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THE EFFECT OF VITICULTURAL AND CHEMICAL PRACTICES ON ASSESSMENT OF POST HARVEST SHELF LIFE AND UNIFORM COLOUR DEVELOPMENT IN GRAPE CVS. RED GLOBE AND CRIMSON SEEDLESS

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ABSTRACT

It is a prerequisite that export grapes should have more shelf life to remain fresh for longer period and evenly coloured to fetch high price in the International market. Considering this, a trial was conducted in clusters collected from 4 years old vines of Red Globe and Crimson Seedless during 2015-16 and 2016-17. The obtained results revealed that, the minimum PLW was recorded in Red Globe (13.58 and 11.86%) and Crimson Seedless (23.56 and 15.53%), respectively in both seasons, the minimum percentage of fallen berries in Red Globe (2.52 and 1.01%), respectively in season-I and II whereas, in Crimson Seedless it reflected in season II (1.93%) by the application of berry thinning, ethrel dip (500 ppm) and basal leaf removal. The maximum total anthocyanins in Red Globe (2.80 and 4.54 mg/g FW), in Crimson Seedless (3.19 and 3.47 mg/g FW) was registered with similar treatment as stated above. The assessment for colour characteristics by colorimetric readings (L*, C, H and CRIG value) also reflected in similar application of treatment. Hence, the results stated that clusters treated with good viticultural practices along with ethrel dip resulted in maintaining the even colour development, quality and post harvest shelf life at ambient room temperature.

INTRODUCTION

Grape (*Vitis vinifera* L.) is considered as one of the major fruit crops occupying more than 1,38,000 ha area with a production of 29.67 lakh tonnes and productivity of 21.80 MT/ha which accounts for a production share of 3.25% among fruit crops in India (Anon, 2017). Among grape growing states, Karnataka stands second in area wise after Maharashtra. In mild tropics of Southern Karnataka, area under coloured grapes is increasing steadily due to exotic cultivars. It is a prerequisite that exported quality grapes should possess good shelf life and quality to fetch a good price in the market. In order to compete in the market, harvested grapes must retain their shelf life for at least few weeks at ambient room temperature (Morris *et al*., 1992). This study with improved viticultural practices applied at fruit set and veraison stage, combined with applications of the plant growth regulator ethephon, significantly improved the berry size, evenly coloured berries and packable yield. Thinning operation, besides improving the appearance of clusters, it helps in effective control of berry rotting as due to less compaction, even plant protection chemicals easily reaches to the interior areas that ultimately resulting in a better shelf life and quality of berries.

The commercial value of grapes is influenced mainly by the appearance and colour. Therefore, poor coloration of these coloured grapes, grown in mild tropical regions is a frequent problem that decreases production efficiency (Peppi *et al*., 2006). The coloration of grapes is related to anthocyanins, which are plant pigments responsible for the majority of blue, purple, and all tones of red found in flowers, fruits, some leaves, stems, and roots. On grapes, the accumulation of colour begins at veraison and seems to be regulated, atleast partially, by ethrel application. Often, 'Red Globe and Crimson Seedless' fails to achieve the desired level of red colour, which inhibit the accumulation of anthocyanins (Spayd *et al*., 2002), the class of pigments that impart red colour to berries (Peppi *et al*., 2006). Careful canopy management and good viticultural practices, and application of ethrel, optimize the colour of grapes (Dokoozlian *et al*., 1994), but even grapes subjected to these ideal cultural practices may remain poorly coloured, especially when grown in regions or seasons with suboptimal temperatures (Spayd *et al*., 2002; Tsomu *et al*., 2015). Various studies have suggested that the exogenous application of this plant growth regulator increases the anthocyanins and colour development of the berry skin with maturation (Cantin *et al*., 2007; Peppi and Fidelibus, 2008; Peppi *et al*., 2008).

