could be the result of an increase in bunch size and berry size. An increase in the berry size can also be a major factor contributing to the bunch weight.

As early as 1962, Weaver and his coworkers reported that application of GA_3 along with 4-CPA reduced berry set and increased weight per cluster. Dass and Randhawa (1968) revealed that increase in bunch weight when 50 ppm GA_3 was applied 2 -3 DAFB in 'Bhokri' and also induced Seedlessness. Nilnond and Sukumalanandana (1988) reported that GA_3 application at 25, 50 and 75 ppm to panicles 15days after full bloom stage resulted in higher bunch weight in Sultanania, Black Sultanania, Beauty Seedless, Ruby Seedless, Delight and Early Muscat varieties of grapes. Khan and Singh (1989) found that maximum bunch weight was observed in Kishmish Chernyi cultivar of grapes when treated with 25 ppm

Gibberellic acid at full bloom and again 30 days later. Lakshamanan *et al*. (1992) found that application of GA_3 (50 ppm) by spray and bunch dipping increased bunch weight of Thompson Seedless, Tas-A-Ganesh and Arkavathi grapes. According to Hayatt *et al.* (1994) bunch weight was significantly increased at maturity stage (558.4 g) when GA_3 40 ppm was applied at full bloom and after full bloom stages in Perlette grape cultivar.

Application of GA_3 before full bloom stage not only helps in rachis elongation but also helps in later stages for increased bunch weight. In this direction several workers have tried pre bloom application of GA_3 to test this hypothesis. Jeong *et al*. (1998) revealed that Kyoho grape clusters when dipped in GA_3 solution (25 ppm) before full bloom and ten days after full bloom in 100 ppm GA_3 increased the cluster weight significantly. Dokoozlion *et al*. (2001) reported that application of 2.5 g per hectare GA_3 at near full bloom stage increased cluster weight. Mohammed and Hulamani (2000) reported that GA_3 (75 ppm) at the full bloom stage resulted in the highest bunch weight (32.5 g) and highest number of berries per bunch in 'Arkavathi' grapes. Pires *et al*. (2000) observed that the application of Gibberellic acid once, 2 weeks after full bloom (5, 10, 15, 20, 25, 30, and 35 ppm) had a significant effect on increase in bunch weight in Centennial Seedless grapes. E1-Ghany *et al*. (2001) revealed that application of GA_3 as spray to clusters twice at 10 ppm to clusters with a length of 5 to 7 cm and again after 5 to 7 days increased the bunch weight. Godara *et al*. (2002) found that the maximum increase was observed with the application of Gibberellic acid 50 ppm at full bloom stage followed by Gibberellic acid 50 ppm at berry set stage. Dass and Randhawa (2006) studied that dipping the clusters in GA_3 at 50–100 mg per liter at 2–3 days after full bloom significantly increased berry weight of Pusa Seedless grape. Formolo *et al*. (2010) studied that Gibberllic acid and cluster thinning on Seedless grapes BRS clara and reported that best results for cluster weight of bunches was observed in treatments 5-cluster thinning and double application of $GA_{3,}$30+30 mg ,differing from all other treatments. Magdalena *et al*. (2011) found that mixture of Gibberellic acid (50 mg L^{-1}) and NOA (0.2 %) were shown to have a significant effect on bunch weight irrespective of method of application in 'Einset Seedless' grape.

Recently Meena *et al*. (2012) recorded positive effects with application of GA_3 (25 ppm) on cluster weight when treated at full blossom stage in 'Perlette' grapes. Taleb and Salameh (2012) found that GA_3 (50 ppm) in combination with girdling (at berry set stage) developed heavier bunches with increased number of berries in 'Black Magic'. Zahedi *et al*. (2013) observed that highest cluster weight was recorded with 50 ppm GA_3 applied at berry set stage and when berries were 4 mm in length in both cultivars Perlette and Yaghuti under Iran condition. Chaitakhob *et al.* (2014) reported that bunch dipping with GA_3 (30 μlL^{-1}) + BA (10 μlL^{-1}) at 50% of full bloom affected the bunch size, width and bunch length /width ratio in 'Perlette' grapes.

2.1.1.5 Bunch volume

According to Chitkara and Chudawat (1972) studied that application of 40 ppm GA_3 at full bloom stage was more effective in increasing volume of berries. Berry weight increased significantly with 300 ppm GA_3 applied 14 DAFB in 'Orlando Seedless' & GA_3 significantly increased fruit volume and fresh flesh weight in both cultivars Perlette and Yaghuti with 50 ppm GA_3 applied at berry set stage and when berries were 4 mm in length(Zahedi *et al*., 2013).

2.1.2 Berry characters

2.1.2.1 Average berry weight

Average berry weight is one of the important characters demanded in international market. Bold berries fetches premium price. Production of bold berries involves elongation of rachis in the initial stages of cluster emergence followed by maintaining optimum berry numbers per unit rachis length, which can increase berry weight. In this direction several studies were conducted to improve average bunch weight in Seedless grapes. Srivastava and Bisht (1969) reported that spray of 40 ppm GA_3 at berry shatter stage or one week after fruit set had significantly increased the size of the berries and 10 ppm GA_3 had also increased the size of the berries in 'Thompson Seedless' when applied to clusters at petal fall or at shatter stage. Dhillon *et al.(*1973) obtained higher berry weight in 'Beauty Seedless' when treated with 50, 100 or 150 ppm GA_3 at full bloom stage and berry weight got increased with higher concentrations. Sandhu *et al*. (1985) obtained increased berry area by dipping the

cluster in GA_3 (20 ppm) in 'Perlette' grapes. Kashyap *et al*. (1989) reported that application of GA_3 20 ppm and 75 ppm at bloom and fruit set stages significantly increased the berry weight (4.32 g) than control (2.16 g) in Thompson Seedless grapes. GA_3 application at all concentration resulted in the elongation of berries. Lakshmanan *et al.* (1992) studied that Spraying of gibberellic acid at 50 ppm twice, once at calyptra fall stage and other at pea stage in seeded varieties like 'Pachadraksha' and 'Anab-e-Shahi' and bunch dipping at the same concentration in 'Thompson Seedless' and 'Arkavathi' increased berry diameter.

Recently, Ranpise *et al.* (2000) reported highest berry weight (263.3 g) for 10 berries when CPPU 3 ppm + GA_3 25 ppm applied at 3 mm berry size in Thompson Seedless grapes & Zabadal and Diitmer (2000) found that application of Gibberellic acid (25 and 50 ppm) when berry diameters of 3, 5, 7 and 9 mm. GA_3 at 50 ppm when berries averaged 5 mm diameter was most effective for increasing berry weight in Vanessa grapevine.

El-Ghany *et al*. (2001) reported an increased berry diameter when 'Thompson Seedless' grape clusters were treated with 10 ppm. GA_3 sprayed twice at 5 to 7 cm cluster length and again 30 ppm at one week after set.

Wu-Jun *et al.* (2001) observed that increase in grape berry weight in Fujiminori with the application of 25 mg /liter GA_3, fruit weight increased when Italia grapevines sprayed with 3, 4, 5, 6, 8 or 12 mg CPPU /liter along with 40 mg Gibberellic acid. Andrew and Christiana (2004) found that Post bloom application of GA_3 (40 ppm) increased the berry size, berry weight and reduced the number of seeds significantly in 'Sovereign Coronation. Chen-JinYong *et al.* (2005) reported that dipping of clusters in 40-60 mg GA_3 per liter increased the fresh fruit weight of Red Globe grapes. Ramteke *et al.* (2008) found that berry size and berry weight of 'Sharad Seedless' grapes were increased with the application of GA_3 at 40 and 30 ppm along with 10 ppm BA at 3–4 mm and 6–7 mm berry size stage, respectively. Formolo *et al*. (2010) studied that effect of Gibberllic acid and cluster thinning on Seedless grapes BRS clara and reported that diameter greater than 17 mm size was reached in the treatments 4-cluster thinning and single application of 60mg/L of GA_3 is followed by cluster thinning and double application of GA_3 ,30+30 mg/L.

Rafaat *et al*. (2012) found that for three consecutive years in 'Thompson Seedless', spraying GA_3 (40 ppm) increased weight, size, diameter and berry index shape of berries. Taleb and Salameh (2012) reported that GA_3 (50 ppm) in combination with girdling (at berry set stage) developed heavier berries and increased berry diameter in 'Black Magic'.

2.1.2.2 Berry diameter

El-Ghany *et al*. (2001) reported an increased berry diameter when 'Thompson Seedless' grape clusters were treated with 10 ppm. GA_3 sprayed twice at 5 to 7 cm cluster length and again 30 ppm at one week after set and Roberto *et al.* (2002) observed that the application of Gibberellic acid at 3g /100 liter in 'Ruby' grapes at 30 days after flowering recorded more width of berries in Brazil. Berry length, diameter and weight were significantly greater in bunches treated with the higher concentrations of GA_3 (20, 25, 30 and 40 mg L^{-1} at 45, 50, 55 and 65 days after October pruning). Maximum berry size, diameter was observed with 20 ppm GA_3 at pre bloom stage along with clipping of berries at pea stage (Gowda *et al*., 2006). Similarly, reported that double application of GA_3 (30 ppm) at 5 mm berry diameter and 30 days after increased the berry diameter spraying clusters with 20 ppm GA_3 + 75 ppm NAA resulted in highest berry weight, size, diameter Formolo *et al.* (2010). GA_3 (50 ppm) in combination with girdling (at berry set stage) developed heavier berries and increased berry diameter in 'Black Magic' (Taleb *et al*.,2012) & spraying GA_3 (40 ppm) increased weight, size, diameter and berry index shape of berries in 'Thompson Seedless' Rafaat *et al*. (2012).

2.1.2.3 Berry length

As Gibberellins are known to involve in cell elongation, its direct effect is on berry length increment in most of the Seedless cultivars. In this direction, the GA_3 which is applied during pre bloom stage for rachis elongation is known to influence berry length significantly in positive mode.

Mohammed-Farooq and Hulamani (2000) reported that the highest berry length (1.60 cm) was obtained in berries treated with Gibberellic acid at 25 ppm. The interaction between growth regulators and the stage of treatment was also significant. Application of CPPU + GA_3 significantly affected the berry length in Thompson

Seedless grapes. CPPU 3 ppm + GA_3 25 ppm applied at 3 mm berry size, recorded the highest length (2.47 cm) of berry. Mohammed and Hulamani (2000) studied that application of GA_3 (25 ppm) at the stage of elongated inflorescence axis in 'Arkavathi' grapes, increased berry length. Dokoozlian and Peacock (2001) studied the effects of Gibberellic acid (5, 10, 15 or 20 g GA_3 ha^{-1}) applied at blooming (approximately 80 % cap fall) on the berry growth, fruit composition and productivity of Autumn Royal table grapes. $GA_3$10 ppm applied at 5 to 7 cm cluster length and again after 5 to 7 days and twice for sizing at 30 ppm one week after fruit set significantly increased the berry length. Pires *et al*. (2003) observed that GA_3 at 20 to 30 ppm applied 10 DAFB was effective in increasing the berry length. Dimovska *et al*. (2011) studied that the different concentration of GA_3 (5, 10 and 20 mg L) during the three different periods of the vine growing (before blooming, after blooming and before veraison) in two different Seedless cultivars *viz.* Thompson and Belgrade, addition of Gibberellic acid at concentration of 20 mg L^{-1} increased the berry length and weight in both the cultivars significantly. Meena *et al*. (2012) studied that Positive effect with application of GA_3 (25 ppm) on physical characteristics of berries *i.e.* berry weight and length were noticed when treated at full blossom stage in 'Perlette' grapes. Rafaat *et al*. (2012) found that for three consecutive years in 'Thompson Seedless', spraying GA_3 (40ppm) increased weight, size, length and berry index shape of berries. Recently, Dimovska *et al*. (2014) observed that application of 20 ppm GA_3 at 7-10 days before blooming and 7-10 days after blooming in 'Flame Seedless' grapes increased the berry length, width, weight and berry shape index significantly.

2.1.3 Observation on biochemical analysis

2.1.3.1 Total Soluble Solids

In table grapes, yield per vine is a function of number of bunches per vine and average bunch weight. The average bunch weight is not only contributed by its length and diameter, but also by total sugars present per berry. A positive correlation was established between total soluble solids and yield per vine by several workers in the past Sing *et al.* (1993) studied that the increase in total soluble solids may be due

to quick metabolic transformation in soluble compounds. The increase in total soluble solids could also be attributed to the effect of Gibberellic acid and Gibberellic acid like substances which can increase the capacity of grapes berries to draw more carbohydrates through increment in auxin content. Singh *et al*. (1994) observed that GA_3 (50 ppm) spray at bloom stage increased the TSS. Zabadal *et al.* (2000) studied that application of GA_3 at 50 ppm when berries averaged 5 mm in diameter gave increased TSS in ripe berries. Liu-JinLang *et al*. (2002) reported that use of 200 mg GA_3 per liter or 200 mg GA_3 per liter + 200 mg 6-BA per liter in late June to mid-July and again after 7 days increased total soluble solids content in Fujiminori grape variety. Taleb and Salameh (2012) found that 50 mg L^{-1} of GA_3 was effective in increasing the total soluble solids in 'Black Magic'. Zahedi *et al.* (2013) found that the highest TSS (%) was recorded with 50 ppm GA_3 applied at berry set stage when berries were 4 mm in length 'Perlette' under Iran condition. Chaitakhob *et al*. (2014) reported that bunch dipping with GA_3 (30 μlL^{-1}) at 50 % of full bloom increased the TSS, significantly in Perlette grapes.

2.1.3.2 Titratable acidity

Rather than measuring total soluble sugars alone, it is titratable acidity which contributes for better taste in table grapes because of its proper blend which determines mouth feel. So, acidity is also one of the important factors in table grapes which determines fruit quality. But, how far GA_3 influences acidity are not studies well and most of the studies showed non-significant influence of GA_3 on this quality parameters.

Kashyap *et al*. (1989) recorded the lower titratable acidity (0.63 %) in Thompson Seedless grapes when treated with 20 ppm GA_3 at bloom and 75 ppm GA_3 at fruit set stage. Khan *et al*. (1997) studied that acidity of juice was not influenced significantly, with increase in concentration of GA_3 (25, 50 or 75 ppm) applied to bunches at full bloom and one month later in Kishmish Cherni grape. Ahmad and Zargar (2005) studied that the GA_3 (50 ppm) coupled with Trunk girdling and Ethephon resulted in increased decreased acidity as compared to control when applied at 50 per cent bloom in 'Perlette grapes'. Dimovska *et al.* (2011)

found that among the different concentration of GA_3 (5, 10 and 20 mg L-1) applied during the three different periods of the vine growing (before blooming, after blooming and before veraison) in two different Seedless cultivars *viz.* Thompson and Belgrade, addition of Gibberellic acid at concentration of 20 mg L^{-1} resulted in higher levels of total acids in the 'Thompson Seedless' grapes. Taleb and Salameh (2012) found that 50 mg L^{-1} of GA_3 was effective in decreasing total titratable acidity. It also reduced the color of the fruits significantly in 'Black Magic'. Dimovska *et al.* (2014) studied that the application of 20ppm GA_3 at 7-10 days before blooming and 7-10 days after blooming in Flame Seedless grapes decreased the acidity content of berries.

2.1.3.3 Sugar acid ratio

According to Ahmad and Zargar (2005) GA_3 (50 ppm) coupled with Trunk girdling and Ethephon resulted in increased TSS/acidity ratio as compared to control when applied at 50 per cent bloom in 'Perlette grapes'.

