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Effect of climate on the quality and berry coloration of red globe grape variety with cold storage ability in Eğirdir/Isparta

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Abstract. Regional climatic conditions can have a dramatic effect on the degree and rate of natural grape coloration and quality parameters. In this study it was aimed to evaluate effect of the climate for Red Globe variety cultivated in Lakes Region which is in Eğirdir town of Isparta city in Turkey. Red Globe grape variety was evaluated for quality and especially for berry skin coloration and cold storage ability. Study was done between 2013–2015. Vineyard was designed according to randomized block design with three replicates. Rational pergola system was used. Excellent berry coloration for Red Globe grape variety was determined and average quality parameters yield per vine (7.0–9.8 kg), soluble sugar content %16.–17.6) titratable acidity (4.2–4.4 g/lt), single berry weight (9.0–10.2 g), and phenological observations were done. Yield and other quality parameters were evaluated well in this period. Grapes were stored in cold storage (NA) conditions with SO_2 and without SO_2 pads after harvest. Quality changes were determined in storage period by 1 month interval, it was carried out with weight loses, fruit skin color, fruit firmness, total soluble solids, pH, titratable acidity, sensual evaluations, microbiological and shelf life analyzes. It was evaluated that with SO_2 pads Red Globe variety can be stored commercially up to 90–100 days. It was determined that climate of the region had a good positive effect on the excellent coloration and quality parameters and cold storage performance of the Red Globe.

1. Introduction

Grape (*Vitis vinifera* L.) is considered as one of the most important commercial fruit crops of temperate to tropical regions [1]. The grape is gaining popularity for its high nutritive value, excellent in taste, multipurpose use and better returns [2]. Turkey lies on the most convenient temperate zone for viticulture around the world is among the countries which have a voice throughout the world with its vineyard and yield values. Today, almost 77 million tones of world grape production that is almost 4 million tones are yielded in Turkey [3] and this production is characterized as primary table grapes (53%) and as secondary raisin yield (35%) [4]. Table grape production relies upon numerous viticulture practices to ensure good yield and superior quality.

Climate is a pervasive factor in the success of all agricultural systems, influencing whether a crop is suitable to a given region, largely controlling crop production and quality. Climate influences on grapevine quality must be considered at the macroscale (synoptic climate) to the mesoscale (regional climate) to the toposcale (site climate) to the microscale (vine row and canopy climate). Climate is clearly one of the most important factors in the success of all agricultural systems, influencing whether a crop is suitable to a given region, largely controlling crop production and quality, and ultimately driving economic sustainability [13]. While decisions about what to crop to grow commercially are largely driven by regional history and tradition, they are also influenced by regional to international economics. However, both tradition and economics are ultimately driven by the ability to grow the crop sustainably within a given climate [14]. Research on climate trends and future projections for table grape production is limited. However, recent research on aspects of global environmental change on wine grape production reveals significant changes but also many unknowns [27]. From a general climate perspective, wine regions worldwide have seen changes in average climate structure producing warmer and longer growing and dormant periods [28].

Global table grape markets demand high quality fruit with size, firmness, sugar and color attributes that meet local and export market requirements. Commercial standards for red colored grapes place great emphasis on the intensity and uniformity of color in both the berries and the overall cluster. All the factors that influence color development in red table grapes the ones that have the greatest impact and are least controllable are the regional climate and weather conditions. The increase in temperatures is likely to continue, allowing future wine production in areas that are presently too cold for vine cultivation, whereas the present grape growing regions will have to adapt to these changes [5,6]. The impact of climate change on wine production will presumably vary according to the type of wine produced and the geographical location, with milder effects expected in coastal regions [6–8]. If phenological stages advance, the maturation of berries is likely to take place under warmer conditions. Experiments have shown that the accumulation of anthocyanins, which are responsible for berry coloration, is lower when maturation occurs at higher

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temperatures [5]. During grape production, skin coloration and total soluble solids of the flesh are the most important factors influencing quality. It is well known that coloration of grape berry skin is influenced by various environmental conditions; therefore, coloration is used as an index for ripening [9,10]. Red Globe variety has sometimes coloration problems where it is cultivated and desired berry homogenous coloration was not got generally several studies have reported that normal coloration of grape berry skin resulted from the accumulation of anthocyanins under cool conditions during the ripening stages of grape fruits. While cool conditions are favorable to berry skin coloration, a continuous high temperature generally inhibits accumulation of pigments such as anthocyanins in the skin of grape berries [11,12].