The exotic cv. Red Globe have large clusters, weighing around 600-800 g. The flesh is crunchy and the berries have good post harvest storage characteristics. However, the reddish berry colour is commonly deficient in vigorous vines with excessive crop load. The lack of sunlight on these clusters also causes deficiency in berry colour (Kishino and Roberto, 2007). Crimson Seedless is a late-season, bright red and seedless cultivar that was initially bred in California (Ramming *et al.*, 1995; Mohsen, 2011). Its berries are firm, crisp and have good flavour; skin colour can vary from cherry red to black (Cameron, 2001). In India, as well as in other countries such as Australia, Chile, South Africa and California, obtaining an adequate red colour at harvest is a major problem (Cameron, 2001; Singh Brar *et al.*, 2008; Ferrara *et al.*, 2013). At least 30% of the fruits produced by this variety may remain on the vine un harvested due to inadequate red colour development, with negative consequences for the grower (Dokoozlian *et al.*, 1995).

The paper aims to evaluate the effect of various viticultural applications on the shelf life assessment and even colour development in coloured grapes.

MATERIALS AND METHODS

The present investigation entitled 'Effect of viticultural and chemical practices on assessment of post harvest shelf life and uniform colour development in coloured grapes cv. Red Globe and Crimson Seedless' was undertaken at Indian Institute of Horticultural Research, Bangalore during two consecutive years 2015-16 and 2016-17 on 4 years old vines on the effects of various viticultural practices *viz.*, berry thinning (at 8-mm berry size), basal leaf removal, bunch covering and ethrel application @ 500 ppm either in single or in combinations. All standard cultural practices were followed during the year of study. The cultivars Red Globe and Crimson Seedless was grafted onto Dogridge rootstock and trained on Y-trellis system, spaced at 2.5 m apart within rows, with 3 m between rows, and cane pruned.

Berry thinning *i.e.*, manual thinning was done at 8-10 mm stage with scissors when berries are at pea sized stage. From each cluster, 25 to 30% of berries are evenly removed to avoid cluster compactness. Manual thinning plays an important role in controlling crop and improves its quality and hastens the ripening (Cartechini, 1998). Ethephon (trade name Ethrel) is commonly applied to red pigmented table grape cultivars at the initiation of fruit ripening to enhance berry colour development. Basal leaf removal is a viticulture practice where the basal leaves of the shoot are removed at veraison stage which helped in more translocation of reserves towards bunches and better exposure to sunlight (Kriedemann *et al.*, 1969). Along with these viticultural practices, bunch covering at veraison stage was applied to see the treatmental variation. Apart from these, various combinations were implemented and compared with untreated control. The experiment was laid out in Randomized Block Design (RBD) with eight treatments and three replications. A total of three bunches were harvested replication and treatment wise and kept at ambient room temperature and observed visually for week days *i.e.*, Day-1 to Day-7, calculated for the following observations of physiological loss in weight (PLW), percentage of fallen berries, percentage of rotten berries, total anthocyanin content and colorimetric readings.

The randomly selected three bunches from each treatment was kept at ambient room temperature for the assessment of physiological loss in weight (PLW). Immediately after harvesting the treated bunches were weighed and considered as initial weight. On the subsequent seventh day, each replicate were again weighed and considered as final weight. Percent loss in weight for each treatment of observation was calculated using the following formula suggested by Srivastava and Tandon (1968). The mean physiological loss in weight (PLW) was worked out and expressed as percentage.

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

These PLW calculated clusters were also used for assessing the number of rotten berries per bunch from Day-1 until week days after harvest at ambient room temperature, the rotten berries from the bunch was separated, counted and expressed as per cent.

$$\text{Rotten berry (\%)} = \frac{\text{Total number of berries in a bunch}}{\text{Total number of rotten berries in a bunch}} \times 100$$

The similar clusters that are used for PLW were also used for assessing the number of fallen berries per bunch from Day-1 after harvest until week days and it was computed and expressed as percentage.