Rather *et al.* (2011) recorded that girdling + 40 ppm of GA_3 proved most effective in increasing the quality in terms of TSS/acid ratio (27.24 %) in Perlette grapes.

Chaitakhob *et al*. (2014) reported that bunch dipping with GA_3 (30 μlL^{-1}) at 50 % of full bloom increased TSS /acidity ratio significantly in Perlette grapes.

2.1.3.4 Anthocyanin

Ozer *et al*. (2012) studied to determine the effects of berry thinning and Gibberellin (GA_3) on yield and fruit quality of Recel Uzumu table grapes. A combined six treatments of Gibberellin (control and 40 ppm) and cluster tipping (control, 1/3 and 1/2) were applied at the 3-5 mm berry size stage. Anthocyanin content of Gibberellin sprayed grapes was less than for non-sprayed vines. The anthocyanin content, for Gibberellin sprayed grapes decreased from 53.95 to 42.26 mg /kg. Similarly, Gibberellic acid application after full bloom has led to a decrease in anthocyanin content of Kyoho grapes (Lee Changhoo *et al.*, 1996).

2.1.3.5 Total Phenols

Avenant *et al*. (2017) investigated effect of Gibberellic acid (GA_3) and N-(2-Chloro- 4-pyridyl)-N-phenylurea (CPPU) treatments to reduce or eliminate browning of white table grape cultivars. Twenty treatment combinations of GA_3 (no GA_3, 10,

20, 30 and 40 ppm) and CPPU (no CPPU, 1, 2 and 4 ppm) were applied and replicated eight times. Both GA_3 (highest 3 concentrations) and CPPU treatments (highest 2 concentrations) significantly increased the total phenol content of the grapes after cold storage. Increased phenol content of 'Regal Seedless' was correlated with an increased astringent taste, with serious negative implications regarding consumer preferences and market access.

2.1.3.6 Total sugar

E1-Ghany *et al*. (2001) studied that in 'Thompson Seedless' grapes, GA_3 was applied as spraying to clusters of 5-7 cm length at 10 ppm and 30 ppm at one week after set increased the fruit set, decreased the acidity, increased the total sugar and reducing sugar content of grapes berries.Tambe *et al*. (2002) studied that the application of GA_3 in combination with Brassinosteroid (1 ml litre^{-1}) was found effective in increase in total sugar content of the berries. Masroor *et al.* (2005) found that Girdling in combination with bunch dipping of 40 ppm of GA_3 proved an effective increase in total sugar and the reducing and non reducing sugar content in 'Perlette' grapes. Gowda *et al.* (2006) recorded highest total sugar and reducing and non-reducing sugar contents in berries when compared to non-treated berries with 20 mg L^{-1} of GA_3 at pre-anthesis (45 days after October pruning) + 25 mg L^{-1} of GA_3 at pre-anthesis (50 days after October pruning) in 'Thompson Seedless' grapes.

Denis *et al.* (2010) recorded Highest total sugar content was recorded with 50 ppm GA_3 application at full bloom in 'Cardinal' and 'Michele Palieri.

Dimovska *et al.* (2011) found that among the different concentration of GA_3 (5, 10 and 20 mg L-1) applied during the three different periods of the vine growing (before blooming, after blooming and before veraison) in two different Seedless cultivars *viz.* Thompson and Belgrade, addition of gibberellic acid at concentration of 20 mg L-1 resulted in higher levels of sugar and total acids in the 'Thompson Seedless' grapes.

2.2 EFFECT OF DIFFERENT CHEMICALS ON FLOWER AND BERRY THINNING

2.2.1 Bunch characters

2.2.1.1 Total length of rachis

As indicated in the introduction section, Red Globe grapes sets excess berries after full bloom stage. If the all set fruits are carried till harvest, the cluster will be highly compact and each berry will not develop to its maximum size. For reducing berry set, one of the cheap and effective means is to use flower thinning chemicals as use of GA_3 for flower thinning in Red Globe is not recommended. In other temperate fruits like Apple Peach, Pear, Plum, Cherries etc. several flower thinning chemicals were tried and are found to be effective. However, in grapes not much work has been carried out in this direction. Hence, little literature on effect of other flower thinning chemicals has been narrated here. In this direction, Omari *et al*.(2016) found highest bunch length when 0.5 % $CuSO_4$ was used at 25 % cap fall stage for flower thinning in Flame Seedless, while in case of Sharad Seedless instant Coffee powder 3% produced significantly maximum bunch length (28.70 cm) than the rest of conventional thinning agents. In his study, Olive oil and Clove oil were found to be effective chemicals for flower thinning in both Flame and Sharad Seedless grapes.

2.2.1.2 Number of berries per bunch

The main aim of flower thinning is to reduce number of berries per bunch and thereby increasing berry size. In this direction, El-Boray *et al*. (2012) studied that all thinning treatments decreased fruit number per tree compared to the untreated control. The treatments were Soyabean oil at 6% and 9%; Ammonium thiosulphate (ATS) at 1.5 % & at 3 % , Hand Blossom Thinning (HBT) at 10 cm, 15 cm,20 cm & control (unthinned trees).The treatment that most significantly reduced fruit number per tree was HBT at 20 cm. Similarly, in another study, Abd-Allah *et al.* (2013) revealed that by spraying the extract at 0.25 or 0.50 % comparing with GA_3 at 5 ppm at full bloom. the effect of spraying lemongrass extract at 0.25 or 0.50 and GA_3 at full bloom on berry dimensions, weight and number of berries per cluster of 'Flame Seedless' grape during the two studied seasons. Generally, application of lemongrass extract at 0.25 &0.50 % had the same effect of GA_3 on reducing the number of berries per cluster. Alrashedi *et al*. (2016) studied that the treatment of 4 % Lime

Sulphur alone resulted in 50.72 % fruit retention and the same treatment in combination with olive oil reduced fruit retention to 42.13 %.

2.2.1.3 Bunch compactness

Abd-Allah *et al*. (2013) revealed that Lemongrass extract at 0.25 or 0.50 % comparing with GA_3 at 5 ppm at full bloom. the effect of spraying lemongrass extract at 0.25 or 0.50 and GA_3 at full bloom on berry dimensions, weight and number of berries per cluster of 'Flame Seedless' grape during the two studied seasons. Regarding cluster compactness, all treatments reduced bunch compactness than the control. This was noticed in both studied seasons. Results show that the reducing of cluster compactness was due to the effect of lemongrass in both concentrations as well as GA_3 on reduction number of berries per cluster. Generally, the application of lemongrass extract at 0.25 & 0.50 % had the same effect of GA_3 on reducing the cluster compactness but lemongrass extract at 0.50 % increased cluster weight than the control. Therefore, the lemongrass extract application at 0.50 % at full bloom is recommended.

2.2.1.4 Total cluster /bunch / bunch weight

Omari *et al.* (2016) studied that the spraying coffee powder, Olive oil and Clove oil 3 % at 50 and 100 % cap fall and $CuSO_4$ at 0.5 % and 0.7 % concentration at 25 % and 50 % cap fall had clear trend on increasing the yield and quality parameter. In Flame Seedless, the maximum bunch weight at 25 % cap fall were observed in $CuSO_4$ 0.5%, (367.22 g) as compared to standard GA (212.10 g). Similarly, in Sharad Seedless the maximum bunch weight was recorded in Coffee powder 2 % (379.38 g), the minimum number of bunch weight were observed in standard GA, (291.92 g). The maximum bunch weight at 50 % cap fall were observed in $CuSO_4$ 0.5 %, (420.15 g) compared to standard GA (279.72 g). In case of Sharad Seedless the maximum bunch weight were recorded in Olive oil 2% (426.49 g) the minimum number of bunch weight were observed in standard GA (304.98 g). The maximum bunch weights at 100 % cap fall were observed in Olive oil 3 % (506.19 g) as compared to standard GA (361.42 g). While in case of Sharad Seedless the maximum bunch weight were recorded in Olive oil 3 % (402.83 g) the minimum number of bunch weight were observed in standard GA, (299.29 g).

2.2.2 Berry Character

2.2.2.1 Average berry weight

El-Boray *et al*. (2012) studied the effect of different thinning techniques on fruit set, leaf area, yield and fruit quality parameters of *Prunus persica*, L.Batsch cv.Florida Prince. Hand Blossom Thinning @ 20 cm gives good fruit weight compared to unthinned control and other treatments, i.e. it resulted in 63.34 and 61.59 g during first and second season respectively.

Abd-Allah *et al.* (2013) found that Lemongrass extract of spraying the extract at 0.25 or 0.50 % comparing with GA_3 at 5 ppm at full bloom. The effect of spraying lemongrass extract at 0.25 or 0.50 % and GA_3 at full bloom on berry dimensions, weight and number of berries per cluster of 'Flame Seedless' grape during the two studied seasons. Weight which was higher with Lemon grass extract application at especially 0.50 % than the other treatments including the control fruit weight was least in the trees treated with the lowest concentration.

Chang *et al*. (2015) studied the cluster thinning effects on the fruit and wine quality of Doonuri Grape and they found that berry weight was larger when retaining a single cluster rather than 1.5 or 2 clusters per shoot.

Alrashedi *et al.* (2016) revealed that maximum fruit weight (0.14 kg) was observed in the fruits treated with 4 % Lime sulphur + Olive oil. The fruit weight as least in the trees treated with the lowest concentration (1 %) of Lime sulphur and control.

2.2.2.2 Berry Diameter

El-Boray *et al*. (2012) found that fruit diameter is more or high rate on ATS treated Peach trees, so yielded larger size fruit, diameter of fruit also more. Similarly, Organic agent like Lemongrass extract at 0.25 or 0.50 and GA_3 at full bloom stage sprayed and berry dimensions, weight and number of berries per cluster of 'Flame Seedless' grape during the two studied seasons. Lemongrass affected berry diameter in the second season only (Abd-Allah *et al.*, 2013).

Chang *et al*. (2015) observed that berry diameter was larger when retaining a single cluster rather than 1.5 or 2 cluster per shoot in Doonuri Grape.

Alrashedi *et al*. (2016) found that fruit size increased significantly with the higher concentrations (4 %) of Lime Sulphur alone (69.57 mm) and with Olive oil (68.58 mm) than all other treatments. The decrease in fruit diameter correlated well with the percent of LS in the spray, 4 % having the greatest diameter and 1 % less and control fruit was the smallest (57.70 mm).

2.2.2.3 Berry Length

El-Boray et *al*. (2012) found that fruit height highest in the very large in all the treatments compared to the control in Hand Blossom Thinning at 20 cm yielded the largest fruit length.

Chang *et al*. (2015) found that the berry length was larger when retaining a single cluster rather than 1.5 or 2 clusters per shoot in Doonuri Grape.

2.2.3 Observation on biochemical analysis

2.2.3.1Total soluble solids

El-Boray *et al*. (2012) revealed that the different thinning techniques increased soluble solid content of Florida Prince Peach fruit juice compared to the control during the two seasons. They found HBT at 20 cm presented the highest value of SSC %, it resulted in 12.07 and 10.74 %.

Chang *et al.* (2015) found that total soluble solids increased as cluster thinning declined. At harvested, the TSS of 1 or 2 clusters showed significant difference.

Alrashedi *et al*. (2016) found that TSS decreased along with the percentage of bloom thinning .TSS was highest (12.29) in control fruit while the fruit harvested from the trees treated with the combination of 4 % Lime Sulphur and Olive oil showed the lowest (10.84) SSC.

Omari *et al*. (2016) found that the minimum TSS at 25 % (18.39 °brix) 50 % (16.59 °brix) and (16.62 °brix) 100 % cap fall were noticed in $CuSO_4$ 0.7 % and maximum were recorded in (22.38 %) ,Coffee powder 3 % and (23.15 %) Olive oil in Flame Seedless while in case of Sharad Seedless minimum TSS recorded in standard GA and maximum TSS noticed in at 25 % cap fall stage in T_3 (23.00 %) Clove oil 50 % cap fall (22.85 %), Coffee powder 3 % at 100 % cap fall respectively.

2.2.3.2 Titratable acidity

El-Boray *et al*. (2012) revealed that the different thinning technique decreased the titrable acidity of Florida Prince Peach fruit juice compared to the control. Lowest in the treatment ATS at 3 % resulted 0.7 % and 0.69 %.

Chang *et al*. (2015) they found that titrable acidity was more in 1 and 2 clusters showed significant differences in 'Doonuri' Grape.

Alrashedi *et al*. (2016) found that all the treatments reduced titratable acidity in the juice compared to the control. When the trees were sprayed with the combination of LS and Olive oil, the harvested fruit had a lower level of acidity compared to control as did the fruit from trees sprayed with only LS. The acidity differed significantly between both cultivars.

Omari *et al*. (2016) found that the minimum acidity at 25 % (0.33 %), 50 % (0.35 %) and 100 % (0.31 %) cap fall were noticed in (T_9) Coffee powder 3 % while regard to (T_6) Olive oil 3 % maximum acidity were recorded in (T_{12}) $CuSO_4$ 0.7 % (T_1 and T_{13}) respectively. While in case of Sharad Seedless minimum acidity recorded in T_6 (0.35 %) and T_3 (0.37 %) Clove oil 3 % and maximum acidity noticed at 25 %, 50 % and 100 % cap fall in (T_{13}) standard GA.

2.2.3.3 Sugar acid ratio

El.Boray *et al*. (2012) revealed that the different thinning technique increased SSC/acid ratio content (17 and 15.17) during the two seasons of Florida Prince Peach fruit juice compared to control. They found that ATS at 3 % HBT at 20 cm presented the highest value SSC/ acid ratio.

Alrashedi *et al*. (2016) studied that the effects of spraying Lime Sulphur (LS) alone and in combination with organic olive oil on blossom thinning, fruit retention, size and quality in organically grown apples. They found that SSC/TA ratio was higher in the fruit harvested from trees treated with the combination of lime sulphur and Olive oil compared to control and treatment of Lime Sulphur alone.

Omari *et al*. (2016) found that the significantly minimum TSS: acid ratio at 25 %, 50 % and 100 % cap fall was noticed in (T_{12}) $CuSO_4$ 0.7 % and (T_{13}) standard GA, maximum TSS: acid ratios were recorded in (T_9) Coffee powder (68.63 %), (61.20 %) and (75.40 %) T_6 Olive oil 3 % respectively. While in case of Sharad

Seedless minimum TSS: acid ratio recorded in (T_{13}) standard GA and maximum TSS: acid ratio noticed at 25 %, 50 % and 100 % cap fall in T_6 Olive oil 3 % (65.00 %) T_3 Clove oil 3 % (62.20 %) and T_9 Coffee powder 3 % (68.34 %) respectively.

2.2.3.4 Anthocyanin concentration

Chang *et al*. (2015) studied the cluster thinning effects on the fruit and wine quality of Doonuri Grape & they observed cluster thinning increased, total anthocyanin contents increased with early maturity when retaining 1 and 1.5 clusters per shoot, values were higher than with 2 clusters. Total anthocyanin content increased quickly during ripening of a single cluster.

2.2.3.5 Total phenols

Chang *et al*. (2015) studied that cluster thinning effects on the fruit and wine quality of Doonuri Grape and they observed that total polyphenol content increased with early maturity. Total polyphenol content showed significant differences by treatment after verasion and when retaining 1 and 1.5 clusters per shoot, values were higher than with 2 clusters.

