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Effect of different covering materials used during the pre-harvest stage on the quality and storage life of 'Sultana Seedless' grapes

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Abstract

Covering the grapevine rows to delay the maturity and harvest date became widely practiced in 'Sultana Seedless' vineyards. The research work was conducted to test different cover materials (polypropylene cross-stitch, life pack, mogul and transparent polyethylene) in respect to their effects on grape quality and storability. Harvest was delayed for one month in covered plots. Harvested grapes were packed and transferred to storage rooms after pre-cooling. During packing, the grape clusters were sealed in PE bags with sulphur dioxide pads. The grapes were stored for 90 days in the first year and 120 days in the second year, at –0.5°C and 90% RH. All the grape clusters were healthy and of marketable quality after 90 days of storage period. In the first year, at the end of the storage, only those grapes harvested from the rows covered with polypropylene cross-stitch showed fungal growth. The sensory quality scores revealed a lower level of preference after 120 days of storage. The effects of the covering materials tested were similar regarding grape quality and storage performance except the transparent polyethylene that damaged the grapevine leaves.

Keywords: table grape; cover type; delayed harvest; quality, storage.

Practical Application: Table grape production is an important activity in the western part of Turkey. The 'Sultana Seedless' grape's production and exports rank both dry and table are one of the highest in the world market. There is a definite need for supplying the grapes for longer periods, both for the export and domestic markets. The results presented in the paper will contribute to a wide range of grape producers not only in Turkey but in all grape producer regions and suppliers.

1 Introduction

Grape is one of the most popularly produced and globally well-known fruit crops with 67.067.128 tonnes in 2012 (Food and Agriculture Organization of the United Nations, 2013). Grape production in Turkey was 4.275.659.409 tonnes, ranking 6th in the world (Turkish Statistical Institute, 2013). Grape also became the chief in Turkish fruit exports, at 239.577 tonnes in 2011. The Aegean Region stands first in grape production and export. 'Sultana Seedless' is the most important cultivar (98%) among the grape varieties exported. Table grapes are mostly exported to the Russian Federation followed by Germany, Ukraine and Bulgaria (Aegean Exporters Associations, 2012).

In the Aegean Region (Western Turkey), the 'Sultana Seedless' ('Sultani Çekirdeksiz') variety is widely cultivated for both table and dried raisin production. Nearly 1.5 million tonnes of grapes are currently being produced in the Aegean provinces. Alaşehir and Sarıgöl districts of the Manisa province are the intensive grape producing regions, with most of the packing houses located in these districts. In this region, the 'Sultana Seedless' 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 10-30% higher than the September prices. Therefore, there is a definite need for supplying the 'Sultana Seedless' 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.

In recent years, producers delay the harvest time by covering the vines with various covering materials. In the Aegean Region, polypropylene cross-stitch is the most common covering material employed. Several types of covering material are used on vines across the world. In Australia, plastic rain covers are utilized to protect the fruit from pre-harvest rain damage. In California (USA), the 'Red Globe' grapes, harvested between mid-August and mid-October encourage some growers to use plastic rain covers to protect the fruits and market during the late periods (Liberman, 2009).

The storage life of table grapes is influenced by the pre-harvest 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 (Crisosto & Mitchell, 2002; Kader, 2002; Crisosto & Smilanick, 2004; Sen et al., 2012). Grape deterioration during storage is characterized by weight loss, stem browning, softening, shattering and decay (Crisosto et al., 2001; Perkins-Veazie et al., 1992). Postharvest grape deterioration can be due to

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the physical, physiological or pathological factors prevailing in the vineyard (pre-harvest) or after harvest (Zoffoli et al., 2009). Table grapes tend to senesce and deteriorate during postharvest handling, which limits their market life (Crisosto & Mitchell, 2002). Quality deterioration in the grape clusters is visible as weight loss, rachis senescence or necrosis, grape shatter, fruit softening, undesirable color changes in the grape or rachis, and the development of fungal rot (Carvajal-Millán et al., 2001; Crisosto et al., 2002; Daudt & Fogaça, 2013).

