International Journal of Agriculture Innovations and Research
Volume 2, Issue 6, ISSN (Online) 2319-1473

# Efficacy of using Rain Protective Plastic Films against Cracking of Four Sweet Cherry (*Prunus avium* L.) Cultivars in Greece

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***Abstract* - Cherry cracking due to rain is the major problem for cherry cultivation. Several methods have been proposed for alleviating this problem, including the use of rain protective coverings. The aim of this research was to study the effect of rain protective covering on fruit cracking, fruit quality and photosynthetic parameters of four sweet cherry cultivars. The experiments were conducted during three successive years. Half of a commercial cherry orchard was covered by high density polyethylene plastics, whereas the other half remained uncovered (control). The results showed that the covering had no affect on the productivity and mean fruit weight in all cultivars, except for 'Early Lory' which had higher values in 2009. The cracking percentage of all cultivars was significantly lower in covered trees than the controls, resulting in a positive tendency on marketable yield. In 2010, total antioxidant activity was higher in the covered fruits of 'Ferrovia', 'Early Star' and 'Van' compared to the control, whereas in 'Early Lory' it was lower. However, in 2011 no difference was observed between control and covered trees for all cultivars. Photosynthetic rate of 'Early Star' and 'Van' in 2010 was not affected by the covering, while in 'Ferrovia' it decreased. In 2011, the photosynthetic rate of all cultivars was the same between covered and control trees. Furthermore, the three-year observations on the climatic conditions during the covering period indicated that they may also have an influence on fruit quality. Covering of the cherry trees with the plastic polyethylene films increased marketable yield and did not have any adverse effect on fruit quality.**

***Keywords* - Cherry, Cracking, Fruit Quality, Photosynthesis.**

## I. Introduction

The main problem in cherry production is fruit cracking due to rainfall during the ripening period (Borve et al., 2003). The cracking of sweet cherries caused by rainfall shortly before harvest is one of the major limitations to successful sweet cherry production in many parts of the world. Despite many years of research there seems to be a lack of understanding of many of the fundamental mechanisms involved in this phenomenon, and many results and explanations obtained in experiments relating to the problem are contradictory. Cherry becomes particularly sensitive to cracking around 15 days before it ripens (Christensen, 1972). Cherry fruit cracking is caused by osmotically driven water penetration through a wetted fruit surface which increases the volume of the fruit to a degree that the fruit skin can not tolerate (Glenn and Poovaiah, 1989).

The release of new sweet cherry (*Prunus avium* L.) cultivars is often advised taking into consideration their adaptability to the environmental characteristics of the various growing districts, the fruit size, shape, skin colour, flesh firmness, bloom and ripening time, self-fruitfulness and resistance to cracking (Greco et al., 2008).

Several methods have been proposed to reduce cracking. Substances with a high osmotic potential, such as calcium have been used worldwide (Christensen, 1996). Rain protective covering is another method to avoid fruit cracking in climates with frequent precipitation. Trials with rain protective covering of sweet cherry trees have been reported by several authors (Wermund et al., 2005; Blanke and Balmer, 2008; Borve et al., 2008). In Norway, only the 5% of fruits continued to crack under cover and Cline (1995) further demonstrated that covers improved fruit size and quality compared with uncovered trees. However, in New Zealand, Trought (1986) found that 40% of fruit continued to crack under elaborate covering systems in some seasons. Borve and Meland (1998a) stated that climatic conditions during the covering period may influence the plastic covering effects on fruit ripening and the effects of plastic covering may also change between years and locations. Usenik et al. (2009) reported that tree covering reduced crop losses due to fruit cracking and rotting without negative effects on fruit quality and that covers significantly reduced percentage of cracked 'Hedelfinger' fruit.