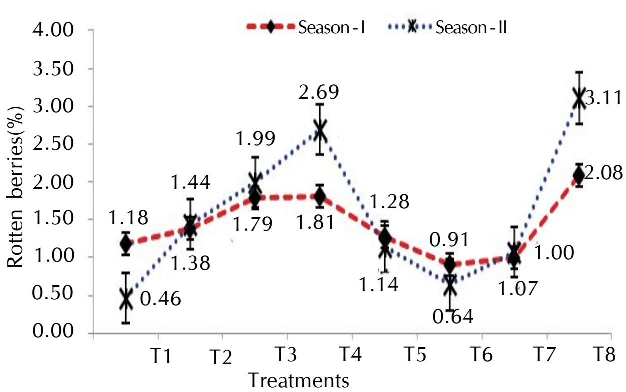


Figure 1: Effect of viticultural and chemical practices on berry rotten percentage in grapes cv. Red Globe

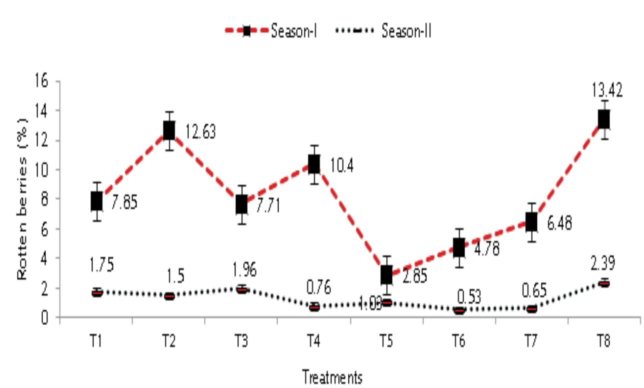
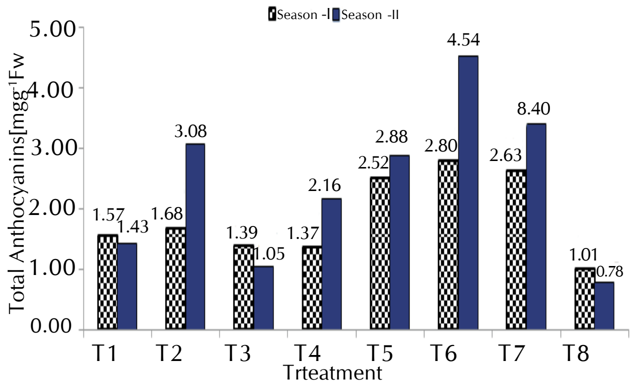
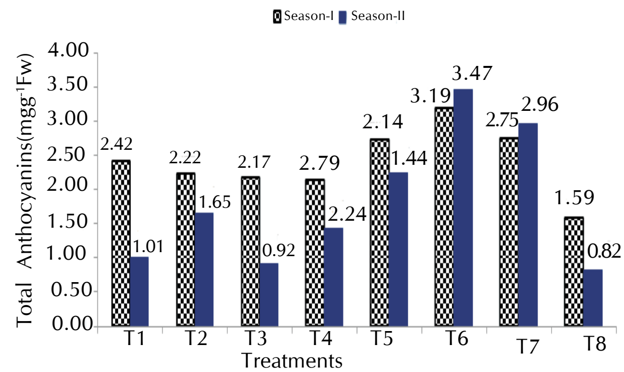


Figure 2: Effect of viticultural and chemical practices on berry rotten percentage in grapes cv. Crimson Seedless



Treatment details: T_1 –Berry thinning at 8-10 mm size; T_2 –Ethrel dip (500 ppm) at veraison; T_3 –Basal leaf removal at veraison; T_4 –Bunch covering at veraison; T_5 –Berry thinning + Ethrel dip (500 ppm); T_6- Berry thinning + Ethrel dip (500 ppm) + Basal leaf removal; T_7- Berry thinning + Ethrel dip (500 ppm) + Basal leaf removal + Bunch covering; T_8 - Control.

Figure 3: Effect of viticultural and chemical practices on total anthocyanins content in grapes cv. Red Globe



Treatment details: T_1 –Berry thinning at 8-10 mm size; T_2 –Ethrel dip (500 ppm) at veraison; T_3 –Basal leaf removal at veraison; T_4 –Bunch covering at veraison; T_5 –Berry thinning + Ethrel dip (500 ppm); T_6- Berry thinning + Ethrel dip (500 ppm) + Basal leaf removal; T_7- Berry thinning + Ethrel dip (500 ppm) + Basal leaf removal + Bunch covering; T_8 – Control.