Different covering materials, therefore, are used by producers, although their effects on grape quality and storage life or the differences between the materials used are still not well researched. Data regarding the grape quality and storage induced quality changes on the covered vines remains insufficient.

This research was performed utilizing different covers to examine their effects on grape quality and storage life. Besides, the effect of delayed harvest on fresh table grapes was assessed as with cold storage.

2 Materials and methods

2.1 Plant material

This study was conducted in the 11-year-old 'Sultani Çekirdeksiz' (seedless grapes) vineyard of Manisa Viticulture Research Station, Manisa province. The vineyard was planted in 2000 on rootstock 41B with a plantation distance of 3.0 m × 2.0 m and trained on the double trellis system irrigated via drip irrigation. The table grape management practices recommended and developed by Manisa Viticulture Research Institute were applied to all the treatments.

2.2 Covering material

In the study, polypropylene cross-stitch, lifepack, mogul and transparent polyethylene were the four different covering materials used as protection against the negative impact of the autumn rains. These protective covering materials were placed on the vines during the first week of September in both years. Inverted 'U' type bended anchors (attached to the trellis) were used to cover the four materials tested. Polypropylene cross-stitch (PC), a white fabric covering material is composed of polypropylene. Lifepack (LP) consists of three layers (30 g/m spunbond+20 mc breathable layer+15 g/m spunbond) and is water resistant, with an 8% UV additive top layer. Mogul (Agrimol) (MG) is a white, 30 g/m2, 0.28 mm thick material, with air permeability of 145 cm3/cm2.sn, light transmittance of 70% and 3% UV additive polypropylene. Transparent polyethylene (PE) is transparent, 0.33 mm in thickness, with a light transmittance of 95% and 3% UV additive covering material. Temperature and relative humidity were measured under the covering materials using data loggers.

2.3 Sampling and storage conditions

Grapes under cover were harvested nearly one month after those maturing in open conditions. During first year of the study, the grapes were harvested on September 24th, whereas in the second year, the harvest was on September 22nd. 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 90 days and in the second year for 120 days in storage at –0.5°C and 90% RH. Grapes were sampled at harvest, as well as on the 60th and 90th days; in the second year too, sampling was done on the 120th day of storage. During storage, every box was accepted as a replication.

2.4 Decay development

Distribution of the decay in the grape clusters was determined according to Turkey (1996) and the decay factors were identified at the Ege University, Faculty of Agriculture, Department of Plant Protection.

2.5 Quality assessment

Berry removal force of berries was measured with a penetrometer on 25 berries drawn at random from different bunches of the replications. Results were expressed in Newtons (N).

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 (Ruiz et al., 2005). 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 (Karacali, 2009).

2.6 Sensory analysis

Six panellists 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 Artés-Hernández et al. (2004).

Rachis condition was then rated according to Crisosto et al. (2002), 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.

2.7 Statistical analysis

The study was planned as a randomized split plot design with three replications and six vines per parcel. All computation and statistical analyses were done using IBM® SPSS® Statistics 19, a statistical software (IBM, NY, USA). Significant differences between the means for each year and storage period were determined employing Duncan's multiple range tests at $P< 0.05$ and $P< 0.01$. Standard Deviation (SD) of the means was also calculated from the replicates.

3 Results

3.1 Decay development

In both years of the study, no deterioration was observed during the 90 days of storage. However, in the second year, at the end of 120 days of storage, moderate deterioration (spotting or decay up to 1/5-2/5 of the bunch) was observed in the grapes covered with PC. *Botrytis cinerea* was identified to be the causal agent of decay. Grapes sampled on the 120th day of storage were discarded for the analysis, as they had lost marketability.