2.2.3.6 Total sugars

El-Boray *et al*. (2012) revealed that the different thinning technique increased total sugars content (8.37 and 8.33 microgram m/L) in treatment ATS at 3% presented the highly significant effect when compared to other treatments.

Chapter III

Material and Methods

Chapter III

MATERIAL AND METHODS

The present investigation on **"Standardization of growth regulators for rachis elongation in Crimson Seedless and berry/flower thinning in Red Globe grapes (*Vitis vinfera* L)"** was undertaken at the experimental vineyard of ICAR - Indian Institute of Horticultural Research (ICAR - IIHR) located at Hessaraghatta, Bengaluru during the year 2016 - 2017. The material and methods adopted during the investigation are described here.

3.1 EXPERIMENTAL SITE

The experimental station at Hessaraghatta has a mild tropical climate. It is situated at an elevation of 890 meters above sea level, 12^0 68' North latitude and $77^0$38' East latitude. Soil nutrient status of the experimental field had the following nutrients as given in Appendix –II.

3.2 WEATHER CONDITIONS

The average rainfall of the area is about 850 mm. The minimum temperature at the experimental site ranged from 11^0C to 28 ^{0}C and maximum temperature ranges from 20.2^0C to 35^0C. Relative humidity ranges from 26 to 80 per cent. The soil is red sandy loam with a pH of 7.2. The meteorological data recorded during the period of research is given in Appendix -I.

3.3 SELECTION OF THE VINEYARD

Four year old vines of cv. Crimson Seedless and Red Globe (*Vitis vinifera* L.), grafted on Dogridge rootstock and trained on to the 'Y' trellis were utilized for imposition of treatments in the experiment. The spacing followed was 3.3 m × 2.0 m. Uniform cultural practices were followed for all the vines, which included manuring, fertilizer application, irrigation through drip system, the vines were kept free from weeds, disease and pests by adopting appropriate plant protection measure.

3.4 METHOD OF PRUNING

The method of pruning consisted of removal of not only the past season shoots at the level indicated but also the removal of unwanted old woods and dead

shoots during pruning. Grape vines in this region grow continuously without any dormancy. Hence, pruning is done twice in a year. The summer pruning is popularly called as back or foundation pruning, which is done normally during the month of April after harvest of previous year crop. The entire shoots are pruned leaving just basal two buds near the cordon. While, the winter pruning is called as forward or fruit pruning usually done in the month of September to October. In this pruning, the canes are pruned depending on the position of fruitful buds. In the present study, the shoots having sub-cane, were pruned just leaving two buds above the knot, while in straight canes, they were pruned at 5-6th nodes.

3.4.1 Time of pruning

3.4.1.1 Summer pruning

In preparation for the various sub cane treatments the vines were back pruned on April 2016. In this pruning, the canes were cut back to one or two bud levels to check the excessive shoot growth and to encourage the fresh vegetative growth. Two sprays of cycocel (CCC) were given to the foliage at a concentration of 1000 ppm at 10 days interval at about 45 days after the back pruning. This practice not only helps in arresting the shoot growth, but also helps in better fruit bud differentiation. Uracil at a concentration of 50 ppm was also sprayed on shoots at 45 days after pruning. This chemical even though a herbicide, at lower concentration is found to increase the RNA/DNA ratio which favors better fruit bud differentiation.

3.4.1.2 Development of sub canes

Vigorously growing shoots after summer pruning (30-35 days) were pinched or halted at various bud levels on the straight canes to encourage secondary shoots. As a result of pinching one or two buds below, start growing laterally. These lateral shoots are referred to as sub canes on attaining maturity. The practice of sub cane development reduces the problem of apical dominance to a large extent and fertility of the buds is restricted to the middle portion of the cane. The sub cane development was checked uniformly by halting growing tip after 8 leaves, from the point of sub cane emergence. Some of the canes which are slender or weak were not subjected to sub cane development and they are referred as straight canes.

3.4.1.3 Winter pruning

This pruning is also referred to as forward pruning was carried out on 5thOctober 2016. In this pruning matured sub canes (5 to 6 month old) were pruned to 2 - bud levels uniformly and straight canes were pruned at 6 to 8 – bud levels. Poor bud burst is a problem after winter pruning in Seedless cultivars. Bud burst was improved by swabbing 1.5% per cent Dormex (Hydrogen Cyanamide) to the apical buds on the sub canes with cotton swab. The top 2 to 3 terminal buds on the cane or sub cane were smeared.

3.5 HARVESTING

The fruits were harvested after full ripe stage, the labeled bunches were harvested separately and used for taking physical observation. Further, the same samples were used for the estimation of chemical parameters such as juice content, total soluble solids, titratable acidity, TSS: acid ratio, Anthocyanin concentration, Total phenols and total sugars.

3.6 EXPERIMENTAL DETAILS

The field experiment was laid out in Randomized Block Design (RBD) in both Crimson Seedless and Red Globe variety after vines were subjected to forward pruning during October 2016. General view of experimental vineyard is depicted in plate 3.1.

Plate 3. 1 .General view of experimental vineyard Crimson Seedless and Red globe ICAR -IIHR,Bangalore during year 2016 and 2017

EXPERIMENT NO. 1

3.6.1 Evaluation of different concentration of GA_3 for rachis elongation in crimson seedless grape

Location	:	Block I, ICAR-IIHR, Bengaluru
Crop	:	Grape
Variety	:	Crimson Seedless
Statistical Design	:	Randomized Block Design (RBD)
Number of Treatments	:	4
Number of Replication	:	7

3.6.1.1 Treatment details

T_1: GA_3 @5 ppm
T_2 : GA_3@7.5 ppm
T_3: GA_3 @ 10 ppm
T_4: Control

3.6.1.2 Method of GA_3 preparation

Analytical grade GA_3 was used for preparation of stock solution. Stock solution of 1000 ppm of GA_3 was prepared by dissolving in absolute alcohol and desired concentration of GA_3 as per the treatments was prepared by diluting the stock solution.

3.6.1.3 Time and method of GA_3 application

After forward pruning of vines, when the panicles started emerging (about 25-30 days after pruning) and were at parrot green stage, the different GA_3 treatments were imposed by spraying.

EXPERIMENT NO. 2

3.6.2 Evaluation of different Chemicals for flower and berry thinning in Red Globe grapes

Location of work	:	Block I,ICAR-IIHR , Bengaluru
Crop	:	Grape
Variety	:	Red Globe
Statistical Design	:	Randomized Block Design (RBD)
Number of Treatment	:	7
Number of Replication	:	4

3.6.2.1 Treatment details:

T_1: Olive oil 0.5 % at 50 % bloom

T_2: Caffeine at 0.3 % at 50 % bloom

T_3: Hydrogen cyanamide-0.1% at 50 % bloom

T_4: Dinitro-Ortho-Cresol(DNOC) -0.1 % at 50 % bloom stage

T_5: $CuSo_4$– 0.5 % at 50 % bloom

T_6: Manual thinning at 8 mm berry stage

T_7: Untreated Control

3.6.2.2 Preparation of stock solution

Preparation of Olive oil 0.5 % , Caffeine at 0.3 % , Hydrogen cyanamide-0.1% , Dinitro-Ortho-Cresol(DNOC) -0.1% and $CuSO_4$ 0.5 % treatment wise, stock solutions were prepared in a little quantity of water and volume was made up to one liter by adding distilled water and working solution of respective treatment was prepared just before application.

3.6.2.3 Method of application

After forward pruning of vines, at about 40-45 days after pruning when the vines attained full bloom stage, the above mentioned treatments were sprayed to clusters thoroughly (for treatments T_1 to T_5). However, for the manual thinning, the berries were thinned out using scissors when they were 8 mm or commonly termed as pea stage. In T_7 treatment the clusters were neither chemically treated nor manually thinned and maintained as control.

3.7 OBSERVATIONS RECORDED

Following observation on bunch and berry characters and quality parameters were recorded on each treatment in both the experiments.

3.7.1 Bunch character

During harvest, representative bunches were randomly selected from each replication (Seven and five bunches respectively in experiment 1 and 2) and the following observations were recorded.

3.7.1.1 Total length of Rachis (cm)

The berries were separated from the sampled bunches and after separation the length was measured with the help of flexible measuring tape and average length of rachis was worked out and expressed in centimeters.

3.7.1.2 Number of berries per bunch

The number of berries per bunch was recorded by counting the total number of berries in each of the randomly selected bunches and the average number of berries was computed.

3.7.1.3 Bunch compactness (Berries/cm)

Bunch compactness was calculated by dividing number of berries in a bunch by total rachis length. Higher the number of berries, greater the compactness and vice versa.

$$\text{Bunch Compactness} = \frac{\text{Number of berries per bunch}}{\text{Total length of rachis}}$$

3.7.1.4 Total cluster /bunch weight (g)

Harvested bunches from the tagged vines were weighed and computed for mean bunch weight and expressed in grams.

3.7.1.5 Bunch volume (cm^3)

The volume of the sampled bunches per replication per treatment was determined by water displacement method and expressed in cubic centimeters. The average volume of the bunch was worked out.

3.7.2 Berry character

3.7.2.1 Average berry weight (g)

From the selected bunches, fifty berries per replication were sampled and berry weight was taken by using top loading electronic balance and average berry weight was computed and expressed in grams.

3.7.2.2 Berry Diameter (cm)

Randomly selected ten berries in each replication were used for measuring the diameter by using measuring scale. Average berry diameter of ten berries was calculated and expressed in centimeters.

3.7.2.3 Berry Length (cm)

Randomly selected ten berries in each replication were used for measuring the length by using measuring scale. Average berry length of ten berries was calculated and expressed in centimeters.

3.7.3 Observation on biochemical analysis

3.7.3.1 Total soluble solids (°Brix)

Treatment wise sampled berries were crushed and juice was extracted with the help of muslin cloth. The total soluble solids content of the extracted juice was determined by using digital refractometer (^{0}Brix) and expressed as ^{0}Brix.

3.7.3.2 Titratable acidity (%)

Titratable acidity was determined by titration method (AOAC, 2000) and expressed as percentage of citric acid equivalents. Ten milliliters of sample was mixed with distilled water and filtered using Whatman filter paper-1and volume was made up to 100 ml. Suitable quantity (10 ml) of this aliquot was taken in conical flask and few

drops of Phenolphthalein indicator (Phenolphthalein indicator- 0.5 % in 80 % ethanol) was added and shaken well. Burette was filled with 0.1 N NaOH solution after washing and rinsing. Titration was done and end point was determined by appearance of pink colour and its persistence for at least for few seconds.

$$\text{Acidity(\%)} = \frac{\text{Titre value} \times \text{normality} \times \text{eq.wt of acid} \times \text{volume made up}}{\text{Assay volume} \times \text{Wt. of the sample (g)} \times 1000} \times 100$$

3.7.3.3 Sugar acid ratio It was calculated by dividing the total soluble solids content of the juice in a particular treatment by corresponding titrable acid content. It means that dividing TSS (^{0}Brix) by acidity per cent.

3.7.3.4 Anthocyanin concentration (mg / g)

Anthocyanin concentration was estimated by the Fuleki, (1969) and expressed in g $100g^{-1}$FW.

Procedure

One gram peel was homogenized with Acidic Methanol and allowed to stand for 72 h. The homogenate was filtered and re-extracted the residue for 2-3 times. Extracts were pooled and the volume was made up to 25 ml with AM. Whenever necessary the extract was further diluted with Acidic Methanol. The colour intensity was measured at 540 nm using UV-vis Spectrophotometer by adjusting 100% transmission against Acidic Methanol. Quantity of anthocyanin in the sample was calculated using cyanidin hydrochloride as standard and expressed as mg/100g fresh weight.

$$\text{Anthocyanins (mg/100g)} = \frac{OD_{540} \times \text{Standard value} \times \text{total volume} \times 100}{\text{Weight of sample (g)} \times 1000}$$

3.7.3.5 Total phenols (mg / g)

Total phenol content was estimated by spectrophotometric method using Folin Ciocalteu Reagent (FCR) as suggested by Singleton *et al.* (1965).

Procedure

About 0.5g of pulp was incubated in 20ml of methanol (80%) for 72hrs. Then it was homogenized with 20 ml of methanol (80%) in a pestle and mortar 2-3 times. The extracts were pooled and the volume was made up to 20 ml. About 0.5 ml of the extract was taken in test tubes and 2ml of Folin-Ciocalteau's Phenol Reagent was added followed by 3.3 ml of distilled water and mixed well. After 2 min, 1ml of sodium carbonate solution was added and mixed well. The reaction mixture was allowed to stand at room temperature for 30 minutes and the blue color intensity was read in a spectrophotometer at 700nm. A standard curve was prepared using gallic acid as standard. Total phenol content was expressed as mg gallic acid equivalents/100g using the formula.

$$\text{Total phenols} = \frac{OD_{700nm} \times \text{Std. value } (\mu g/OD) \times \text{Total Vol. of extract} \times 100}{\text{Assay volume} \times \text{Wt. of tissue (g)} \times 1000}$$

3.7.3.6 Total sugar (%)

Total sugars were estimated by the method of Somgyi (1952) and expressed in g $100g^{-1}$FW. Five ml of juice extract was utilized for estimation of sugars. Separated 5 ml sample for total sugars was taken and pipetted out aliquots of 0.1 or 0.2 ml and added 0.5 ml of concentrated HCl to the sample kept it overnight. Next day neutralized it by adding 2-3 drops of phenolphthalein indicator and 40% NaOH until it turns to pink colour. Then the volume was made up to 10 ml with distilled water. Pipette out aliquots of 0.1 ml to test tubes and added 0.9 ml water. Then 1ml of alkaline copper tartrate reagent was added to each tube and the tubes are placed in boiling water for 10 minutes. The tubes are cooled and added 1 ml of arsenomolybolic acid reagent to all the tubes. The volume was made in each tube to 10 ml with water. Read the absorbance of blue colour at 620 nm after 10 min. From the graph drawn, amount of total sugars present in the sample was calculated.

Total Sugars (g/100g) =

$$\left\{ \frac{OD_{620nm} \times \text{Std. value } (\mu g/OD) \times \text{Total volume} \quad \text{x Total Vol. of extract} \times 100}{\text{Assay volume x Sample taken for drying x Weight of the sample (g)} \times 1000} \right\} \text{ x } 2$$

3.8 STATISTICAL ANALYSIS

Data obtained from the experiment was subjected to statistical analysis by using Completely Randomized Design and Factorial Completely Randomized Block Design (Panse and Sukhatme, 1985). The F- test values were tested at 5 per cent level of significance.

Chapter IV

Results and Discussion

Chapter IV

RESULTS AND DISCUSSION

The present study titled **"Standardization of growth regulators for rachis elongation in Crimson Seedless and berry/flower thinning in Red Globe grapes (*Vitis vinfera* L.)"** was conducted at the experimental vineyard of the ICAR - Indian Institute of Horticultural Research (ICAR - IIHR) located at Hessaraghatta, Bengaluru during the years 2016 and 2017. The results obtained are presented in this chapter under appropriate headings and subheadings with tables.

4.1 EFFECT OF GA_3 FOR RACHIS ELONGATION IN CRIMSON SEEDLESS GRAPE

4.1.1 Bunch characters

4.1.1.1 Total length of Rachis (cm)

Significant differences among the treatments were recorded for rachis length and are presented in Table 4.1. The bunches treated with GA_3 @ 5 ppm *i.e.* T_1 recorded maximum total rachis length of 124.90 cm (plate 4.3) followed by those treated with GA_3 @ 7.5 ppm which recorded rachis length of 89.53 cm. The minimum length of the rachis (55.69 cm) was recorded in untreated control (T_4).