In the Lakes Region (Mid-Western Turkey), the 'red Globe' variety is initially cultivated for both table and cold storage. Isparta and Burdur cities and its districts of the Lakes Region are the intensive grape producing regions with most of the packing houses located in these cities. In this region, the 'Red Globe' prices are at their lowest level when the supply peaks for the fresh market. The table grape prices are at about 10–20% while in November they rise to about 50–70% higher than the September prices. Therefore, there is a definite need for supplying the 'Red Globe' grapes for longer periods, both for the export and domestic markets. The harvest can be delayed if the grapes are stored in the on-vine or under cold conditions.

As the cold storage capacity is rather limited, excessive quantities of grape cannot be stored. On-vine storage appears to be the most convenient solution. In practicing on-vine storage, climatic and pathological problems may affect storage life, resulting in a drop in the grape quality. Table grapes constitute a major world crop, which can be stored for as long as 4 months under optimal conditions ($-1\sim0\,^{\circ}$C and 90∼95% RH). A primary difficulty associated with prolonged storage of table grapes is grey mold, caused by *Botrytis cinerea* [15–17], invading grape flowers and berries by different infection pathways including directly penetration or through wounds [18,19]. Following the establishment of fungal hyphae, *B. cinerea* may become inactive for long periods with no symptoms in grapes until the fungus is reactivated during storage [19].

Postharvest problems like berry shattering, decay and stem desiccation are some of the important factors that limit the marketing of table grapes. Gray mold, caused by *Botrytis cinerea* Pers., is the most economically important postharvest disease of table grapes. In spite of the fact that the use of sulfur dioxide in controlling gray mold is common practice, it has some advantages.

The storage life of table grapes is influenced by the preharvest ecological conditions, fruit maturity at harvest and pre-cooling, SO_2 fumigation and storage conditions, including the temperature and relative humidity during post-harvest handling [20–22]. Grape deterioration during storage is characterized by weight loss, stem browning, softening, shattering and decay [23].

The objective of this study that is to evaluate effect of the climate for Red Globe variety in Lakes Region which is in Eğirdir town of Isparta city in Turkey. In our study Red Globe grape variety was evaluated for yield, quality and especially for berry skin coloration and cold storage ability with SO_2.

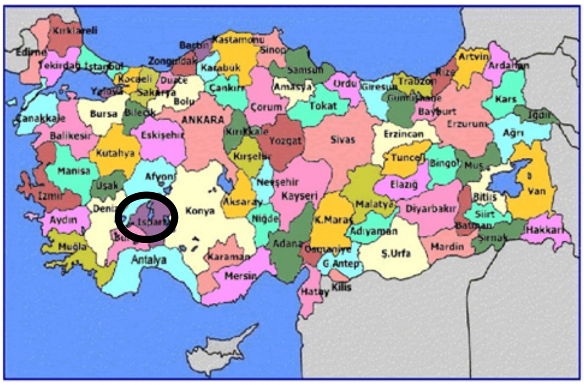

Figure 1. Turkey Map and Isparta City.