Figure 4: Effect of viticultural and chemical practices on total anthocyanin content in grapes cv. Crimson Seedless

$$\text{Fallen berries (\%)} = \frac{\text{Total number of fallen berries in a bunch}}{\text{Total number of berries in a bunch}} \times 100$$

The method proposed by Cynkar (2004) was employed for quantification of total anthocyanin content. 1 g of berry skin sample was homogenized with acidic methanol (1:99) and further incubated for 48 h. The obtained mixture was ground and residue re-extracted with methanol (acidic) 2 to 3 times, later it was pooled and made upto 25 ml with acidic methanol. The intensity of colour was read at 540 nm by adjusting 100% transmission against AM (acidic methanol). The amount of anthocyanins in unknown sample was calculated using cyanidin hydrochloride as standard and expressed as mg/g fresh weight.

$$\text{Anthocyanins (mg/g FW)} = \frac{\text{A540} \times \text{Standard } (\mu g) \times \text{Final extract of volume} \times \text{Dilution Factor}}{\text{Wt. of the sample (g)} \times 1000}$$

Skin color is a key quality attribute required by the consumer. Fruit colouration is due to the presence of various pigments such as chlorophylls, carotenoids and anthocyanins (Singh Brar *et al*., 2008; Wei *et al*., 2011). Skin anythocyanin content has been used to infer grape berry colour, but anthocyanin content has a non-linear effect on berry colour characteristics such that relatively large differences in pigment content may have little effect on berry colour (Peppi *et al*., 2006, 2007a & b). Thus, we measured the surface colour of berries in each sample with a reflectance colorimeter, CR-10 (Konica Minolta Co., Ltd, Osaka, Japan). Three different measurements were taken at three equidistant points on the equatorial region of 10 berries from each treatment in tagged clusters and the obtained values were expressed in terms of L (lightness), C (chroma) and H (hue) values. L represented lightness of colour which ranged from 0 (black) to 100 (white). Chroma (c) represented the purity/saturation of a colour, which represented the purity or intensity of hue. Hue (H) was the actual colour of an object such as red, green, yellow, blue etc. and a hue angel of 0º = red; 90º = yellow; 180º= bluish green and 270° = blue (Sudhakar Rao and Shivashankara, 2015). The colour index for red grapes (CIRG) (Cantin *et al*., 2007) was then determined using the formula: CIRG = [(180 h°)/(L* + C*)] and the mean values for each sample were subjected to statistical analysis. CIRG allows an objective definition of the external colour in different red grape cultivars. Based on this index, the berries can be classified into five categories: green-yellow (CIRG<2); pink (2<CIRG<4); red (4<CIRG<5); dark red (5<CIRG<6); and blue-black (CIRG>6) (Carreno *et al*., 1996). The obtained results were subjected to statistical analysis by using online OPSTAT software and analyzed as per Panse and Sukhatme (1985) to separate the means at 5% level of significance.

RESULTS AND DISCUSSION

Grape is one of the prestigious fruit crops of India. Its cultivation has been found to be one of the most remunerative farming enterprises in the recent years. A grape being non climacteric fruit gets subjected to physiological deterioration and loss in weight during storage especially at ambient temperature (Biale, 1960). It is an important character to possess better shelf life at ambient room temperature for long distance transportation that fetches high price in the market.

The minimum PLW per cent in Red Globe (13.58 and 11.86%) and Crimson Seedless (23.56 and 15.53%) was recorded in clusters treated with combination of berry thinning, ethrel dip (500 ppm) and basal leaf removal in either of seasons and significantly superior over control (Table 1). The maximum loss in weight during season-I (18.72%) in Red Globe was registered with basal leaf removal, and at season-II (18.28%) recorded in control, whereas, in Crimson Seedless at season-I in control (32.83%), at season-II (21.01%) in bunch covering at veraison. The more PLW in untreated control was due to more compact clusters where thinning operation was not followed, more respiration rate, more microbial infection and finally more loss in weight. It inferred that the minimum PLW always leads to freshness of table grape, which ultimately shows