The primary goal to produce loose bunches is to elongate rachis by use of chemicals. GA_3 may be applied to seedless table grapes several weeks before flowering (bloom) to elongate the rachis, or the main bunch stem. Application of GA_3 after 48 hours depicted in plate 4.1. The application is commonly made when average cluster length is about 100-150 mm and is most commonly performed on 'Thompson Seedless' (Sultana). However, studies have reported that while these treatments may initially accelerate rachis growth, there were no significant improvements on bunch length compared to untreated fruit by harvest time. In contrast, some workers have reported that pre-bloom GA_3 applications have detrimental effect on vine fruitfulness, reducing both cluster size and number during the following season and are generally not recommended for this purpose. Increase in cluster length could be mainly due to increase in the length of rachis cell promoted

by Gibberellin. The effect of gibberellins on rachis length was reported earlier by Morris *et al*. (1987); Taleb *et al.* (2010) and Dimovska *et al.* (2014). In the present study, increased concentration of GA_3 though could elongate the rachis length; it had adverse effect on overall appearance of bunch in the form of coiling of rachis (Plate.4.2). The very mild dose of GA_3 at 5 ppm could produce good quality bunches with optimum increase in rachis length at the time of harvest.

4.1.1.2 Number of berries per bunch

Observations on number of berries per bunch are presented in Table 4.2. Statistically non significant differences among the treatments were recorded. T_4 (control) recorded the maximum number of berries per bunch (140.71) among the all treatments while where GA_3 @ 5 ppm (T_1) application recorded the least number of berries per bunch (102.43). The export of table grapes to European Union demands rigid standards, the approximate number of berries per bunch fixed is in the range of 90-110 which weighs about 400-450 g. So, in the present investigation, treating the panicles with 5 ppm GA_3 could elongate the rachis effectively and reduce berry number which could accommodate about 102 berries which are ideal for marketing purpose.

In addition to rachis elongation, GA_3 can also bring about flower thinning by several mechanisms. The first hypothesis states that GA_3 acts as a pollenicide, or that it interferes with pollen germination or pollen tube growth. This hypothesis says that GA_3 reduces pollen viability in both seeded and seedless varieties. The second hypothesis is based on relative concentrations of GA_3 to other plant hormones such as cytokinins and auxins. Some researchers have proposed that GA_3 applied at bloom alters the balance of hormones in the berry, causing flower abscission to occur. Supporters of this hypothesis state that elevated levels of GA_3 promote thinning while cytokinins promote fruit set. The final hypothesis suggests that GA_3 encourages nutrient or carbohydrate competition between flowers and shoots, or

Table 4.1 Effect of different concentrations of GA_3 on total length of Rachis in Grape cv.Crimson Seedless.

Treatments	Total length of Rachis (cm)
T_1:GA_3 @ 5 ppm	124.91
T_2:GA_3@ 7.5 ppm	89.53
T_3:GA_3 @ 10 ppm	83.91
T_4:Control	55.69
SE(m)±	9.88
CD(P=0.05)	29.57

Table 4.2 Effect of different concentrations of GA_3 on number of berries per bunch in Grape cv. Crimson Seedless.

Treatments	Number of berries per bunch
T_1:GA_3 @5 ppm	102.43
T_2:GA_3 @7.5 ppm	110.43
T_3:GA_3 @ 10 ppm	119.14
T_4:Control	140.71
SE(m)±	10.52
CD(P=0.05)	NS

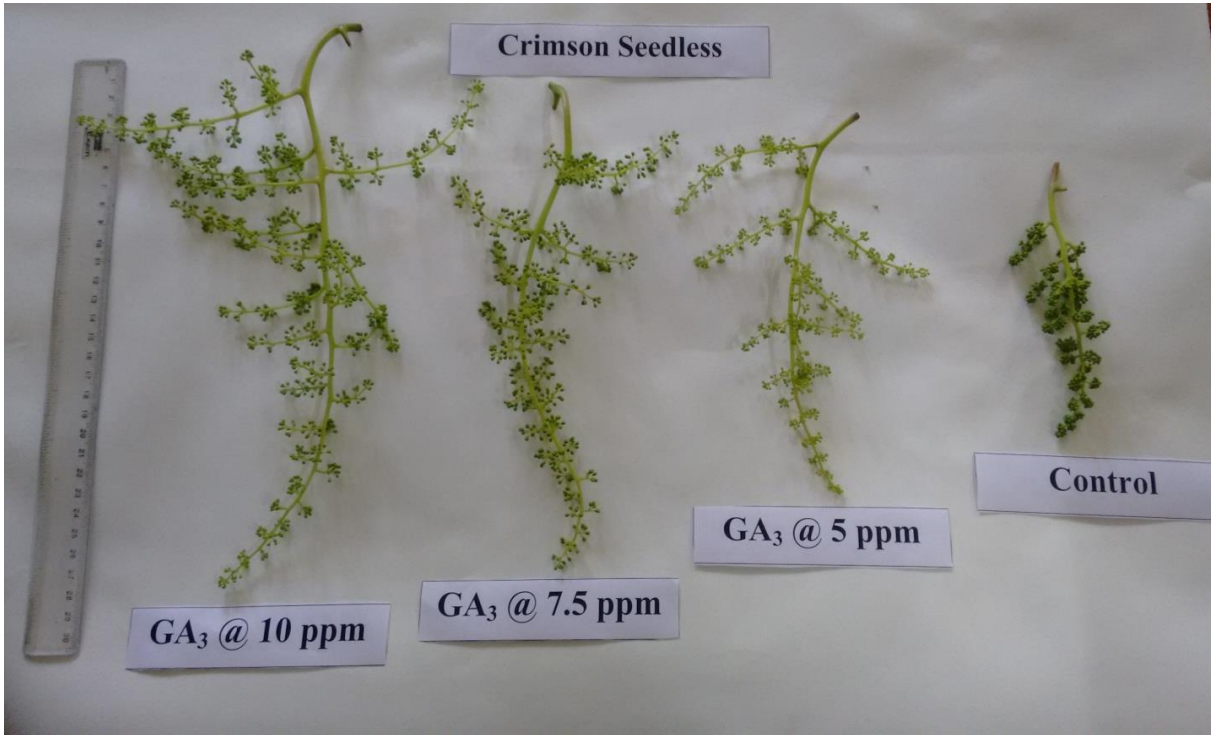

Plate 4.1 Rachis elongation after 48 hours of GA_3 application

Plate 4.2 Rachis elongation at fruit set stage (10 days after spraying of GA_3)

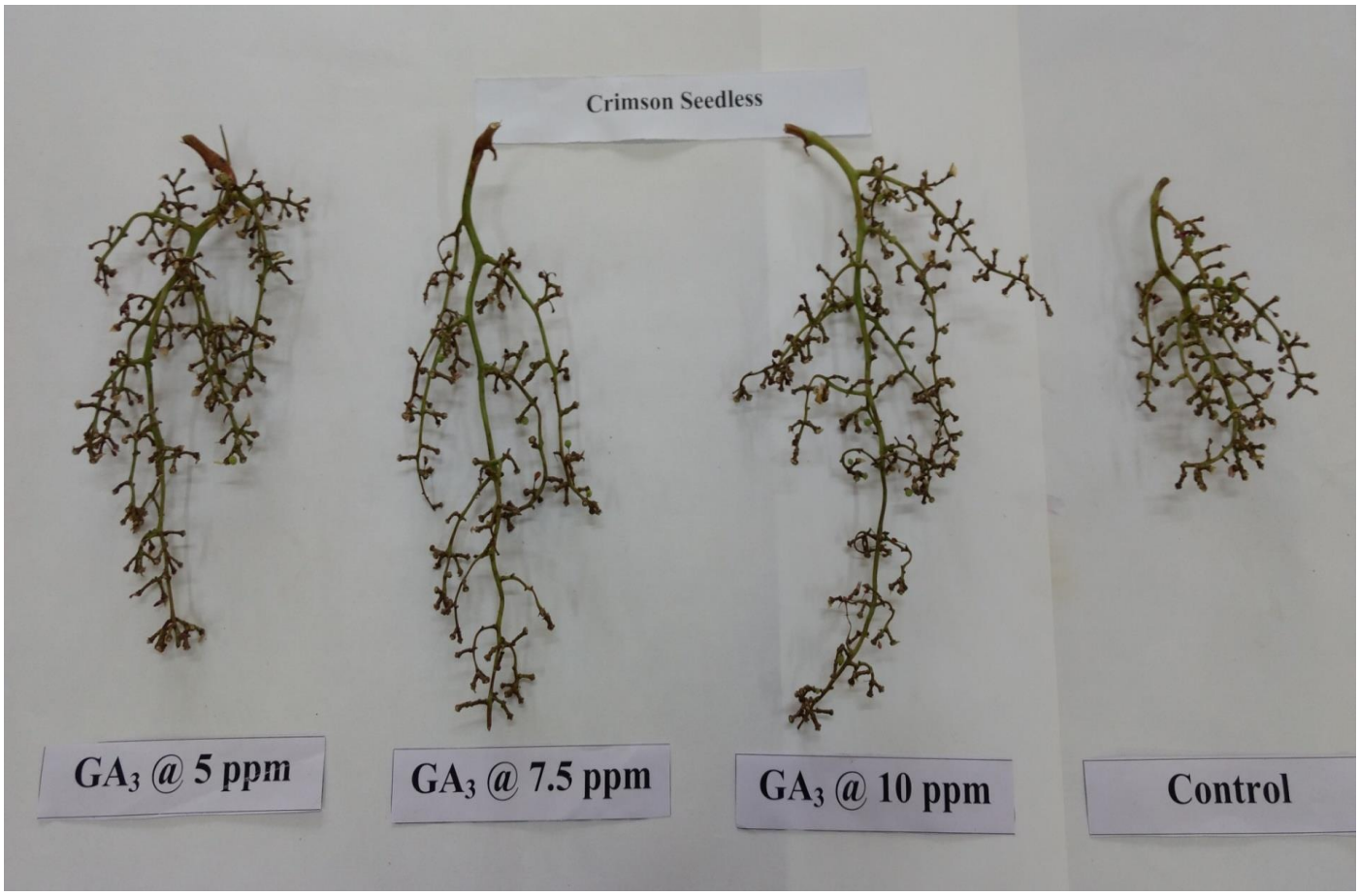

Plate 4.3 Effect of different concentration of GA_3 on Rachis length in Crimson Seedless

among individual flowers in a cluster. One version of this hypothesis is that GA_3 stimulates shoot growth, thereby diverting nutrients away from developing berries. Another version states that GA_3 stimulates nutrient competition between berries within a cluster by promoting rapid cell division and expansion at berry set. Thus, the larger berries become stronger competitors for nutrients and carbohydrates and the smaller, weaker berries fall off because they cannot effectively compete. Similar effect of Gibberllin on number of berries was reported by earlier workers (Morris, 1987; Taleb, 2010 and Taleb and Salameh, 2012).

GA_3 is applied to most seedless table grape varieties and application reduce the berry set from 10% to 30% which allow fruit sizing manipulations to be performed without resulting in bunches that are too tight. The primary factor impacting the effectiveness of GA_3 berry thinning application is the climate during and immediately after bloom. Hot (>32°C), dry conditions favour maximum berry thinning, while cool (<24°C), wet conditions reduce treatment effectiveness. The relative vegetative vigour of vines may also influence the thinning response. High vigour vines favour maximum berry thinning (due to rootstock choice, N-fertilisation or irrigation) and low vigour vines generally have tighter bunches and requires slightly higher rates of GA_3 to reduce bunch compactness.

GA_3 berry thinning applications are often made once or twice during the bloom period, depending on variety and location. Most studies indicate that single and multiple applications result in similar levels of thinning, but multiple applications commonly produce larger, longer berries at harvest due to their effects on berry cell division and elongation. The first application is typically applied near 50% cap fall and the second near 85% cap fall. Flowering (bloom) stage is determined by visually estimating the percentage of all exposed/open flower bud.

4.1.1.3 Bunch compactness (Berries / cm)

Observations on bunch compactness are presented in Table 4.3. Statistically significant differences among the treatments were recorded. Treatment T_1 *i.e.* GA_3 at 5ppm recorded the less bunch compactness (0.94 berries/ cm of rachis length) among all the treatments while, T_4 where no GA_3 application was attempted recorded the more

bunch compactness (2.59 berries / cm of rachis length) resulting in very tight clusters. Though GA_3 @ 7.5 and 10.00 ppm could produce loose clusters, their bunch shape was not desirable due to severe coiling of rachis.

GA_3 is commonly used to reduce fruit set of certain seedless table grapes. GA_3-mediated berry thinning on seedless cultivars Similar result was obtained by Emad Abd El-Razek *et al*. (2015) Concerning the cluster compactness, result show that the control has excessive compact cluster (12.9 and 13.26 berries/cm in both seasons) compared with all treatment that have 8.31 to 9.09 and 8.29 to 9.13 berries/cm in both years which is in accordance with present study. In the present study, negative correlation of (r= -0.743) was recorded between rachis length and bunch compactness (Fig.1).

4.1.1.4 Total cluster /bunch/Average bunch weight (g)

Observations on bunch weight are presented in Table 4.4. Statistically non significant differences among the treatments were recorded. Treatment T_1 (GA_3 @ 5 ppm) recorded the maximum bunch weight (507.49 g) among all treatment, T_4 where no GA_3 application was attempted recorded the least bunch weight (442.54 g). Effect of GA3 concentration on bunch weight is illustrated in plate 4.4.

The increase in the berry weight was believed to be mainly due to cell division in the initial stages and later due to faster cell expansion associated with the influx of metabolites and water into the berry. Sachs and Weaver (1968) also opined that, the berry development in 'Thompson Seedless' grape is a "hormonal directed transport of metabolites". Kashyap *et al.* (1989) have reported increase in berry weight by using GA_3 in the 'Thompson Seedless' variety. The increase in berry size can be a major factor contributing to the bunch weight. Similar results have been reported by Pires *et al*. (2000), Navarro *et al*. (2001), Kushal and Sandhu (1987) in Perlette grapes, Anitha (1993) in Anab-e-Shahi and Dilkush, Masroor Ahmad *et al.* (2005) in Perlette grapes and Mohamed Farooq *et al.* (2001) in Arkavati grapes. The effect of gibberellins on bunch weight was also reported by Taleb (2010), Meena *et al*. (2012) and Dimovska *et al.* (2014). The non significant difference could be due to equal increase in the berry size / bunch size due to effect of GA_3 on cell elongation and nutrient diversion from source compared to untreated control.

4.1.1.5 Bunch volume (cm^3)

Observations on bunch volume are presented in Table 4.5. Significant differences among the treatments were recorded. Among all treatments bunches treated with GA_3 @ 5 ppm (T_1) (1763.43 cm^3) registered maximum bunch volume followed by untreated control (T_4) (1733.57 cm^3). The least bunch volume was recorded in bunches treated with GA_3 @ 10 ppm T_3 (1590.43 cm^3). GA_3 significantly increased fruit volume and fresh flesh weight in both cultivars Perlette and Yaghuti with 50 ppm GA_3 applied at berry set stage and when berries were 4 mm in length Zahedi *et al*. (2013). Though bunch volume cannot be directly influenced by GA_3 application, the weight of berries and berry diameters indirectly contributed for this parameter.