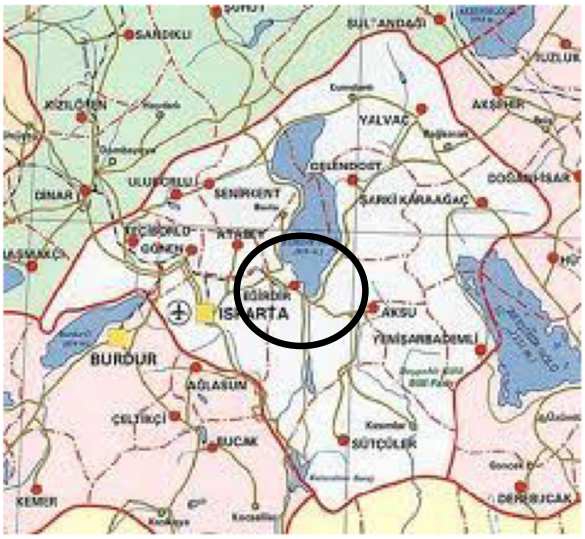

Figure 2. Lakes Region and Egirdir town.

Table 1. Some Climatic data of the experiment area.

Year	Avg. Temperature (°C)	Min. Temperature (°C)	Max. Temperature (°C)	Avg. Precipitation (mm)	Avg. Humidity (%)
Average	12.2	−14.9	38.6	764	66.5
2012	12.9	−12.7	38.6	622	68.9
2013	13.1	−7.9	34.1	654	63.7
2014	13.4	−6.3	36.1	669	70.9
2015	12.8	−10.7	35.1	849	67.4

2. Material and method

This experiment was conducted during the 2013–2014 and 2014–2015 growing season. This study was carried out in Egirdir Fruit Research Institute farmlands. Egirdir is a district of Isparta. Its altitude is 920 m high and it represents passing zone climate and ecological conditions. Geographical coordinates of Egirdir district; are 37° 50′ 41″, 38° 16′ 55″ N latitude, 30° 57′ 43″, 30° 44′ 39″ E latitude [19,20]. Isparta is known to have ideal ecological conditions for viticulture in Lakes Region where Isparta is located (Figs. 1 and 2). Average rainfall is between 445–849 mm, and temperature varies between −14°C and + 37°C (Table 1).

Soil analyses were done in Egirdir Fruit Research Station Soil analyses laboratories. Soil analyses report is on Table 2. According to soil analyses 140 R rootstock

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Table 2. Soil analyses of the experiment area.

Physical Analyses		
	Texture	Clayish Loam
	pH	7.78
	Lime (%)	9.8
	Saturation (%)	49
Chemical Analyses		
	Organic matter (%)	2.8
	N (ppm)	1617
	P (ppm)	4.52
	K (ppm)	221.1
	Ca (ppm)	4679
	Mg (ppm)	492
	Na (ppm)	13.48
	Fe (ppm)	13.64
	Cu (ppm)	4.23
	Mn (ppm)	6.25
	Zn (ppm)	1.04

was chosen for its good performance and vigorous development for Red Globe grape variety according to soil report.

2.1. Plant material

Vineyard was established with in row with spacing 2 m × 3 m with drip irrigation and on Red Globe variety grafted on 140R rootstock. Soil is in clayish loam texture with 7, 70 pH and contains lime. Vines were trained to rational pergola system and spur pruning system. Canopy height of the pergola system was 2.20 m. At the time of the winter pruning, the vines were cordon-pruned and leaving 4 cordons and there were 5 arms of 3/4 spur on each cordon.

140 R is a very hardy rootstock suitable for the most challenging drought conditions. It is also able to tolerate active lime up to 20% and is adapted to acid soils. 140 R has good tolerance to saline conditions and is able to exclude grape juice chloride and sodium in saline conditions to a significantly greater extent than *Vitis Vinifera* as well as most other rootstocks, it is also suitable for sites susceptible to drought as well as those with high salinity. 140 R has a long vegetative cycle which may delay ripening or cause excessive vigor on high growth potential sites in cooler regions.

Red-Globe is a table grape variety introduced from North America. It has a long shelf life, is easy to transport, and is suited to planting in arid or semi-arid areas with trellises. Red Globe is an attractive variety of pink slightly purple colored large round berries with fleshy pulp. The attractive clusters of Red Globe contain large-sized, seeded berries. The Red Globe is popular for both direct consumption as well as decorating a variety of food preparations and suitable for storing in cold.