Table 1: Effect of various viticultural and chemical practices on post harvest shelf life attributes of grapes cv. Red Globe and Crimson Seedless

Treatments	Physiological loss in weight (%)				Percentage of fallen berries (%)			
	Red Globe		Crimson Seedless		Red Globe		Crimson Seedless	
	Season I (2015-16)	Season II (2016-17)	Season I (2015-16)	Season II (2016-17)	Season I (2015-16)	Season II (2016-17)	Season I (2015-16)	Season II (2016-17)
Berry thinning at 8-10 mm	14.63	16.95	25.44	17.06	5.53	1.12	6.82	2.43
Ethrel dip (500 ppm) at veraison	18.18	17.19	31.72	19.17	8.51	1.64	12.45	2.89
Basal leaf removal	18.72	17.53	26.54	20.28	8.36	1.32	11.19	2.52
Bunch covering at veraison	15.65	17.53	29.47	21.01	5.54	1.25	11.61	3.38
Berry thinning + Ethrel dip (500 ppm)	13.15	13.57	26.52	17.06	2.81	1.02	5.89	2.12
Berry thinning + Ethrel dip (500 ppm) + Basal leaf removal	13.58	11.86	23.56	15.53	2.52	1.01	6.70	1.93
Berry thinning + Ethrel dip (500 ppm)+ Basal leaf removal + Bunch covering	14.87	16.82	24.82	15.49	3.47	1.07	9.23	2.10
Control	17.78	18.28	32.83	20.72	9.97	2.30	12.45	5.99
CD (pd″ 0.05)	0.834	1.378	4.076	3.263	0.768	0.291	1.147	0.51
SE (m)±	0.272	0.450	1.331	1.065	0.251	0.095	0.375	0.167

Treatment details: T_1 –Berry thinning at 8-10 mm size; T_2 –Ethrel dip (500 ppm) at veraison; T_3 –Basal leaf removal at veraison; T_4 –Bunch covering at veraison; T_5 –Berry thinning + Ethrel dip (500 ppm); T_6- Berry thinning + Ethrel dip (500 ppm) + Basal leaf removal; T_7- Berry thinning + Ethrel dip (500 ppm) + Basal leaf removal + Bunch covering; T_8 – Control

Table 2: Effect of various viticultural and chemical practices on assessment of berry colour development using colorimeter in grapes cv. Red Globe

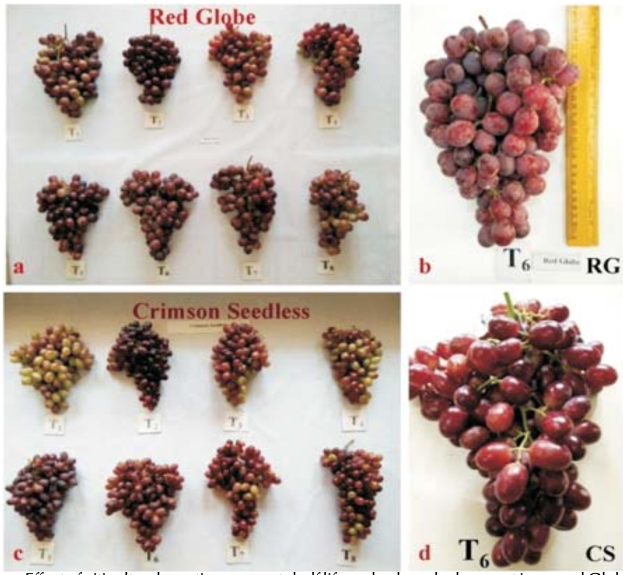
Treatments	Season-I (2015-16)				Season-II (2016-17)			
	L	c	h	CIRG	L	c	h	CIRG
Berry thinning at 8-10 mm	31.84	6.67	27.07	3.98	29.57	6.80	17.33	4.48
Ethrel dip (500 ppm) at veraison	28.09	5.53	18.19	4.82	28.75	6.83	16.88	4.58
Basal leaf removal	29.45	4.38	17.79	4.81	33.47	10.00	37.83	3.21
Bunch covering at veraison	29.06	4.47	20.23	4.77	34.19	9.49	28.10	3.48
Berry thinning + Ethrel dip (500 ppm)	26.85	5.81	16.85	5.00	26.07	7.13	13.39	4.63
Berry thinning + Ethrel dip (500 ppm) + Basal leaf removal	25.49	4.13	15.08	5.57	25.54	4.73	9.71	5.54
Berry thinning + Ethrel dip (500 ppm) + Basal leaf removal + Bunch covering	27.52	4.29	15.75	5.17	27.67	8.28	13.73	5.11
Control	36.30	8.02	42.83	3.10	34.60	11.02	40.70	3.12
CD (pd″ 0.05)	2.097	1.169	2.72	0.349	2.321	1.029	2.692	0.322
SE (m)±	0.685	0.382	0.888	0.114	0.758	0.336	0.879	0.105