3.2 Quality assessment

The berry removal force of the grapes covered with MG was found to be higher than those covered with the other covering materials on the 60th day of storage. The positive effect of the MG was lost by the end of the storage period. The effect of the MG covering material on the berry removal force was significant ($P< 0.05$) in all the three sampling periods (0, and after 60 and 90 days) in the second year of the study. The berry removal force of the grapes using MG as the covering material was higher in the pre-storage and during the first half of the storage period (60th day). On the 90th day of storage, the berry removal forces of the grapes covered with the LP and MG covering materials were found to be higher than those protected with PE. At the end of the storage period, the differences between the covering materials on the berry removal force were lost and the results showed similar effects (Figure 1).

While the effect of the covering materials on the L^* color values was significant in the first year, it was non-significant in the second year. The L^* values of the grapes covered with LP were higher during the pre-storage and 60th day of storage in the first year. In the last sampling period, the differences among the effects on the L^* color values were insignificant (Table 1).

The effects of the covering materials on the a^* color values of the grapes during storage was non-significant in both study years. The a^* colour values ranged between –2.13 and –0.62 in the first year and between –4.50 and –1.37 in the second year (Table 2). There was no significant effect of the covering materials on the b^* color values of the grapes during storage. The b^* color values of the grapes varied between 10 and 13 (data not shown).

The effects of the covering materials on the TSS were non-significant in the first year; however, in the second year, on days 90 and 120, it was found to be significant ($P< 0.05$). On both the sampling dates, PE was found to enhance TSS when compared with the other covering materials (Table 3).

The effects of the covering materials on TA during storage were non-significant and the TA was observed to range between 0.51 and 0.62 mg tartaric acid/100 ml. On the 60th day of storage, the TA content of the grapes was significantly higher ($P< 0.01$) under the PC covering than the other covering materials tested. The effect of the PC covering material continued to decrease after the 90th day of storage and resulted in higher TA content compared with the grapes covered with MG or PE. The effects of the covering materials on TA were similar during the other sampling periods. In both years, the TA decreased towards the end of the storage period when compared with the initial values. This decrease seemed clearer, particularly in the second year (Table 4).

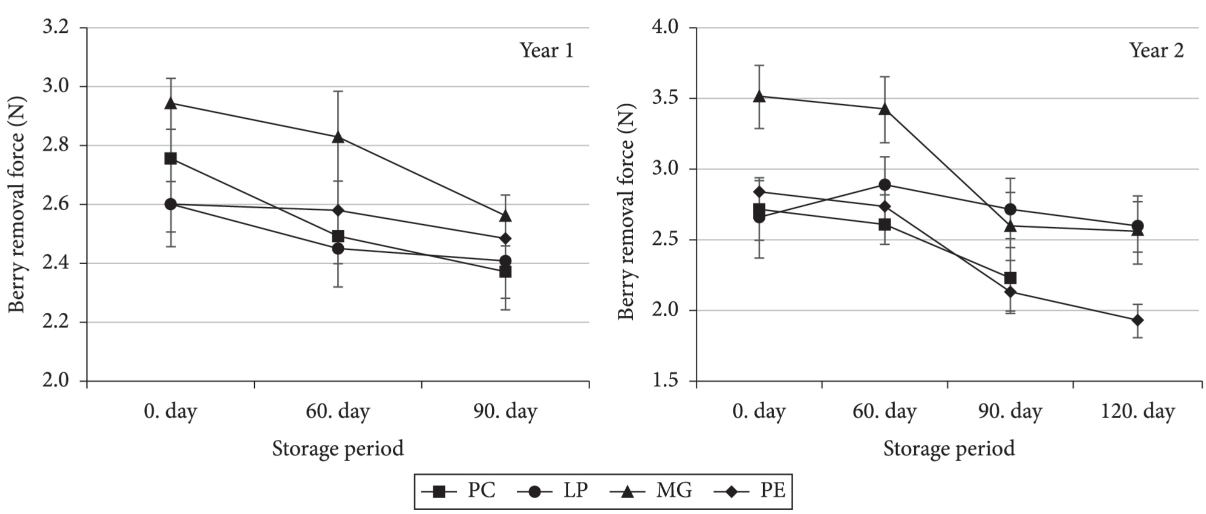

Figure 1. Effects of different covering materials applied at pre-harvest stage on the berry removal force of 'Sultana Seedless' grapes in the first and second years. Results are the means of three replicate samples ±SD.