2.2. Experimental methods

Following measurements were taken in 2013–2014 and 2014–2015 vegetation periods for this study.

2.2.1. Yield Quality and colour analysis

After harvesting, total yield (g) were determined and 50 berries were sampled from each replication, then sampled

Figure 3. A picture from the Red Globe vineyard study area.

Figure 4. Red Globe cluster from the vineyard.

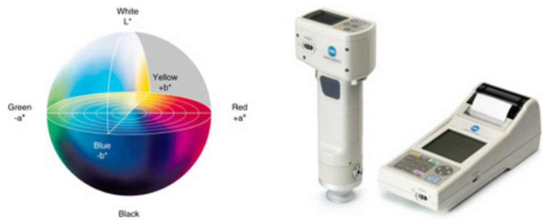

Figure 5. Color chart and by Minolta Co (CR-300) colorimeter.

berries from each replication were weighed and average berry weight (g) was determined. Color measurements (L, a, b, Chr, Hue) were made by Minolta Co (CR-300). Also CIRG index (Color Index of Red Grapes) was estimated according to the (16). Berries were squeezed for each replication and the percentage of total soluble solids percentage (TSS %) was measured by the refractometer. Also juice pH was measured by pH meter. Total titratable acidity percentage (TA %) was measured by titrating the berry juice with 0.1 N NaOH. The TA% was expressed as grams of tartaric acid per 100 ml of juice [18].

Trial is designed as randomized blocks with 3 replications, and each replication comprised 10 vines. Results are evaluated by Jump 7.0 JMP statistical software package. Data were subjected to analysis of variance and differences among averages were evaluated by LSD test.

2.2.2. Sampling and storage conditions

Grapes were harvested when they reached to the maturity index that is accepted. During first year of the study, the grapes were harvested on September 29th, whereas in the second year, the harvest was on October 1st. Grape clusters (total weight about 5 kg) were placed in 30 × 40 × 15 cm PE bags and boxed. The boxes were transferred to the precooling room (−0.5° C, 95% RH) for 24 hours and prepared for storage temperature. Then, SO_2-generating pads were used according to the supplier's recommendations, with 1.2–1.4 g kg^{-1} $Na_2S_2O_5$ being distributed in one polyethylene SO_2-generating pad (Fresca, Quimetal, Santiago, Chile) with a fast and a constant slow release phase of SO_2, placed above the grapes inside the polyethylene bag. In the first year, the grapes were preserved for 120 days and in the second year for 120 days in storage at −0.5°C and 90% RH. Untreated application was done as control in two years period. Quality changes were determined that occurred throughout the storage period by 1 month interval, it was carried out with weight loses, fruit skin color, fruit firmness, total soluble solids, pH, titratable acidity, sensual evaluations, microbiological. During storage, every box was accepted as a replication.

2.2.3. Quality assessment, Sensory analysis in cold storage

The external color of the berries was measured at the equatorial area of each grape face, using a colorimeter and the average scores were recorded in terms of CIE-$L^*a^*b^*$ values [24]. The color values were recorded as L^*, a^* and b^* values representing the light-dark spectrum with the range from 0 (black) to 100 (white), the green-red spectrum ranging from −60 (green) to +60 (red) and the blue-yellow spectrum ranging from −60 (blue) to +60 (yellow) dimensions, respectively. The colorimeter has a viewing area, 8 mm in diameter, calibrated with a white tile. The color of 25 berries was measured for each replication. The total soluble solids (TSS) content of the juice was determined with a digital refractometer (Atago PR-1, Tokyo, Japan) and expressed as percentage. Titratable Acidity (TA) was measured by titration with 0.1 N NaOH to pH 8.1. The results were expressed as g tartaric acid/100 ml fruit juice. The maturity index was calculated as the TSS/TA ratio [25].