4.1.2 Berry characters

4.1.2.1 Average berry weight (g)

Observations on average berry weight are presented in Table 4.6. Significant differences among the treatments were recorded. Among all treatments bunches treated with GA_3 @ 5 ppm (T_1) (4.93 g) registered maximum average berry weight followed by GA_3 @ 7.5ppm T_2 (4.85 g). The least average berry weight was recorded in bunches untreated control T_4 (3.99 g). A negative correlation was recorded (r= -0.489) between average berry weight and number of berries per bunch, which is evident in T_4 that in spite of more number of berries, the average berry weight was least (Fig.2).

The berry weight enhancing effect of the growth regulators proved to be very striking. The increase in berry weight was mainly due to the cell division at initial stages and later due to faster expansion of cells associated with the influx of metabolites and water into the berry which caused in the overall increase in berry weight. Lakshmanan *et al.* (1992) also reported that, the berry development in Thompson Seedless grapes might be due to the role of hormones which mobilize elaborated food material, increase in water uptake, solute storage and synthesis of cell components. Water influx contributes towards the berry weight and it is possibly under an indirect hormonal control because of the promotional effect of auxin, cytokinin and GA. The increased berry weight in T_1 treatment may be directly

Table 4.3 Effect of different concentrations of GA_3 on bunch compactness in Grape cv. Crimson Seedless.

Treatments	Bunch compactness
T_1:GA_3 @ 5ppm	0.94
T_2:GA_3 @7.5 ppm	1.27
T_3:GA_3 @ 10 ppm	1.43
T_4:Control	2.59
SE(m)±	0.18
CD(P=0.05)	0.54

Table 4.4 Effect of different concentrations of GA_3 on bunch weight in Grape cv. Crimson Seedless.

Treatments	Bunch weight(g)
T_1:GA_3 @5 ppm	507.49
T_2:GA_3 @7.5 ppm	482.03
T_3:GA_3 @ 10 ppm	499.59
T_4:Control	442.54
SE(m)±	37.25
CD(P=0.05)	NS

Plate 4.4 Effect of different concentration of GA_3 on bunch in cv. Crimson Seedless.

Table 4.5 Effect of different concentrations of GA_3 on bunch volume in Grape cv. Crimson Seedless.

Treatments	**Bunch volume (cm^3)**
T_1:GA_3 @ 5ppm	1763.43
T_2:GA_3 @7.5 ppm	1631.429
T_3:GA_3 @ 10 ppm	1590.429
T_4:Control	1733.571
SE(m)±	30.984
CD (P=0.05)	92.770

influenced by very significant rachis elongation in this treatment which must have facilitated good growth of individual berries in the bunch.

4.1.2.2 Berry Diameter (cm)

An observation on berry diameter is presented in Table 4.6. Statistically non significant differences among the treatments, bunches treated with GA_3 @ 7.5 ppm (T_2) recorded the highest berry diameter (1.75 cm) among the all treatments T_4, where untreated control was recorded the least berry diameter (1.69 cm).

The increase in berry diameter can be the result of radial expansion of cells in addition to longitudinal increase. The effect of Gibberellin on berry diameter was supported by many earlier findings (Morris, 1987; Gowda *et al.,* 2006; Taleb, 2010 and Dimovska *et al.,* 2014). In cultivation of seedless varieties GA_3 is routinely employed to improve the berry size, but at a higher concentration (100 ppm) the response of the seeded Red Globe variety to exogenous application of GA_3 illustrates that endogenous GA_3 levels in the seed were not fully sufficient to achieve the maximal physiological efficiency.

4.1.2.3 Berry Length (cm)

Significant differences among the treatments were recorded for berry length which is presented in Table 4.6. The bunch treated with GA_3 @ 5 ppm (T_1) were showing highest berry length (2.59 cm) followed by T_2 GA_3 @ 7.5 ppm (2.54 cm), they were significantly superior to the rest of all treatments. The minimum length of the berry (2.276 cm) was recorded in T_4 untreated control. Though the treatment T_3 (10 ppm) which is very lower concentration for rachis elongation for other seedless grapes, for the variety Crimson Seedless it is super optimal and thus the berry length might have not elongated as it did in T_2 and T_3 treatments where lesser concentration was used.

Tomar *et al.* (1999) reported that application of GA_3 significantly increased the berry length in Thompson Seedless, mainly due to its effect on distal than proximal parenchymatous tissues of berry. The findings on improvement of berry size in the present study are in close conformity with earlier reports (Patil *et al*.,

Table 4.6 Effect of different concentrations of GA_3 on berry characters in Grape cv. Crimson Seedless

Treatments	**Average berry weight(g)**	**Berry Diameter(cm)**	**Berry Length(cm)**
T_1:GA_3@5ppm	4.93	1.73	2.59
T_2:GA_3@7.5ppm	4.85	1.75	2.54
T_3:GA_3 @ 10ppm	4.67	1.75	2.46
T_4:Control	3.99	1.69	2.28
SE(m)±	0.18	0.03	0.05
CD (P=0.05)	0.53	NS	0.14

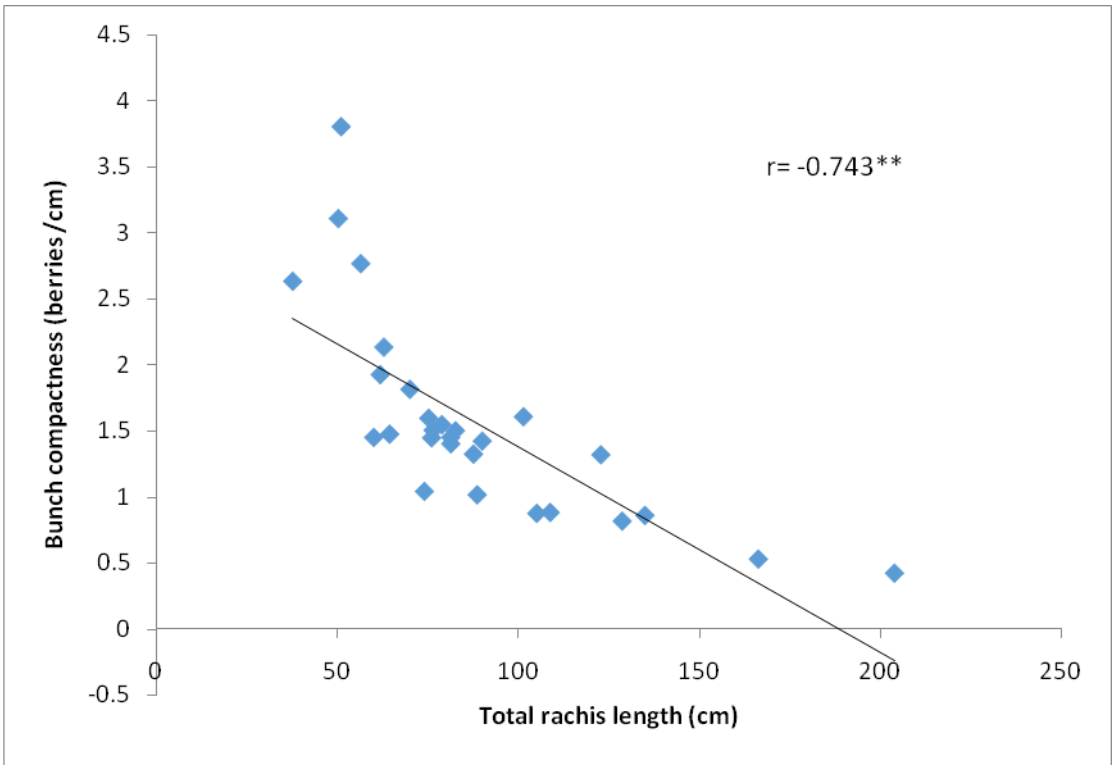

Fig 4.1 Correlation between total rachis length and bunch compactness in Crimson Seedless grapes

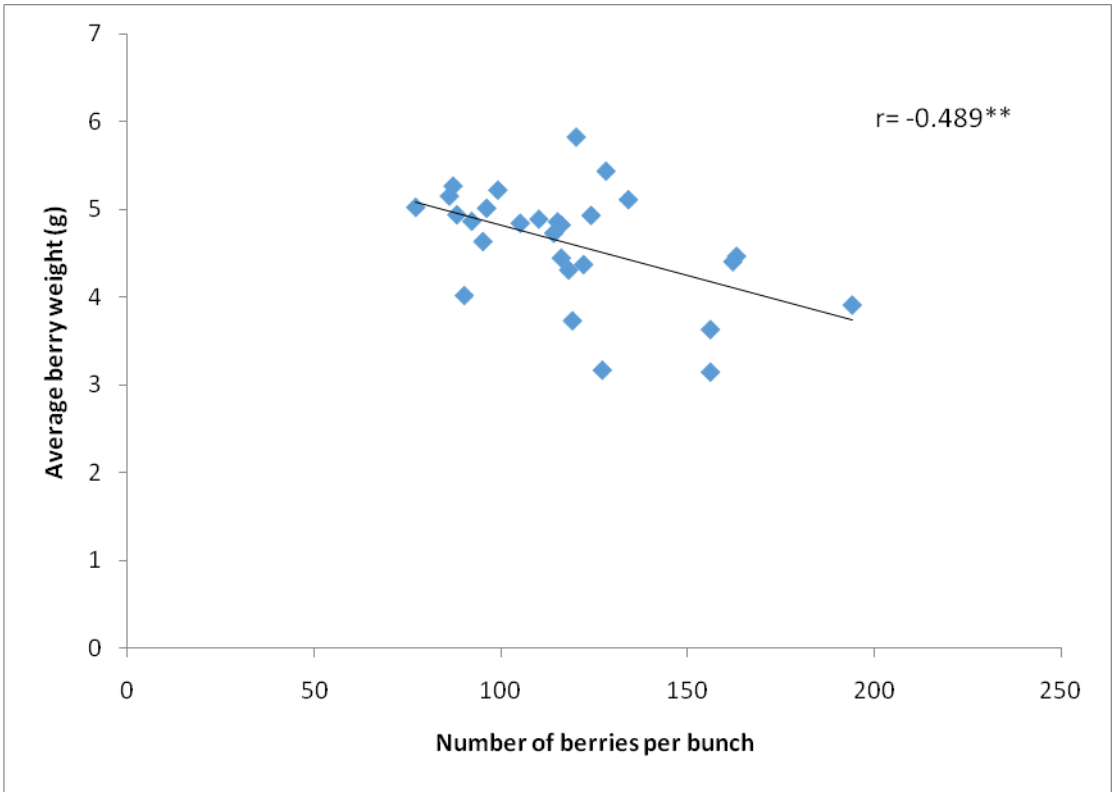

Fig 4.2 Correlation between Number of berries per bunch and berry weight in Crimson Seedless

1980; El-Ghani, 2001; Gowda *et al.*, 2006; Meena *et al.*, 2012 and Dimovska *et al.*, 2014).

4.1.3 Observation on biochemical analysis

4.1.3.1 Total soluble solids (˚Brix)

Observations on total soluble solids are presented in Table 4.7. Statistically non significant differences among the treatments were recorded. Treatment T_1 *i.e.* GA_3 at 5 ppm recorded the highest Total soluble solids (18.59˚Brix), followed by T_4 *i.e.* control (18.29˚Brix) among the all treatments T_2 where GA_3 @ 7.5 ppm application was recorded the least total soluble solids (17.51˚ Brix).

In any fruit, increased total soluble solids were observed as a result of accumulation of more carbohydrates. The possible reason for increase in the TSS could be due to increased capacity of the grape berries to draw more carbohydrates through increased auxin content directly or indirectly by quicker metabolic transformation of soluble compounds induced by GA_3 as suggested by Singh *et al.* (1993)

4.1.3.2 Titratable acidity (%)

Observations on titratable acidity are presented in Table 4.7. Significant differences among the treatments were recorded. Among all treatments bunches untreated control (T_4) (0.520 %) registered maximum titratable acidity followed by GA_3 @ 10 ppm T_3 (0.418 %). The least titratable acidity recorded bunches treated with GA_3 @ 5 ppm T_1 (0.241 %).

Application of GA_3 may be involved in decreasing the acids by converting them into sugars. Reduction in the acidity may be also due to utilization of acids as a substrate of respiration during the ripening and neutralization of organic acids due to potassium in tissue. In the present study, the least titratable acidity might be due to its higher total soluble solids (TSS) concentration which is explained by the hypothesis stated above under 4.1.3.1.

4.1.3.3. Sugar acid ratio

Data on sugar acid ratio are presented in Table.4.7. Significant differences

Table4.7 Effect of different concentrations of GA_3 on TSS, Titrable acidity and Sugar acid ratio in Grape cv. Crimson seedless.

Treatments	**TSS (˚Brix)**	**Titrable Acidity (%)**	**Sugar Acid ratio**
T_1:GA_3 @5 ppm	18.59	0.24	83.82
T_2:GA_3 @7.5 ppm	17.51	0.32	66.67
T_3:GA_3 @ 10 ppm	17.69	0.42	47.16
T_4:Control	18.29	0.52	38.87
SE(m)±	0.404	0.06	8.47
CD(P=0.05)	NS	0.17	25.36

Table 4.8 Effect of different concentrations of GA_3 on Anthocyanin concentration Grape cv. Crimson seedless

Treatments	**Anthocyanin concentration (g /100g)**
T_1:GA_3 @ 5 ppm	177.33
T_2:GA_3 @ 7.5 ppm	247.91
T_3:GA_3 @ 10 ppm	173.76
T_4:Control	167.14
SE(m)±	16.50
CD (P=0.05)	49.41

Table 4.9 Effect of different concentrations of GA_3 on total phenols in Grape cv. Crimson seedless

Treatments	**Total Phenols (g /100g)**
T_1:GA_3 @ 5 ppm	112.75
T_2:GA_3 @ 7.5 ppm	172.66
T_3:GA_3 @ 10 ppm	217.61
T_4:Control	155.18
SE(m)±	23.73
CD (P=0.05)	71.06

Table 4.10 Effect of different concentrations of GA_3 on total sugars in Grape cv. Crimson seedless.