Table 3: Effect of various viticultural and chemical practices on assessment of berry colour development using colorimeter in grapes cv. Crimson Seedless

Treatments	Season-I (2015-16)				Season-II (2016-17)			
	L	c	h	CIRG	L	c	h	CIRG
Berry thinning at 8-10 mm	28.27	7.33	32.92	4.15	32.78	9.96	39.81	3.28
Ethrel dip (500 ppm) at veraison	27.71	6.30	20.51	4.67	27.27	4.75	22.69	4.91
Basal leaf removal	27.87	7.09	24.54	4.45	32.71	8.24	39.32	3.44
Bunch covering at veraison	29.90	10.39	35.29	3.60	31.59	10.37	34.19	3.47
Berry thinning + Ethrel dip (500 ppm)	26.86	6.38	20.76	4.79	27.71	9.39	23.67	4.22
Berry thinning + Ethrel dip (500 ppm) + Basal leaf removal	26.70	4.08	21.30	5.13	26.27	4.22	21.67	5.19
Berry thinning + Ethrel dip (500 ppm) + Basal leaf removal + Bunch covering	26.77	8.32	21.71	4.56	28.16	7.59	22.42	4.41
Control	31.57	10.94	40.00	3.29	36.68	11.27	51.09	2.69
CD (pd+ 0.05)	2.594	0.84	3.232	0.320	1.094	0.997	5.704	0.191
SE (m)±	0.847	0.274	1.055	0.105	0.357	0.326	1.863	0.062

better shelf life where thinning as an important viticultural operation to be followed. This loss in weight was minimum during the first two days under the ambient temperature; however, the moisture loss from the berries in the form of PLW was more during the subsequent period of storage and this is mainly due to evaporation of water from berries, respiration and degradative processes occurring during storage (Harrd and Salunkhe, 1975). Moisture content of most of the non climacteric fruits is very high and weight loss occurs at a faster rate during storage and transport can be a serious economic factor. Similar observations were recorded with Kumar and Chharia (1990), Doshi and Adsule (2008), Gill *et al*. (2015).

The weak attachment of pedicel to the berries in a bunch leads to berry fall. Among the various viticultural practices followed, minimum range (1.01-5.89%) of berry fallen



a: Effect of viticultural practices on post shelf life and colour devlopment in cv. red Globe

b: The best treatment, berry thininh (8mm stage) + Ehtrel dip (500 ppm) + Basal leaf removal in Red Globe

c: Effect of viticultural practices on post harvest shelf and colour devlopment in grapes cv. Crimon Seedless

d: The best treatment, berry thining (8mm stage) + Ehtrel dip (500 ppm) + Basal leaf removal in Crimson Seedless

Figure 5: Effect of viticultural and chemical practices for improvement in shelf life and uniform colour development in grape cvs. Red Globe and Crimson Seedless

percentage was recorded in grapes which are treated as compared to 5.99-9.97% in untreated grapes on seventh day (Table 1). The minimum fallen berries percentage was recorded in bunches treated with combination of berry thinning, ethrel dip (500 ppm) and basal leaf removal in both the seasons of Red Globe and in Crimson Seedless at season-II, whereas, at season-I, thinning and ethrel dip registered lower percentage. This could be attributed to the increase in pedicel thickness and also due to less compact clusters which allowed for proper development and firm attachment. This reduced berry fall due to increased pedicel thickness was also observed by Rao and Nalwadi (1968) in Anab-e-Shahi and Pandheri Sahebi grapes.