Six panelists trained in the discriminative evaluation of table grapes conducted the sensory analysis. The SO_2 taste and odor were evaluated on a three-point scale (1: none; 2: moderate; 3: severe). Visual appearance, flavor and crunchiness of grapes were evaluated on a nine-point scale (1: extremely poor or soft in texture; 3: poor or soft; 5: moderate and limit of marketability; 7: good; 9: excellent) according to. [26]. Rachis condition was then rated according to [20], as follows: (1) healthy = entire stem including the pedicels being green and healthy, (2) slight = stem in good condition, but with noticeable browning of pedicels, (3) moderate = browning of the pedicels and secondary stem or (4) severe = pedicels, secondary and primary stem completely brown.

3. Results and discussion

3.1. Yield quality and color analysis results

Evaluations, findings and observations were obtained as a result of these analyses and measurements related to yield quality and color are given in tables 3, 4, 5, 6, 7. Excellent berry coloration for Red Globe grape variety was determined in three years period without any other chemical treatments (ABA, ethephon e.t.c) in the trial when compared to previous studies. It was evaluated with

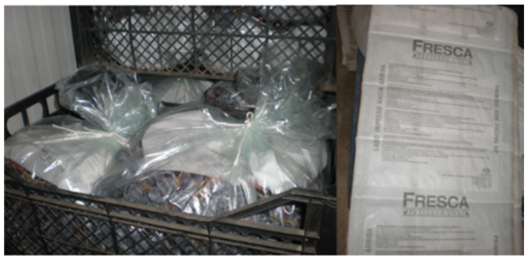

Figure 6. Red Globe boxes in cold storage and SO2 pad used.

Table 3. Phenologic stages of Red Globe variety between 2013–2015.

Variety	Bud Burst Time	Inflores. time	Berry colour set time	Harvest Harvest
Red globe	15–25/04	14–16/06	07–16/08	29–09/01–10

Table 4. Measurements and analyses performed in 2013–2014 year.

Fresh grape yield kg/vine	Av. bunch (g)	100 berry w.(g)	Total soluble solids (%)	Titra. acidity (g/l)	Maturity index
7.4	819	9.1	16.1	4.2	38.3
8.1	788	8.6	17.8	4.4	40.4
7.6	717	9.8	17.2	4.1	41.9

Table 5. Measurements and analyses performed in 2014–2015 year.

Fresh grape yield kg/vine	Av. bunch (g)	100 berry w.(g)	Total soluble solids (%)	Titra. acidity (g/l)	Maturity index
9.2	826	10.2	17.3	4.0	43.2
8.5	847	9.4	18.1	4.3	42.1
8.4	785	9.1	17.5	4.2	41.6

dark red violet color (OIV code 225) with average L 36.55, a 2.05, b −3.31, c 4.21, h 293.57 values measured by Minolta CR-400 colorimeter. Excellent coloration was due to favorable climatic condition of the Lakes Region Climate. Also climatic data was recorded in every year and three years average quality parameters yield per vine (7.0–9.8 kg), soluble sugar content % 16.–17.6) titratable acidity (4.2–4.4 g/lt), single berry weight (9.0–10.2 g), bunch weight and phenological observations were done in every year. Yield and other quality parameters were evaluated well in three years period.

Red Globe variety was evaluated in the study, all phenological stages were determined (table 3) Buds burst time, inflorescence time, verasion (berry colour set time) period and harvest time were given in for 2 vegetation years in table 3. Buds burst time was in the between 15–25 April in Full blossom time in was in the middle of June. Generally Red Globe variety was harvested at the end of the September and in the first week of October in the study.

3.2. Quality assessment, Sensory analysis in cold storage results

Grapes were stored in cold storage (NA) conditions with So2 and without SO_2 pads (control treatment) after harvest. Quality changes were determined that occurred throughout the storage period by 1 month interval, it

Table 6. Average colour measurement values of 2013–2014 and 2014–2015 years.

Year	L	a	b	c	h
2013 2014	36.5 a	2.05 a	−3.3 a	4.21 a	293.5 a
2014 2015	37.4 a	1.88 a	−3.8 a	4.54 a	289.4 a

**Grouping with same letter are not significantly different.*

Table 7. Cold storage average quality analyses in 2013–2014 period.