Treatments	**Total sugars (g/100g)**
T_1:GA_3 @ 5 ppm	18.21
T_2:GA_3 @ 7.5 ppm	15.91
T_3:GA_3 @ 10 ppm	16.08
T_4:Control	17.44
SE(m)±	0.38
CD (P=0.05)	1.14

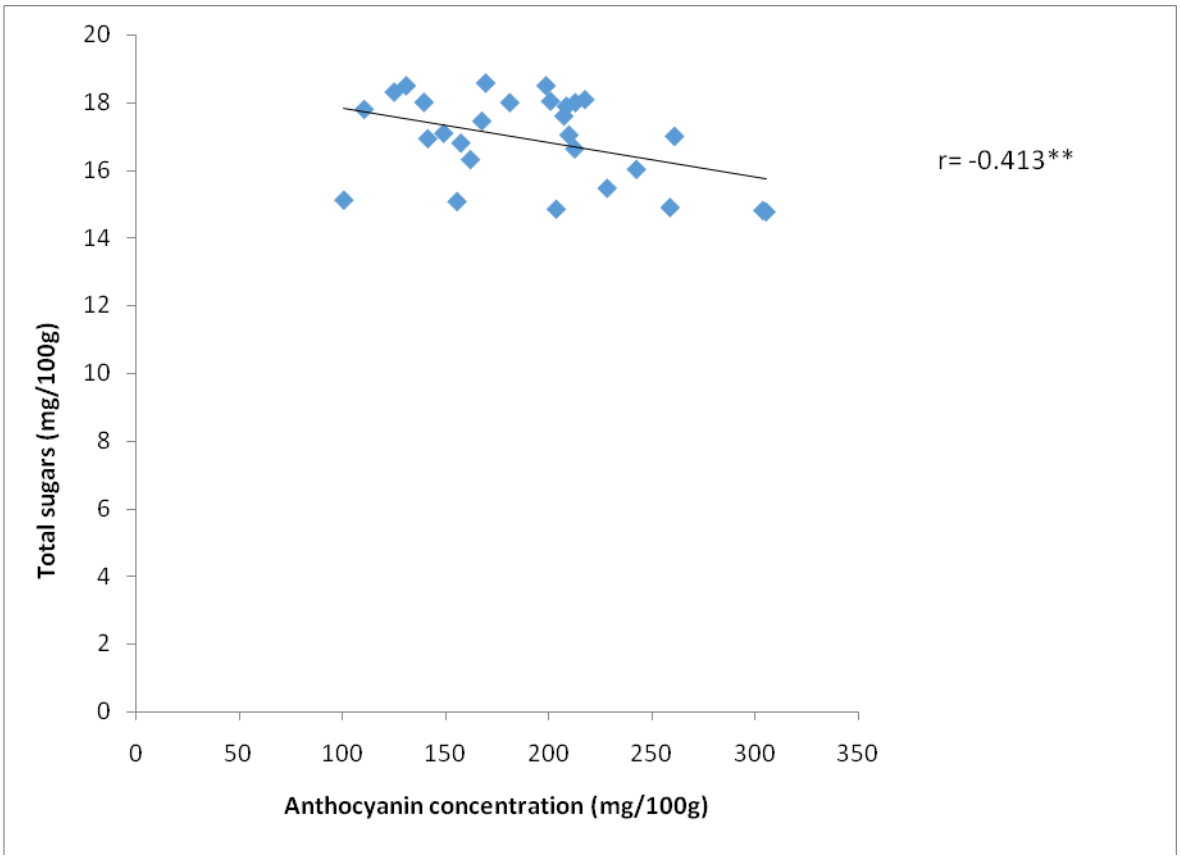

Fig 4.3 Correlation between total sugars and Anthocyanin in Crimson Seedless grapes

Table 4.11 Correlation matrix among different Bunch and Berry characters in Crimson Seedless Grapes

Characters	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	1													
2	-0.311	1												
3	-.743**	.721**	1											
4	0.004	-0.102	0.118	1										
5	.531**	0.022	-0.294	-.511**	1									
6	0.263	-.489**	-.473*	-0.162	0.302	1								
7	0.082	-0.312	-0.225	-0.115	0.129	.772**	1							
8	.450*	-.443*	-.606**	-0.225	0.343	.811**	.714**	1						
9	0.237	0.129	-0.001	0.274	0.085	-0.259	-0.233	0.043	1					
10	-.453*	0.174	.380*	-0.074	-0.177	-0.187	-0.107	-0.369	0.028	1				
11	.556**	-0.149	-.441*	0.179	0.139	0.180	0.103	0.343	0.127	-.874**	1			
12	-0.244	0.234	0.149	-.599**	0.347	-0.091	-0.133	-0.228	-0.264	0.006	-0.193	1		
13	0.048	-0.304	-0.270	0.010	-0.111	0.292	0.174	0.162	-0.361	-0.172	0.218	-0.152	1	
14	0.158	-0.005	0.073	.539**	-0.040	-0.153	-0.242	0.051	.699**	-0.052	0.136	-0.359	-.413*	1

among the treatments were recorded. Among all treatments bunches treated with GA_3 @ 5 ppm (T_1) registered maximum sugar acid ratio (83.82) followed by GA_3 @ 7.5 ppm T_2 (66.67). The least sugar acid ratio recorded bunches untreated control T_4 (38.87).

The effect of gibberellins on Sugar acid ratio was also reported by Ahmad and Zargar *et al*. (2005), Rather *et al.* (2011), Chaitakhob *et al*. (2014).

4.1.3.4. Anthocyanin concentration (mg /100 g)

Observations on anthocyanin concentration are presented in Table.4.8. Significant differences among the treatments were recorded. Among all treatments bunches treated with GA_3 @ 7.5ppm (T_2) registered maximum anthocyanin concentration (247.914 mg/100 g) followed by GA_3@ 5ppm (T_1) (177.33 mg/100 g). The least anthocyanin concentration recorded in bunches with no GA_3 application *i.e.*., T_4 (167.14 mg/100 g). The highest anthocyanin concentration in T_2 might be due to its lower total sugar concentration which has exhibited negative correlation (r =-0.413, Fig 4.3) and vice versa in treatments T_1 and T_3**.** The sugar conversion into anthocyanin biosynthesis is reported by few workers in different flowers and fruit crops as reported by Cengiz Ozer *et al*. (2012).

4.1.3.5 Total phenols (mg /100 g)

Data on total phenols content are presented in Table 4.9. Significant differences among the treatments were recorded. Among all treatments bunches treated with GA_3 @ 10 ppm (T_3) registered maximum total phenols (217.61 mg/100 g) followed by GA_3 @ 7.5ppm (T_2) (172.66 mg/100 g). The least total phenols recorded in bunch treated with GA_3 @ 5ppm (T_1) (112.75 mg/100 g).

4.1.3.6. Total sugars (g/100 g)

Observations on total sugars are presented in Table 4.10. Significant differences among the treatments were recorded. Among all treatments bunches treated with GA_3 at 5 ppm (T_1) registered maximum total sugars (18.211 g/100 g) followed by bunches untreated with GA_3 (T_4) (17.444 g/100 g). The least total sugars recorded in bunches treated with GA_3 at 7.5 ppm T_2 (15.914 g/100 g).

The increase in reducing, non-reducing and total sugars might be ascribed to the conversion of starch and acids into sugars in addition to continuous mobilization of sugars from leaves to berries (Singh *et al.*, 1993).

4.2 EFFECT OF DIFFERENT CHEMICALS FOR FLOWER AND BERRY THINNING IN RED GLOBE GRAPE

In Red Globe grapes, though GA_3 application is not recommended owing to its seeded characters, all flowers which will set fruits and carried forward till maturity and ripening. Unlike other seedless varieties where, GA_3 is applied at higher concentrations for flower thinning, in this variety there is a need to apply some alternate chemicals for flower thinning in order to achieve desirable number of berries at harvest. Hence, some alternate chemicals were tried to reduce fruit set by flower thinning to achieve desired number of berries with acceptable berry size. The observations on different berry parameters are narrated below:

4.2.1 Bunch characters

4.2.1.1 Total length of Rachis (cm)

Significant differences among the treatments were recorded for rachis length is presented in Table 4.12. The bunches treated with Olive oil @ 0.5 % *i.e.* T_1 were showing highest rachis length (122.73 cm) followed by Caffeine 0.3 % @ 50 % bloom T_2 (104.60 cm), $CuSO_4$-0.5 % @ 50 % bloom T_5 (99.2 cm), DNOC-0.1 % @ 50 %bloom T_4 (86.78 cm), MT @ 8 mm berry stage T_6 (63.77 cm), H_2CN_2 -0.1 % @ 50 % bloom T_3 (52.25 cm) and significantly superior to the rest of treatments. The minimum length of the rachis (32.57 cm) was recorded in untreated control T_7.

It is evident from the data that conventional thinning agents at higher concentration recorded the maximum rachis length is depicted in plate 4.5, 4.6 & 4.7, when applied at full bloom stage. Some of the alternate chemicals have mild hormonal activity and hence, in addition to act as flower thinning agents they must have influenced cell elongation and put forth significant differences in rachis elongation. The increase in rachis length was largely associated with cell elongation of rachis and increase in bunch size. Such increase in the bunch size and cell

elongation of rachis is due to profound effect of conventional thinning agents and other growth regulators used during the growth and development of grapes berries. Similar increase in rachis length has been reported by several research workers like Godara *et al*. (2002) in Perlette grapes. Gill *et al*. (1987) in Thompson seedless and Anitha (1993) in Anab-e-Shahi and Dilkush varieties, Omari *et al*. (2016) in Sharad seedles and Flame seedless when treated with other flower thinning agents except GA_3.

4.2.1.2 Number of berries per bunch

Observations on number of berries per bunch are presented in Table 4.13. Statistically non significant differences among the treatments were recorded. Treatment Caffeine @ 0.3 % at 50 % bloom (T_2) recorded the maximum number of berries per bunch (118.50), followed by Olive oil 0.5 % @ 50 % bloom T_2 (112.75),among the all treatments manual thinning at 8 mm berry stage (T_6) where application of different thinning agents was not attempted recorded the least number of berries per bunch (78.00).

The numbers of berries per bunch were Non significantly influenced by application of conventional thinning agents. It is the universal accepted feature of the Gibberellic acid and conventional thinning agents *viz.* Olive oil, Caffeine and $CuSO_4$ has thinning effect on grapes at initial growth of bunches. Thinning the flower clusters by reducing fruit set helps in increasing the size and shape of berries. Similar results have been reported by Kashyap *et al*. (1989).

4.2.1.3 Bunch compactness (Berries / cm)

Observations on Bunch compactness are presented in Table 4.14. Statistically significant differences among the treatments were recorded. Treatment T_1 *i.e.* Olive oil 0.5 % @ 50% bloom recorded the less bunch compactness (0.91) followed by $Cuso_4$ 0.5 % @ 50 % bloom T_5 (1.09), Caffeine 0.3 % @ 50 % bloomT_2 (1.17), among the all treatments T_7 where no application was attempted recorded the more bunch compactness (2.56).

The bunch compactness was significantly influenced by application of conventional thinning agents this is because conventional thinning agents have same

effect as like GA_3 which reduced number of berries per bunch thereby producing less compact bunches when treated with conventional thinning agents. Similar results

Table 4.12 Effect of organic and inorganic chemicals at various concentrations on Total rachis length in Grape cv. Red Globe.

Treatments	**Total Rachis Length(cm)**
T_1:Olive oil 0.5 % @ 50 % bloom	122.73
T_2:Caffeine 0.3 % @ 50 %bloom	104.60
T_3:H_2CN_2 -0.1 %@ 50 %bloom	52.25
T_4:DNOC-0.1 % @50 %bloom	86.78
T_5:$Cuso_4$ -0.5 %@50 % bloom	99.20
T_6:MT @ 8mm berry stage	63.78
T_7:Control	32.57
SE (m)±	10.05
CD (P=0.05)	30.09

Plate 4.5 Effect of different chemicals on flower thinning (after 48 hours of application) in Red globe.

T1 – Olive Oil 0.5%

T2 – Caffeine 0.3%

T3 – $H_2C_2O_4$ 0.1%

T4 – DNOC 0.1%

T5 – $CuSO_4$ 0.5%

Control

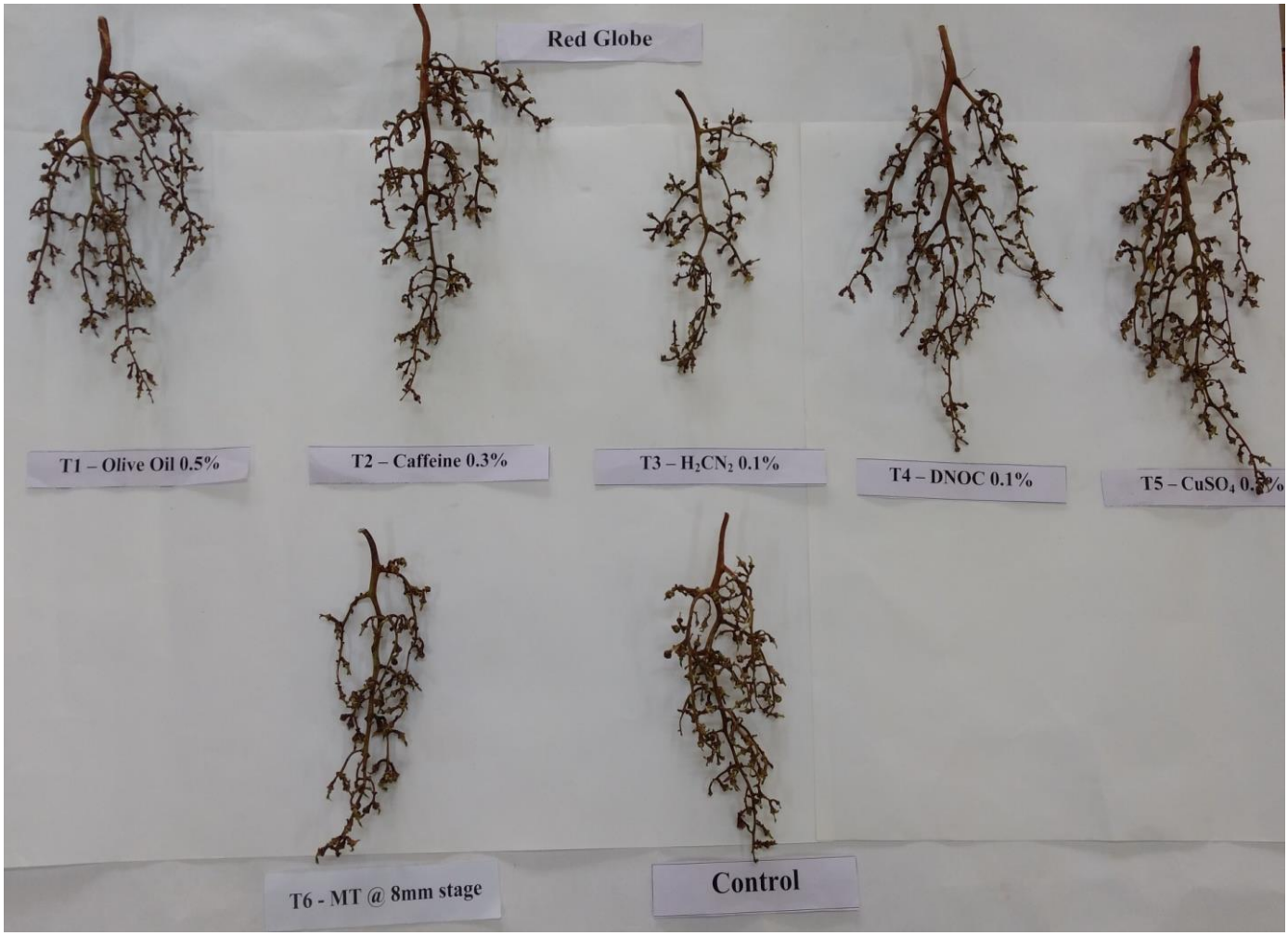

Plate 4.7 Effect of different chemicals on Total rachis length in Red globe.

Table 4.13 Effect of organic and inorganic chemicals at various concentrations on number of berries per bunch in Grape cv. Red Globe.

Treatments	Number of berries per bunch
T_1:Olive oil 0.5 % @50 % bloom	112.75
T_2:Caffeine 0.3 % @ 50 %bloom	118.50
T_3:H_2CN_2 -0.1 %@ 50 %bloom	83.00
T_4:DNOC-0.1 % @50 %bloom	106.50
T_5:$Cuso_4$ -0.5 %@50 % bloom	109.00
T_6:MT@ 8mm berry stage	78.00
T_7:Control	80.75
SE(m)±	14.15
CD(P=0.05)	NS

Table 4.14 Effect of organic and inorganic chemicals at various concentrations on bunch compactness in Grape cv. Red globe.