The difference for percent berry rot was also recorded in selected bunches, during the first year crop in Red Globe, the combination of berry thinning + ethrel dip (500 ppm) + basal leaf removal recorded the lower percent of rotten berries (0.91%) followed by berry thinning + ethrel dip (500 ppm) + basal leaf removal + bunch covering (1.00%) and the maximum (2.08%) in control. With respect to second season, berry thinning at 8-10 mm recorded minimum percentage (0.46%) and it follows by combination of berry thinning, ethrel dip (500 ppm) and basal leaf removal (0.64%) and the maximum (3.11%) in control was registered in Red Globe (Fig. 1). During season-I in Crimson Seedless, the combination of berry thinning and ethrel dip (500 ppm) recorded the lower percentage of rotten berries (2.85%) followed by combination of berry thinning + ethrel dip (500 ppm) + basal leaf removal (Fig. 2). The maximum percentage of rotten was registered in untreated control (13.42%). During the second year crop, a similar result as Red Globe during season-I and the maximum rotten percentage in control (2.39%). This higher percentage of rotten berries in control might be due to more compact bunches, where more respiration rate and microbial infection occurred. Thinning practices along with ethrel dip and basal leaf removal, besides improving the appearance of bunches, also helps in effective control of berry rot due to less compact clusters, ultimately resulting in a better quality produce. Similar results were reported by Doshi and Adsule (2008) and Somkuwar *et al*. 2008.

The commercial value of grapes is influenced by their appearance, including colour. Therefore, poor colouration of red grapes, such as 'Red Globe and Crimson Seedless', grown in slight warm regions is a frequent problem that decreases production efficiency. Skin colour of grapes, which is mainly determined by the content and composition of anthocyanins (Baranac *et al*., 1997), is one of the most important quality characters that determine its market value (Fig. 5). Therefore, there is a great interest in promoting the anthocyanin biosynthesis during grape berry development, for both economic and health reasons.

Among the treatments, the maximum total anthocyanin content in Red Globe (2.80 and 4.54 mg/g FW), in Crimson Seedless (3.19 and 3.47 mg/g FW) in either of seasons was recorded in clusters treated with berry thinning, ethrel dip (500 ppm) and basal leaf removal, which was significantly superior over control (Red Globe, 1.01 and 0.78 mg/g FW) (Crimson Seedless, 1.59 and 0.82 mg/g FW) (Fig. 3 & 4). In grapes, anthocyanin accumulation begins at veraison, with the onset of maturation. In general, grapes have high skin anthocyanin content will appear darker and more-red coloured, than grapes having low anthocyanin content. As the growth and development advanced the chlorophyll content in the berries decreased with the increase in the anthocyanin pigmentation in the berries after veraison. Skin anythocyanin content has been used to infer berry colour. Some of the workers stated that careful canopy and crop management, as well as application of ethephon, optimize the colour of Crimson Seedless grapes (Dokoozlian *et al*., 1994). A plausible cause for this change in colour by these plant growth regulators may be the induction of increased expression of some transcription factors and structural genes in the phenyl propanoid pathway, leading to anthocyanin accumulation (Peppi *et al*., 2008; Gagne *et al*., 2011).

Skin anythocyanin content has been used to infer grape berry colour, but anthocyanin content has a non-linear effect on berry colour characteristics such that relatively large differences in pigment content may have little effect on berry colour (Peppi *et al*., 2006, 2007a & b). Thus, we measured the surface colour of berries in each sample with a reflectance colorimeter.