Treatment	Days	Weight Loss (kg)	Total soluble Solids %	pH	Titra. Acidity (g/l)
SO2 treated	0	5.00	16.0	3.03	4.6
SO2 treated	30	4.88	16.4	3.11	4.5
SO2 treated	60	4.70	16.5	3.06	4.7
SO2 treated	90	4.70	16.5	3.15	5.1
SO2 treated	120	4.56	16.6	3.17	5.2
Average		4.76 a	16.4 b	3.10 a	4.8 a
Untreated	0	5.00	16.0	3.03	4.6
Untreated	30	4.60	16.4	3.16	4.6
Untreated	60	4.36	16.6	3.21	4.9
Untreated	90	4.25	17.0	3.23	5.2
Untreated	120	4.15	17.4	3.26	5.5
Average		4.47 b	16.7 a	3.17 a	4.9 a

**Grouping with same letter are not significantly different.*

Table 8. Cold storage average quality analyses in 2014–2015 period.

Treatment	Days	Weight Loss (kg)	Total soluble Solids %	pH	Titra. Acidity (g/l)
SO2 treated	0	5.00	16.5	3.08	4.6
SO2 treated	30	4.91	16.7	3.15	4.4
SO2 treated	60	4.82	16.4	3.16	4.8
SO2 treated	90	4.70	16.8	3.20	5.0
SO2 treated	120	4.62	16.8	3.16	5.0
Average		4.81 a	16.6 a	3.15 a	4.76 b
Untreated	0	5.00	16.5	3.08	4.6
Untreated	30	4.68	16.4	3.14	4.8
Untreated	60	4.52	16.8	3.26	5.1
Untreated	90	4.35	17.0	3.28	5.3
Untreated	120	4.21	17.0	3.31	5.3
Average		4.52 b	16.7 a	3.21 a	5.0 a

**Grouping with same letter are not significantly different.*

was carried out with weight loses, fruit skin color, total soluble solids, pH, titratable acidity, sensual evaluations, microbiological analyzes.

In both years of the study, much deterioration was observed during the 60 days of storage. However, in the both, at the end of 90, 120 days of storage, moderate deterioration (spotting or decay up to 1/5-2/5 of the bunch) was observed in the grapes with untreated treatment. *Botrytis cinerea* was identified to be the causal agent of decay. Grapes sampled on the 120th day of storage with untreated application were discarded for the analysis, as they had lost marketability.

While the effect of the covering materials on the L^* color Values was significant in both year The L^* values of the grapes treated were higher during the pre-storage and

Table 9. Cold storage average color analyses in 2013–2014 period.

Treatment	Days	L	a	b	c	h
SO2 treated	0	36.5	2.05	−3.3	4.21	293.5
SO2 treated	30	36.1	2.02	−3.2	4.18	291.3
SO2 treated	60	35.7	1.99	−3.2	4.15	286.4
SO2 treated	90	35.5	1.95	−3.0	4.10	280.1
SO2 treated	120	35.0	1.94	−2.9	4.08	278.2
Average		36.6 a	1.99 a	−3.1 a	4.14 a	285.1 a
Untreated	0	36.5	2.05	−3.3	4.21	293.5
Untreated	30	35.1	1.95	−3.0	4.11	287.5
Untreated	60	34.8	1.81	−2.8	4.02	275.1
Untreated	90	33.6	1.78	−2.6	3.92	269.4
Untreated	120	33.2	1.74	−2.5	3.87	264.8
Average		34.6 b	1.86 b	2.8 b	4.02 b	277.2 a

**Grouping with same letter are not significantly different.*

Table 10. Cold storage average color analyses in 2014–2015 period.