Treatments	Bunch compactness
T_1:Olive oil 0.5 % @50 % bloom	0.91
T_2:Caffeine 0.3 % @ 50 %bloom	1.17
T_3:H_2CN_2 -0.1 %@ 50 %bloom	1.58
T_4:DNOC-0.1 % @50 %bloom	1.27
T_5:$Cuso_4$ -0.5 %@50 % bloom	1.09
T_6:MT@8 mm berry stage	1.28
T_7:Control	2.56
SE(m)±	0.203
CD (P=0.05)	0.606

were got by Abd-Allah *et al*. (2013). The reduced compactness of bunches in treatment with Olive oil and Caffeine had negative correlation with increased rachis length. Though the number of berries was highest on these treatments, the reduced compactness might be due to increased rachis length. The inverse correlation was observed for these parameters (r = - 0.516, Fig 4.4).

4.2.1.4 Total cluster /bunch/Average bunch weight (g)

Significant differences among the treatments were recorded for bunch weights are presented in Table 4.15. The bunches treated with Caffeine at 0.3 % at 50 % bloom *i.e.* T_2 were showing highest bunch weight (1244.15 g) followed by T_1 (Olive oil 0.5 % at 50 % bloom), (1167.58 g) and significantly superior to the rest of all treatments. The minimum bunch weight (599.38 g) was recorded in T_7 (control).Effect of different chemicals on bunch Cv. Red Globe is depicted in plate 4.8.

Due to high metabolic activity of the vine and accumulation of carbohydrates by the effect of Copper Sulphate, Olive oil and Coffee powder application increases the bunch weight. Similar results were obtained by (Ahmad *et al*. 1997). Similarly, in Sharad Seedless the maximum bunch weight was recorded in (T_8) Coffee powder 2% (379.38 g). In case of Sharad Seedless the maximum bunch weight were recorded in Olive oil 2% (426.49 g). The maximum bunch weights at 100 % cap fall were observed in (T_6) Olive oil 3 % (506.19 g) While in case of Sharad Seedless the maximum bunch weight were recorded in (T_6) Olive oil 3% (402.83 g) the by Omari *et al.* (2016). Though maximum number of berries was recorded on control bunches, the average bunch weight was minimum in the same treatment which might be due to lesser berry weight. The positive correlation was recorded between average berry weight and total bunch weight which explains the contribution of individual berry weight to total bunch weight rather than total number of berries per bunch.

4.2.1.5 Bunch volume (cm^3)

Observations on bunch volume are presented in Table 4.15. Significant differences among the treatments were recorded. Among all treatments bunches treated with $CuSO_4$– 0.5 % at 50% bloom (T_5) registered maximum bunch volume (6540 cm^3) followed by Hydrogen cyanamide-0.1 % at 50% bloom (T_3) (6525 cm^3).

The least bunch volume recorded in bunches treated with Caffeine at 0.3 % at 50% bloom (T_2) (6007.5 cm^3).

4.2.2 Berry characters

4.2.2.1 Average berry weight (g)

Observations on average berry weight are presented in Table 4.16. Significant differences among the treatments were recorded. Among all treatments bunches treated with Hydrogen cyanamide - 0.1 % at 50 % bloom T_3 (11.712 g) registered maximum average berry weight followed by $CuSo_4$– 0.5 % at 50 % bloom T_5 (11.37 g). The least average berry weight recorded bunches untreated control T_7 (8.96 g). Lakshmanan *et al.* (1992) also reported that, the berry development in Thompson Seedless grapes may be due to the role of hormones which mobilize elaborated food material, increase in water uptake, solute storage and synthesis of cell components. Thinning and loosening effect of GA_3, as noticed by the percentage of fruit-set, are also responsible for greater development of the berries of the treated bunches. The increased berry weight in the treatments *viz.* H_2CN_2, $CuSO_4$, Caffeine and Olive oil might be due to excess flower thinning caused by them. But, the clusters treated with H_2CN_2 and $CuSO_4$ recorded some scorching symptoms on rachis, though they caused effective flower thinning. Hence, treating the clusters at full bloom stage with Olive oil and Caffeine produced bunches with good berry weight without scorching and hence, they could be recommended as effective flower thinning agent for Red Globe grapes. Individual weight of berries also contributes for bunch compactness. Higher the berry weight lesser will be the compactness which is desirable quality for good marketable bunch. In this context, a significantly negative correlation (r = - 0.435) was recorded for average berry weight and cluster compactness (Fig. 4.5).

4.2.2.2 Berry diameter (mm)

Observations on berry diameter are presented in Table 4.16. Statistically non significant differences among the treatments, bunches treated with Caffeine at 0.3 % at 50 % bloom (T_2) recorded the highest berry diameter (2.81 cm) followed by H_2CN_2 -0.1 % @ 50 % bloom T_3 (2.76 cm), among the all treatments T_7 where untreated control was recorded the least berry diameter (2.51 cm).

Table 4.15 Effect of organic and inorganic chemicals at various concentrations on bunch weight & bunch volume in Grape cv. Red globe.

Treatments	**Bunch weight(g)**	**Bunch volume(cm^3)**
T_1:Olive oil 0.5 % @50 % bloom	1167.58	6110.0
T_2:Caffeine 0.3 % @ 50 %bloom	1244.15	6007.5
T_3:H_2CN_2 -0.1 %@ 50 %bloom	705.30	6525.0
T_4:DNOC-0.1 % @ 50 %bloom	963.08	6297.0
T_5:$Cuso_4$ -0.5 %@ 50 % bloom	775.83	6540.0
T_6:MT@ 8mm berry stage	675.73	6522.5
T_7:Control	599.38	6437.5
SE (m)±	97.79	97.96
CD (P=0.05)	292.89	293.32

Plate 4.8 Effect of different chemicals on bunch in Grape cv. Red globe.

This increase in berry diameter can be the result of radial expansion of cells in addition to the longitudinal increase. This kind of expansion of radial growth of berry has also been reported by Ahmad and Zargar (2005) in Blanc Corinth variety. But the net increase in diameter of berry is primarily being the result of increased cell size in the many layered bands of tissue in the pericarp. It can thus be concluded that the initial application of thinning agents to flower clusters reduces berry set and later it may helps in increasing the size of berries and yield due to less competition of berries for available photosynthates. The increase in berry diameter through application of Gibberellic acid and conventional agents like Caffeine, Olive oil, H_2CN_2 has also been reported by Hayatt *et al.* (1994) in Perlette variety; Mohammed Farooq and Hulamani (2001) in Arkavathi grapes; Quadir *et al*. (1989) in Flame Seedless grapes;Wu-Jun *et al.* (2001) in Fujiminori grapes and Anitha (1993) in Anab-e-Shahi grapes. Abd-Allah *et al.* (2013), Chang *et al.* (2015), Alrashedi *et al*. (2016).

4.2.2.3 Berry length (mm)

Significant differences among the treatments were recorded for berry length is presented in Table 4.16. The bunches treated with Caffeine at 0.3 % @ 50 % bloom *i.e.* T_2 were showing highest maximum berry length (3.05 cm) followed by Hydrogen cyanamide - 0.1 % at 50% bloom *i.e.* T_3 (3.05 cm), they were significantly superior to the rest of all the treatments. The minimum length of the berry (2.608 cm) was recorded in T_7 untreated control.

4.2.3 Observation on biochemical analysis

4.2.3.1 Total soluble solids (˚Brix)

Observations on total soluble solids are presented in Table 4.17. Statistically non significant differences among the treatments were recorded. Treatment manual thinning at 8 mm berry stage (T_6) recorded the highest TSS (18.58 ˚Brix) followed by $CuSO_4$ -0.5 % @ 50 % bloom (T_5) (17.7 ˚Brix) among the all treatments. Hydrogen cyanamide-0.1 % at 50 % bloom T_3 where application was recorded the least total soluble solids (15.68˚Brix).

Table 4.16 Effect of organic and inorganic chemicals at various concentrations on berry characters in grape cv. Red Globe.

Treatments	Average berry weight(g)	Berry Diameter(cm)	Berry Length(cm)
T_1:Olive oil 0.5% @50% bloom	10.10	2.69	2.97
T_2:Caffeine 0.3% @ 50%bloom	11.36	2.81	3.05
T_3:H_2CN_2 -0.1%@ 50%bloom	11.71	2.76	3.05
T_4:DNOC-0.1% @50%bloom	10.37	2.74	2.83
T_5:$Cuso_4$ -0.5%@50% bloom	11.37	2..64	2.89
T_6:MT@8mm berry stage	9.82	2.54	2.82
T_7:Control	8.96	2.51	2.61
SE(m)±	0.52	0.07	0.04
CD(P=0.05)	1.55	NS	0.13

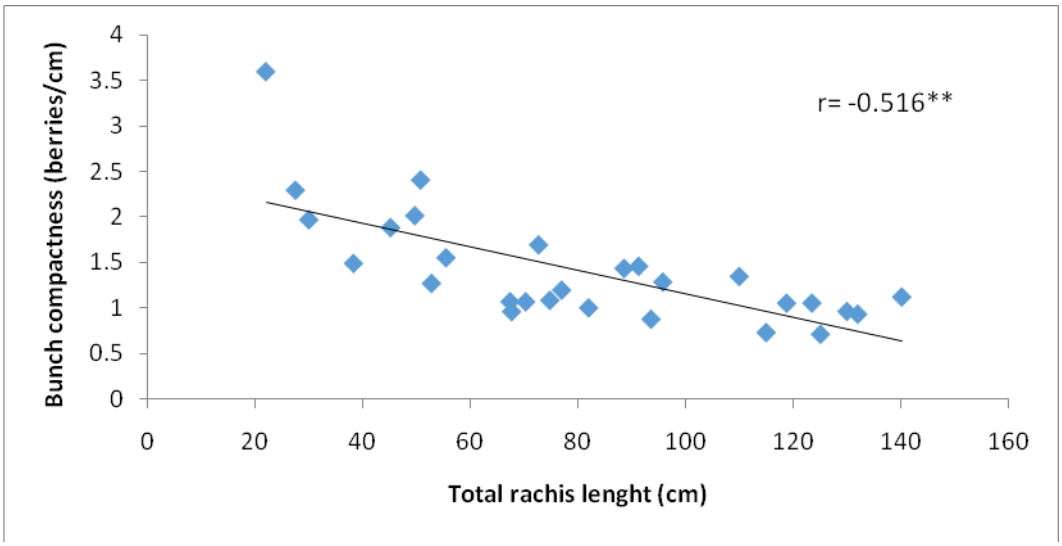

Fig 4.4 Correlation between total rachis length and bunch compactness in Red Globe grapes

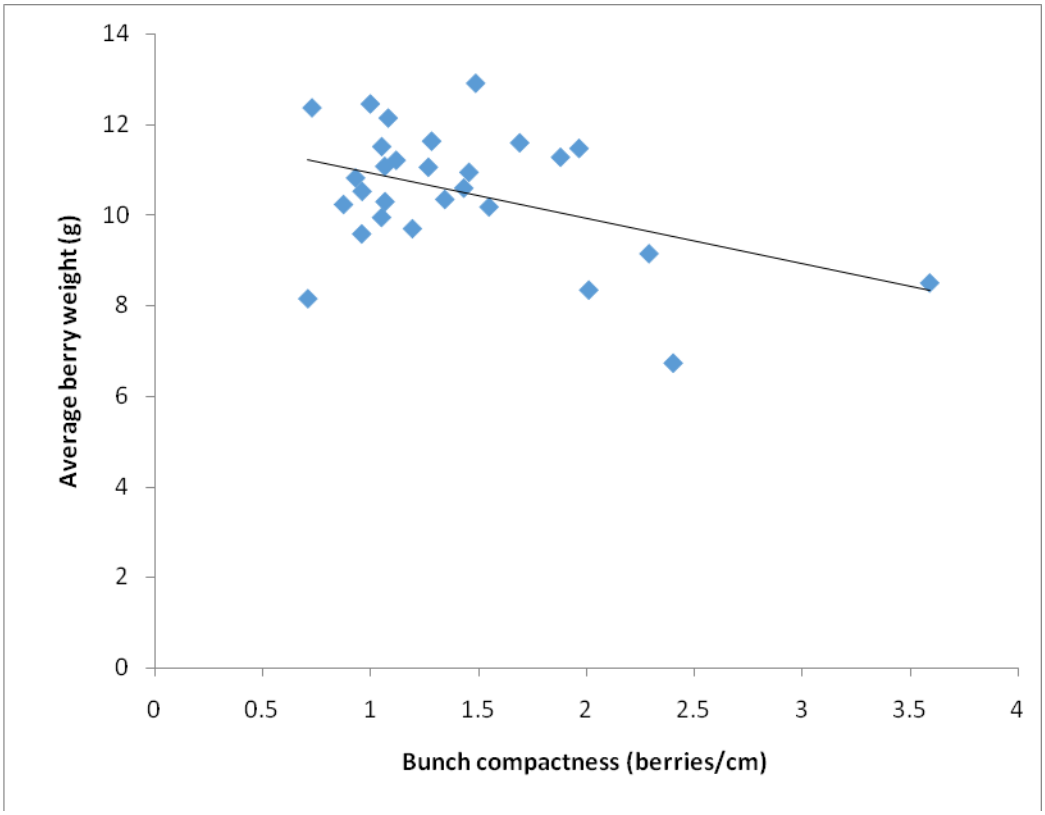

Fig 4.5 Correlation between bunch compactness and average berry weight in Red Globe Grapes.

A possibility can thus also be entertained that the increase in total soluble solids may be due to quick metabolic transformation in soluble compounds Singh *et al.* (1993). Improvement in total soluble solids, has also been found by Quadir *et al.* (1989) and Verma (1991) in Thompson seedless; Singh *et al*. (1994); El-Hammady *et al*. (1998) in Sultaninia grapes and Anitha (1993) in Anab-e-Shahi and Dilkush varieties. El-Boray *et al*. (2012) in Florida Prince Peach, Chang *et al.* (2015) in Doonuri grapes, Alrashedi *et al*. (2016) in Apples, Omari *et al*. (2016) in Sharad seedless and Flame seedless when Similar chemicals were used as flower thinning agents. The maximum TSS in manual berry thinning might be due to effective thinning of berries and retaining only desirable number of berries which maintained highest TSS. However, though the other thinning agents also have brought about better flower thinning, it is not as perfect as manual thinning agents where the number of berries to be retained for full development is fixed. In this context, though manual berry thinning is very effective method of berry thinning, owing to cost involved in manual labors, chemical flower thinning which are cheaply available like Olive oil and Caffeine might be very effective looking into their cost effectiveness. Application of DNOC is also very effective for flower thinning without any scorching or undesirable effects, but looking into its cost it is also might not be economical for common growers. Scorching on rachis because of $CuSO_4$ @ 0.5% & H_2CN_2 @ 0.1% is depicted in plate 4.9.

4.2.3.2 Titratable acidity (%)

Observations on titratable acidity are presented in Table 4.17. Non Significant differences among the treatments were recorded. Among all treatments bunches Dinitro-Ortho-Cresol (DNOC) -0.1 % at 50 % bloom stage (T_4) (0.310 %) registered maximum titratable acidity followed by Olive oil 0.5 % at 50 % bloom (T_1) (0.281 %) and Hydrogen cyanamide-0.1 % at 50 % bloom (T_3) (0.281%). The least titratable acidity recorded in untreated bunches *i.e.* control (T_7) (0.197 %). No relation on effect of chemical flower thinning agents on titratable acidity has been reported. But, owing to rapid conversion of acids into sugars, the reduction in acidity content of treated berries can be mainly due to transformation of organic acids to

sugars. Similar results has been given by El-Boray *et al*. (2012) in Florida Prince Peach, Chang *et al.* (2015) in Doonuri Grapes, Alrashedi *et al*. (2016) in Apples, Omari *et al*. (2016) in Sharad seedless and Flame seedless.