Table 1. Effects of different covering materials applied at pre-harvest stage on L* color values of 'Sultana Seedless' grapes in the first and second years.

Treatment	Year 1			Year 2			
	0. Day	60. Day	90. Day	0. Day	60. Day	90. Day	120. Day
PC	28.86 b[z*]	39.49 b[*]	34.42[NS]	34.83[NS]	44.05[NS]	39.64[NS]	
LP	32.60 a	43.10 a	31.25	31.96	45.58	40.57	33.94[NS]
MG	28.42 b	35.26 c	32.64	33.13	46.03	42.10	36.92
PE	31.05 ab	36.81 bc	34.60	37.85	45.42	40.16	33.69

[z] Means separation within columns by Duncan's multiple range test, $P< 0.05$; [NS] Nonsignificant; * Significant at $P\leq 0.05$.

Table 2. Effects of different covering materials applied at pre-harvest stage on a* color values of 'Sultana Seedless' grapes in the first and second years.

Treatment	Year 1			Year 2			
	0. Day	60. Day	90. Day	0. Day	60. Day	90. Day	120. Day
PC	−2.13[NS]	−1.08[NS]	−1.10[NS]	−4.20[NS]	−4.50[NS]	−3.22[NS]	
LP	−1.73	−0.62	−2.09	−3.95	−4.44	−3.47	−2.36[NS]
MG	−1.91	−1.84	−1.65	−4.00	−4.27	−2.97	−1.37
PE	−1.63	−1.79	−1.97	−3.90	−4.42	−3.44	−2.32

[NS] Nonsignificant.

Table 3. Effects of different covering materials applied at pre-harvest stage on TSS (%) of 'Sultana Seedless' grapes in the first and second years.

Treatment	Year 1			Year 2			
	0. Day	60. Day	90. Day	0. Day	60. Day	90. Day	120. Day
PC	24.5[NS]	22.9[NS]	23.9[NS]	22.7[NS]	21.8[NS]	21.9 b[z*]	
LP	23.6	23.4	23.3	22.9	22.7	21.9 b	19.9 b[*]
MG	24.9	23.5	23.2	23.2	22.3	23.1 ab	22.5 a
PE	23.9	24.2	24.2	22.4	21.5	23.7 a	23.0 a

[z] Means separation within columns by Duncan's multiple range test, $P< 0.05$; [NS] Nonsignificant; * Significant at $P\leq 0.05$.

Table 4. Effects of different covering materials applied at pre-harvest stage on titratable acidity (g tartaric acid/100 ml) of 'Sultana Seedless' grapes in the first and second years.

Treatment	Year 1			Year 2			
	0. Day	60. Day	90. Day	0. Day	60. Day	90. Day	120. Day
PC	0.56[NS]	0.53[NS]	0.55[NS]	0.64[NS]	0.61 [az**]	0.43 a[*]	
LP	0.53	0.55	0.51	0.70	0.39 c	0.41 ab	0.36[NS]
MG	0.59	0.52	0.54	0.71	0.44 b	0.37 b	0.37
PE	0.62	0.54	0.52	0.71	0.36 c	0.34 b	0.35

[z] Means separation within columns by Duncan's multiple range test, $P\leq 0.05$; [NS] Nonsignificant; * Significant at $P\leq 0.05$; ** Significant at $P\leq 0.01$.

The covering materials did not exert any significant effect on the maturity index in the first year. However, in the second year it was significant on the 60th, 90th and 120th days of storage. Maturity index was higher in those grapes covered with PE during all the three sampling periods. On the 60th day of storage PC, 90th day of storage PC, LP and at the end of the storage period, the grapes covered with LP revealed the lowest maturity index values. Changes in the maturity index were observed to be limited in the first year, although in the second year they were more prominent (Table 5).