Treatment	Days	L	a	b	c	h
SO2 treated	0	37.4 a	1.88	−3.8	4.54	289.4
SO2 treated	30	36.4 a	1.85	−3.6	4.36	290.2
SO2 treated	60	35.3	1.80	−3.4	4.13	284.5
SO2 treated	90	35.0	1.77	−3.3	4.11	281.2
SO2 treated	120	34.6	1.73	−3.0	4.07	277.5
Average		35.7 a	1.80 a	3.4 a	4.28 a	284.3 a
Untreated	0	37.4	1.88	−3.8	4.54	289.4
Untreated	30	34.8	1.70	−3.2	4.08	286.5
Untreated	60	34.0	1.59	−3.0	4.00	273.0
Untreated	90	33.2 b	1.54	−2.6	3.89	267.2
Untreated	120	32.7 b	1.51	−2.2	3.82	262.4
Average		34.4 b	1.64 b	2.9 b	4.06 b	269.1 b

**Grouping with same letter are not significantly different.*

Table 11. Cold storage average sensory analyses in 2013–2014 period.

Treatment	Days	So2 taste and Odor	Rachis Rachis	Visual app. Flavor, Crunchiness
SO2 treated	0	1	1	9
SO2 treated	30	1	1	7
SO2 treated	60	1	1	7
SO2 treated	90	3	2	7
SO2 treated	120	3	2	5
Untreated	0	1	1	9
Untreated	30	1	2	7
Untreated	60	1	2	5
Untreated	90	1	3	5
Untreated	120	1	4	3

60th day of storage in the first year. In the last sampling period, the differences among the effects on the L^* color values were significant (Tables 9, 10). The effects of the treatment SO_2 on the a^* color values of the grapes during storage was significant in both study years. The a^* colour values ranged between 2.05 and 1.74 in the first year and between 1.88 and 1.51 in the second year (Tables 9, 10). The b^* color values of the grapes varied between −3.8 and −2.2.

Grapes were evaluated with respect to visual appearance, flavor and crunchiness in storage. SO_2 treated application on the 60th and 90th day of storage the scores

Table 12. Cold storage average sensory analyses in 2014–2015 period.

Treatment	Days	So2 taste and Odor	Rachis Rachis	Visual app. Flavor, Crunchiness
SO2 treated	0	1	1	9
SO2 treated	30	1	1	7
SO2 treated	60	1	1	7
SO2 treated	90	1	2	7
SO2 treated	120	3	2	5
Untreated	0	1	1	9
Untreated	30	1	2	7
Untreated	60	1	3	5
Untreated	90	1	3	3
Untreated	120	1	4	3

were between 7 (good) in both study years. In both years, at the end of the storage (120th day) the grapes untreated with untreated scored 3 in 90 120 days. Neither the taste nor odor was observed at moderate or severe levels during storage in both study years. In both years, only at the end of 90, 120 days storage period, untreated scored 3 with respect to stem browning (Tables 11, 12).

4. Conclusion

Region's ecological characterics showed that late time maturated table grape varieties are more important for production. Lakes region has no chance to produce earlier because of ecological conditions. There many place to produce earlier than Lakes Region in Turkey, so the late time maturated varieties are very important in the region for commercial production.

Fruit skin coloration is an important factor for especially red table grapes. Red Globe had gained well coloration according to other Red Globe cultivation areas without any chemical or etc. in the Lakes Region. This is a very good advantage for cultivating this variety in the region. It was determined that climate of the region had a good positive effect on the excellent coloration and quality parameters and cold storage performance of the Red Globe grape variety. It is advised to growers cultivate Red Globe variety to increase economical income in the region and also advised to the other regions which has same climate conditions. Producing the right grape variety (Red Globe) by the results of the study will contribute economically to farmers region and country.

It was evaluated that with SO_2 pads Red Globe variety can be stored commercially up to 90–100 days. It was determined that climate of the region had a good positive effect on the excellent coloration and quality parameters and cold storage performance of the Red Late time varieties were good for region's conditions. Especially coloration of late time harvested varieties were perfect in the region because of high differences night and morning temperatures. Region has a good potential cultivating late time varieties. Cool storage conditions are also suitable in the region. Stored table grapes can be given to trade well in the region by late harvest.

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