4.2.3.3 Sugar acid ratio

Data on sugar acid ratio are presented in Table.4.17. No Significant differences among the treatments were recorded. Among all treatments bunches treated with Caffeine at 0.3 % at 50 % bloom (T_2) (95.58) registered maximum sugar acid ratio followed by untreated Control (T_7) (83.882). The least sugar acid ratio recorded bunches DNOC -0.1 % at 50 % bloom stage (T_4) (53.94). This increase in TSS/acid ratio could be attributed to increase in TSS content with a corresponding decrease in acidity content of berries over control. These findings are in agreement with the results reported by other workers like El-Boray *et al*. (2012) in Florida Prince Peach, Chang *et al.* (2015) in Doonuri grapes, Alrashedi *et al*. (2016) in Apples, Omari *et al*. (2016) in Sharad seedless and Flame seedless.

4.2.3.4 Anthocyanin concentration (mg /g)

Observations on anthocyanin concentration are presented in Table 4.18. Significant differences among the treatments were recorded. Among all treatments bunches treated with Caffeine at 0.3 % at 50 % bloom (T_2) (265.92 mg/100 g) registered maximum anthocyanin concentration followed by Olive oil 0.5 % at 50 % bloom (T_1) (198.523 mg/100 g). The minimum anthocyanin concentration recorded bunches DNOC -0.1 % at 50 % bloom stage (T_4) (150.455 mg/100 g).

The anthocyanin concentration was significantly influenced by application of conventional thinning agents. Chang *et al*. (2015) reported that application of conventional thinning agents Olive oil, Caffeine and $CuSO_4$ in addition to bringing about effective thinning of flowers it also increased total anthocyanin content with early maturity which is in confirmation of the present study.

Table 4.17 Effect of organic and inorganic chemicals at various concentrations on TSS, Titrable acidity and Sugar acid ratio in Grape cv. Red Globe.

Treatments	**TSS (ºBrix)**	**Titratable Acidity (%)**	**Sugar Acid Ratio**
T_1:Olive oil 0.5 % @ 50 % bloom	16.05	0.28	64.93
T_2:Caffeine 0.3 % @ 50 % bloom	16.83	0.22	95.58
T_3:H_2CN_2 -0.1 % @ 50 %bloom	15.68	0.28	56.51
T_4:DNOC-0.1 % @ 50 %bloom	16.58	0.31	53.94
T_5:$Cuso_4$ -0.5 % @50 % bloom	17.70	0.24	77.08
T_6:MT @ 8mm berry stage	18.58	0.27	68.49
T_7:Control	16.48	0.20	83.88
SE (m)±	0.69	0.03	11.99
CD (P=0.05)	NS	NS	NS

Table 4.18 Effect of organic and inorganic chemicals at various concentrations on Anthocyanin concentration Grape cv. Red globe.

Treatments	**Anthocyanin concentration (mg/100g)**
T_1 :Olive oil 0.5 % @50 % bloom	198.52
T_2 :Caffeine 0.3 % @ 50 % bloom	265.93
T_3 :H_2CN_2 -0.1%@ 50 %bloom	180.09
T_4 :DNOC-0.1% @50 %bloom	138.89
T_5 :$Cuso_4$ -0.5 %@50 % bloom	175.69
T_6 :MT @ 8mm berry stage	192.12
T_7 :Control	155.83
SE (m)±	24.021
CD (P=0.05)	71.92

Plate 4.9 Scorching on rachis with $CuSO_4$ @ 0.5 % and H_2CN_2 @ 0.1 % .

4.2.3.4 Total phenols (mg/ g)

Data on total phenols content are presented in Table 4.19. No Significant differences among the treatments were recorded. Among all treatments bunches untreated Control (T_7) (482.86 mg/100 g) registered maximum total phenols followed by DNOC -0.1 % at 50 % bloom stage (T_4) (176.08 mg/ 100g). The least total phenols recorded bunch treated with Hydrogen cyanamide-0.1 % at 50% bloom T_3 (90.649 mg/100 g). The accumulation of total phenols in grapes some time tends to be based on the berry weight and volume. Higher the berry weight and volume lesser will be the total phenols and vice versa which is evident from Fig 4.6 where significantly inverse relation was observed between these two parameters (r = -0.581). This inverse relation is mostly due to dilution effect of phenols with size of berries as explained by Chang *et al*. (2015).

4.2.3.5 Total sugars (g/100g)

Observations on total sugars are presented in Table 4.20. Non Significant differences among the treatments were recorded. Among all treatments bunches treated with MT@8 mm berry stage T_6 (18.23 g/100g) registered maximum total sugars followed by bunches treated with $CuSO_4$ -0.5 @ 50 % bloom T_5 (17.35 g/100 g). The least total sugars recorded bunches treated with H_2CN_2 -0.1 %@ 50 %bloom T_3 (15.36 g/100g). The increase in total sugar may be due to the conversion of starch and acid into sugars. In addition to this, it can also be due to continuous mobilization of sugar content from leaves to berries as reported by Singh *et al.* (1993).

Table 4.19 Effect of organic and inorganic chemicals at various concentrations on total phenols in Grape cv. Red globe.

Treatments	**Total Phenols (mg/100g)**
T_1 :Olive oil 0.5 % @50 % bloom	127.90
T_2 :Caffeine 0.3 % @ 50 % bloom	148.79
T_3 :H_2CN_2 -0.1 %@ 50 %bloom	90.65
T_4 :DNOC-0.1 % @50 %bloom	176.08
T_5 :$Cuso_4$ -0.5 %@50 % bloom	153.39
T_6 :MT @ 8mm berry stage	151.32
T_7 :Control	482.85
SE(m)±	112.36
CD (P=0.05)	NS

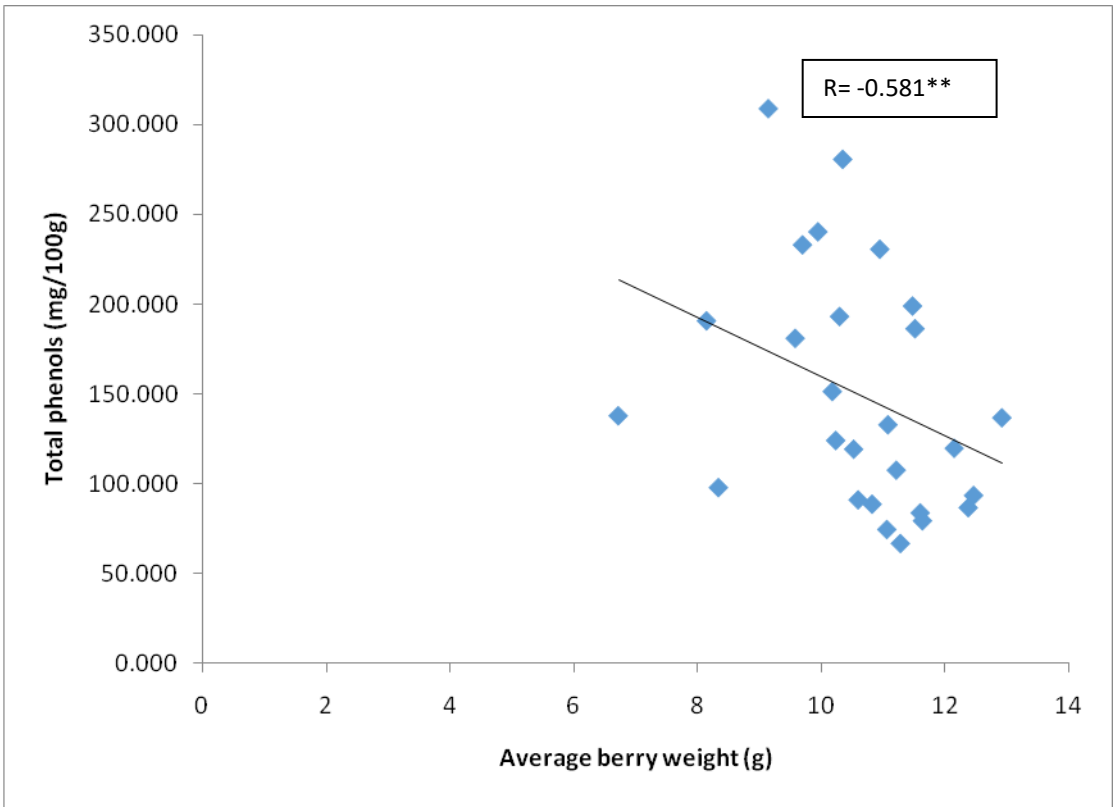

Fig 4.6 Correlation between Total phenols and average berry weight in Red Globe grapes

Table 4.20 Effect of organic and inorganic chemicals at various concentrations on total sugars in Grape cv. Red globe.

Treatments	**Total Sugars (g /100g)**
T_1 :Olive oil 0.5 % @ 50 % bloom	15.67
T_2 :Caffeine 0.3 % @ 50% bloom	16.06
T_3 :H_2CN_2 -0.1 %@ 50 %bloom	15.33
T_4 :DNOC-0.1 % @50 %bloom	16.26
T_5 :$Cuso_4$ -0.5 %@50 % bloom	17.35
T_6 :MT@ 8mm berry stage	18.23
T_7 :Control	16.025
SE (m)±	0.652
CD (P=0.05)	NS

Chapter V

Summary and Conclusions

Chapter V

SUMMARY AND CONCLUSIONS

The present investigations entitled "Standardization of growth regulators for rachis elongation in Crimson Seedless and berry/flower thinning in Red Globe grapes (*Vitis vinfera* L.)" was carried out at the ICAR - Indian Institute of Horticultural Research (ICAR-IIHR) located at Hessaraghatta, Bengaluru during 2016 - 2017. The results obtained from the experiment were summarized here under:

First experiment is conducted to evaluate different concentration of GA_3 for rachis elongation in Crimson Seedless grape.

1. Among all GA_3 treatments clusters treated at pre-bloom stage with GA_3 @ 5 ppm (T_1) shown maximum rachis length (124.91 cm), least bunch compactness (0.94), highest bunch weight (507.49 g), maximum bunch volume(1763.43 cm^3) ,highest average berry weight (4.93 g), berry length (2.59 cm), TSS(18.59 ˚Brix) and registered maximum sugar acid ratio (83.8).
2. Control (T_4) recorded the maximum number of berries per bunch (140.71) with higher cluster compactness and registered maximum titratable acidity (0.52 %).
3. Among the all treatments GA_3 @ 7.5ppm recorded the highest berry diameter (1.75 cm) and registered maximum anthocyanin concentration (247.91 mg/100g).
4. Bunches treated with GA_3 @ 10ppm (T_3) registered maximum total phenols (217.605 mg/100g).

Second experiment was conducted to evaluate different chemicals for flower and berry thinning in Red Globe grape.

1. Clusters treated at 50 % bloom stage with Olive oil @ 0.5 % exhibited maximum rachis length (122.73 cm) and less bunch compactness (0.91).
2. Caffeine @ 0.3 % at 50 % bloom recorded the maximum values for most of the berry parameters *viz.* number of berries per bunch (118.50), bunch weight (1244.15 g), berry diameter (2.81cm), berry length (3.05 cm), maximum sugar acid ratio, value and anthocyanin concentration (265.93 mg /100g).

3. $CuSO_4$ – 0.5 % at 50 % bloom (6540 cm^3) registered maximum bunch volume but had scorching effect on rachis this affected bunch appearance.
4. Hydrogen cyanamide - 0.1 % at 50 % bloom registered maximum average berry weight (11.71 g) .
5. Manual thinning at 8mm berry stage recorded the highest TSS (18.58 ˚Brix)
6. Dinitro-Ortho-Cresol (DNOC) -0.1 % at 50 % bloom stage (0.310%) registered maximum titratable acidity.
7. Untreated Control (482.852 mg / 100g) registered maximum total phenols.
8. Though $CuSO_4$ and H_2CN_2 influenced the berry thinning effectively, there was scorching symptom on the rachis which adversely affected the overall appearance.
9. DNOC at 0.1 % is also a very effective chemical for flower thinning, but because of its high cost, it may not be economical to common growers.
10. Manual berry thinning also is one of the effective means to achieve desirable bunch and berry quality, but looking into the labor involved in thinning, it is also not economical.
11. Treating clusters at 50 % bloom stage with either Olive oil and Caffeine is found to produce good quality bunches

Conclusions

On the basis of first experimental findings, it could be concluded that among all concentrations of GA_3 testers, GA_3 @ 5 ppm was found to be superior to other treatments with respect to elongation of rachis and enhancing bunch and berry quality.

From the second experimental findings, it can be concluded that the caffeine @ 0.3 % is most effective for improving bunch and berry attributes when compared to other treatments and works to be very economical to common grape growers.

Future line of work

1. Investigations on further lower concentration of GA_3 for rachis elongation in Crimson Seedless may be carried out.
2. Further investigation should be carried on lower concentration of $CuSO_4$ to avoid burning or scorching effect on rachis of bunches in Red globe so that it can be effectively recommended as flower thinning chemical in perspective of Organic grape cutlivation.

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Appendices

Appendix I: Monthly meteorological data recorded at ICAR-IIHR, Hesaraghatta, Bengaluru during August 2016 to February 2017

Month and year	Temperature (ºC)		Relative Humidity (%)		Evaporation(mm)	Wind speed (km/hr)	Rainfall (mm)	Rainy days
	Maximum	Minimum	Average at 7:30 AM	Average at 1:30 PM				
August, 2016	27.00	20.60	80.60	58.10	3.00	3.90	16.50	5
September, 2016	25.20	21.70	80.50	54.50	2.90	4.40	58.00	11
October, 2016	26.00	19.00	58.00	38.00	5.00	2.00	15.00	3
November, 2016	27.00	18.00	64.00	28.00	4.00	2.00	9.00	1
December, 2016	28.00	17.00	73.00	37.00	4.00	2.00	62.00	4
January, 2017	20.80	16.30	72.60	37.60	3.90	2.70	0	0
February, 2017	28.70	15.10	54.62	18.31	6.34	0.83	0	0
Total							**160.50**	**24**
Mean	**26.10**	**18.24**	**69.04**	**38.78**	**4.16**	**2.54**		

Appendices II. Physical and chemical properties of experimental vineyard soil at (ICAR-IIHR) Indian Institute of Horticultura Research, Bengaluru during 2016 and 2017.

S. No.	Parameter	Values
1	Particle size distribution (%)	
	Sand	62.85
	Silt	10.90
	Clay	26.25
	Textural class	Red sandy loam
2	pH (1: 2.5)	6.10
3	EC (1:2.5) (dSm $^{-1}$)	0.31
4	Organic carbon (g kg $^{-1}$)	1.59
5	Available nitrogen (kg ha^{-1})	257.58
6	Available phosphorus (kg ha^{-1})	59.74
7	Available potassium (kg ha^{-1})	231.5
8	Exch. Ca (c mol (P +) kg $^{-1}$)	12.85
9	Exch. Mg (c mol (P +) kg $^{-1}$)	2.95
10	Sulphur (kg ha^{-1})	12.50
11	DTPA extractable Fe (mg kg^{-1})	9.85
12	DTPA extractable Mn (mg kg^{-1})	2.85
13	DTPA extractable Zn (mg kg^{-1})	1.65
14	DTPA extractable Cu (mg kg^{-1})	1.28