3.3 Sensory analysis

Grapes were evaluated with respect to visual appearance, flavor and crunchiness in storage. On the 60th and 90th day of storage the scores were between 7 (good) and 9 (excellent) in both study years. In the second year, at the end of the storage (120th day) the grapes covered with PC scored 1, whereas the other covering materials scored around 5 (Figure 2).

Neither the SO_2 taste nor odor was observed at moderate or severe levels during storage in both study years. Stem browning score was 1 in the first year of the study. In the second year, only at the end of 120 days storage period, those vines covered with PC scored 3 with respect to stem browning, whereas the others scored 2 (data not shown).

4 Discussion

Decay development was observed only on the 120th day of storage in the grapes covered with PC. To prevent decay development, the SO_2-generating pads, pre-harvest cultural treatment, especially with respect to plant protection, care during harvest and packaging, pre-cooling and convenient storage conditions were known to be effective (Crisosto & Mitchell, 2002; Crisosto & Smilanick, 2004; Snowdon, 1990). These factors directly affected the decay development during grape storage.

Table 5. Effects of different covering materials applied at pre-harvest stage on the maturity index of 'Sultana Seedless' grapes in the first and second years.

Treatment	Year 1			Year 2			
	0. Day	60. Day	90. Day	0. Day	60. Day	90. Day	120. Day
PC	43.56^{NS}	43.72^{NS}	43.72^{NS}	36.43^{NS}	36.03 c^{z**}	51.0 c**	
LP	44.92	42.55	45.52	32.83	58.13 a	52.90 c	55.07 c*
MG	42.38	45.24	42.63	32.77	50.57 b	61.13 b	61.47 b
PE	38.68	44.99	47.19	31.63	59.30 a	68.90 a	66.80 a

^{z} Means separation within columns by Duncan's multiple range test, $P \leq 0.05$; ^{NS} Nonsignificant; * Significant at $P \leq 0.05$; ** Significant at $P \leq 0.01$.

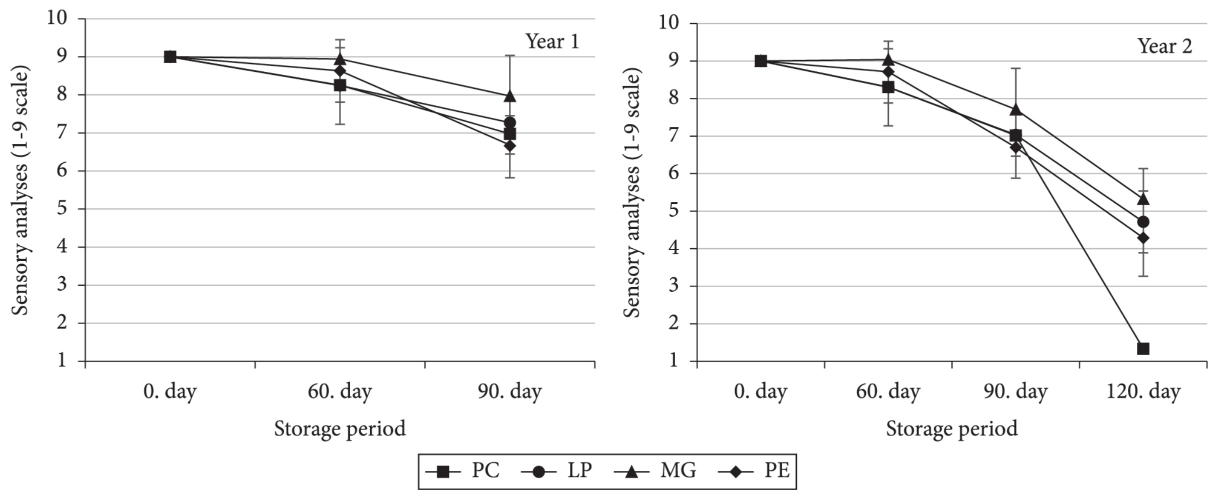

Figure 2. Effects of different covering materials applied at pre-harvest stage on mean sensory analyses (visual appearance, flavor and crunchiness) of 'Sultana Seedless' grapes in the first and second years. PC; polypropylene cross-stitch, LP; life pack, MG; mogul, PE; polyethylene. Results are the means of three replicate samples ±SD.