L* value indicates brightness has increased gradually from bright red coloured/uniform colour to low coloured/uneven colour berries or vice versa. Chroma (c) represented the purity/saturation of a colour, which represented the purity or intensity and hue was the actual colour of an object. In Red Globe, the combination of berry thinning + ethrel dip (500 ppm) + basal leaf removal showed lower L* value (25.49 and 25.54) and it followed by berry thinning and ethrel dip (26.85 and 26.07) in season-I and II, respectively (Table 2). The maximum L* value *i.e.*, towards more brightness or less coloured berries in control (36.30 and 34.60) was registered and in Crimson Seedless (26.70 and 26.27) was resulted similar as in Red Globe. Whereas, the maximum L* value in CS *i.e.*, towards more lightness or less coloured berries in control (31.57 and 36.68) was obtained (Table 3). During berry development, L* values decreased consistently in all treatments from veraison to harvest. Lightness decreased to a greater extent in treated clusters than control. In this study all the treatments with ethrel dip combinations had shown low lightness (L* value) or more bright red coloured in either Red Globe or Crimson Seedless, indicating that the berries subjected to these practices had a darker colouration (Fig. 5). During berry development stage, L* values decreased consistently in all treatments from veraison to harvest. The untreated clusters had significantly higher L* values than treated with ethrel combinations.

Irrespective of cultivars used, clusters treated with Berry thinning + Ethrel dip (500 ppm) + Basal leaf removal had lower C* values (Red Globe, 4.13 and 4.73) and (Crimson Seedless, 4.08 and 4.22) than untreated control (Red Globe, 8.02 and 11.02) and (Crimson Seedless, 10.94 and 11.27), respectively in season-I and II, suggesting treated berries had slightly less pure colour than non treated fruits (Table 2 & 3). However, this slight effect was not perceived by the unaided eye (Cantin *et al.*, 2007; Ferrara *et al.*, 2013; Sharma *et al.*, 2016). Similar results were found by Peppi *et al.* (2007a) with 'Red Globe' grapes, and by Peppi *et al.* (2008) with 'Crimson Seedless.

The hue angle (H) decreased during berry development in all treatments except control, dropping from a value of 42.83 (control) to a range of 9.71 in Red Globe (Table 2). A similar result was seen in Crimson Seedless, the lowest H value (21.30 and 21.67, respectively in season-I and II) in combinational practices (Table 3). This dramatic decrease was observed in the combination of Berry thinning + Ethrel dip (500 ppm) + Basal leaf removal treatment and the maximum H (hue) angle in control (Red Globe, 42.83 and 40.70) (Crimson Seedless, 40.00 and 51.09) were registered. The similar results were observed in previous studies in cv. Crimson Seedless (Cantin *et al.*, 2007; Peppi *et al.*, 2007b; Lurie *et al.*, 2009; Ferrara *et al.*, 2015). Even though the treatments with ethephon alone or in combination improved colour characteristics of berries in this trial, it is important to emphasize that this plant growth regulator can cause the clusters to soften, reducing the commercial value of the grapes; however, this effect is not always expected (Peppi *et al.*, 2007a).

CIRG colour index confirming that a uniform standard was used to select fruit for harvest and packing (Fig 5). Based on the CIRG colour index, all coloured grapes could be classified as pink coloured to dark red ($2 < CIRG < 4$) (Carreno *et al.*, 1995). Irrespective of cultivars used, bunches treated with Berry thinning + Ethrel dip (500 ppm) + Basal leaf removal had higher CIRG values (Red Globe, 5.57 and 5.54) and (Crimson Seedless, 5.13 and 5.19) than untreated control (Red Globe, 3.10 and 3.12) and (Crimson Seedless, 3.29 and 2.69), respectively in season-I and II, suggesting treated berries had higher CIRG value than control (Table 2 & 3). CIRG allows an objective definition of the external colour in different red grape cultivars. Based on this index, the berries were classified into five categories: green-yellow ($CIRG < 2$); pink ($2 < CIRG < 4$); red ($4 < CIRG < 5$); dark red ($5 < CIRG < 6$); and blue-black ($CIRG > 6$) (Carreno *et al.*, 1996). The behavior of the CIRG index and colour parameters L*, C* and hue (H) were similar to those observed in previous studies in cv. Crimson Seedless (Cantin *et al.*, 2007; Peppi *et al.*, 2007; Lurie *et al.*, 2009; Ferrara *et al.*, 2013, 2015). In general, the combination of these good viticultural practices along with ethrel dip have favoured bunches with a significant effect on colour development, accelerating the pigmentation process of the grapes.

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