Berry removal force is an important parameter because a lower removal force is related to shattering or berry drops. The higher berry removal force found in grapes covered with MG showed that the risk of berry drop levels would decrease. No berry drop is preferred during the marketing phase when the grape clusters are picked up from the package. Dropping implies a negative impression to the consumer, as it is accepted as a sign of the fruit not being fresh. Decreased berry removal force is understood to be a result of aging (Crisosto et al., 2001). The positive effect of the MG covering material may be explained as an enhancement of slower maturity under this cover.

The effects of the covering materials on grape color revealed similar results. As the grapes were stored at –0.5°C, color changes were limited in cold storage (Sen et al., 2012). Then a* colour values ranging between –2.36 and –1.10 were observed during the first year and between –4.50 and –1.37 in the second year. These values supported our results.

The effects of the covering materials on the TSS and TA contents and maturity index did not advance in a parallel manner. The TSS content showed variations during storage; however, the TA showed a tendency to decrease with a consequent increase in the maturity index. These trends are reported to be due to fruit senescence as the storage period is extended (Sen et al., 2012). The maturity index changes resulted more from the changes in TA rather than those in the TSS content.

Dual release sulfur dioxide pads and convenient pre-cooling and storage conditions were found to be effective in terms of encountering no residual sulfur dioxide taste or odor in both years of the study (Crisosto & Mitchell, 2002). Controlled SO_2 released in the package also prevented SO_2 induced damages.

A strong relationship is observed between stem browning and water loss. Cumulative water losses occurring during postharvest handling may lead to stem browning, grape shatter, and wilting and grape shrivelling during marketing (Crisosto et al., 2001). Due to quick pre-cooling after harvest, limiting water loss during storage and using SO_2-generating pads, no cluster browning has been observed even after 90 days of storage during both the study years (Crisosto & Mitchell, 2002; Karacali, 2009).

In both the years of study, the visual appearance, flavor and crunchiness of the grapes scored between 7 (good) and 9 (excellent) because of slow aging, limited water loss, absence of cluster browning and decay development. In the grapes covered with PC, decay development influenced the score at the end of storage period (120th day) in the second year of the study to be the most inferior (1.3). These inferior scores are due to decay development and stem browning. Other covering materials scored around 5 with good looking grapes; however, the loss of flavor and crunchiness of the grapes reduced their points. Deterioration of flavor and softening of texture occurred because of long term storage (Kanellis & Roubelakis-Angelakis, 1993).

5 Conclusion

Consequently, by delaying the time of the 'Sultana Seedless' grape harvest with the use of different covering materials, the grapes were stored successfully for 90 days. Transparent polyethylene (PE) was not recommended because it damaged the grapevine leaves. Grapes covered with Mogul (MG) can be preferred because they yield higher values of berry removal force. As the effects of the covering materials tested were similar regarding grape quality, aspects such as parameters of price and convenience in usage, assumed greater importance in decision taking. As decay development occurred at the 120th day of the storage in grapes covered with polypropylene cross-stitch (PC), PC was not suggested for long-term storage. Based upon the results obtained during this long-term (120 days) storage, Mogul (MG) can be preferred compared to other covers however extending the storage period to 120 days is not recommended. Under all covering materials tested, grapes appeared to be in good shape; however, because of their low scores in flavor and crunchiness, they may generate further problems during the marketing stage.

Acknowledgements

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