The rainfall that coincides with the cherry harvest season occurs every year in northern Greece in the areas that sweet cherries are cultivated. The scope of this research was to study the effects of rain protective covering on fruit quality, photosynthetic parameters and on preventing fruit cracking of four sweet cherry cultivars under the climatic conditions of northern Greece since data regarding photosynthetic parameters and fruit quality attributes such as antioxidant capacity and ascorbic acid content are not presented so far in the literature.

## II. Materials and Methods

A commercial cherry (*Prunus avium* L.) orchard (0.3 ha) was covered by polyethylene plastics (white high density polyethylene film, with light transparency ≥85%; Helios, Italy) for 3 consecutive years (2009, 2010, 2011). A part of it, which was served as a control was not covered. The experimental trees of the cultivars 'Early Lory', 'Early Star', 'Van' and 'Ferrovia' were 7 years old, grafted on 'Gisela 5' rootstock and trained as an open vase tree at distances 3.0 x 1.5 m apart. The covering of the trees took place 3 weeks before harvest. Plastic covers

International Journal of Agriculture Innovations and Research
Volume 2, Issue 6, ISSN (Online) 2319-1473

were pulled off at the end of the harvest. Precipitation of each experimental year is shown in Table 1.

Cracking percentage was measured in all fruits of each tree at the harvest time of each cultivar. Productivity (kg/tree) and mean fruit weight of the cultivars were measured at harvest over a period of 3 years (2009-2011). Firmness was measured by the Effegi penetrometer 6mm tip, external color by the Minolta CR-200 chromatometer, total soluble solids by the Atago PR-1 electronic refractometer, and titratable acidity by titration with 0.1 N NaOH. The concentration of total phenolics, the ascorbic acid content and the total antioxidant capacity were measured as described by Koukourikou-Petridou et al. (2007).

Photosynthetic parameters were measured at midday (11h00 – 13h00) using the LCi portable gas exchange system (ADC BioScientific Ltd, Hoddesdon, UK) at harvest date of each cultivar in 2010 and 2011. Water use efficiency was calculated as the ratio of net photosynthetis to transpiration rate to provide an estimation of the carbon gain per unit water loss.

The experiment was conducted and repeated for 3 years. The experimental design was a randomized complete block with three replications of two treatments (control, covered) and five trees per replication. Differences between means were evaluated by using the Duncan's multiple range test at $P \le 0.05$.

## III. Results and Discussion

*Cracking measurements*

In 2009, for the cvs. 'Early Lory' and 'Early Star' no cracking was detected since there was no precipitation at that period (Table 1). However, cracking percentage of the cvs. 'Ferrovia' and 'Van' was significantly lower in the covered trees than the control (Table 2). Moreover, in 2010 and 2011 cracking percentage of all cvs. was significantly lower in the covered trees than the control (Tables 3,4). Borve and Meland (1998b) stated that covered trees of the cv. 'Van' reduced the number of cracked and rotten fruits significantly and increased the marketable yield.

*Yield attributes*

Productivity and mean fruit weight of the cv. 'Early Lory' increased under cover in 2009, however productivity and mean fruit weight of the other cultivars were not significantly affected (Table 2). In 2010 and 2011, productivity and mean fruit weight of all cultivars were not significantly different between the covered trees and the control (Tables 3,4). Usenik et al. (2009) reported that tree covers had no significant influence on sweet cherry fruit weight of the cultivars 'Hedelfinger', 'Kordia', and 'Regina'. In 2009, *L*, *a* and *C* color parameters of the cultivar 'Van' were higher in the covered trees than the control, whereas for the cv. 'Ferrovia' only L was higher (Table 2). In 2010, *L*, *a* and *C* color parameters of the cvs. 'Early Star' and 'Ferrovia' were not different between the covered trees and the control (Table 3). In 2011, *C* value for the cv. 'Early Star', *a* value for the cv. 'Ferrovia' and *a* and *C* for the cv. 'Van' were higher in the covered trees than the control (Table 4).

*Fruit quality attributes*

Fruit firmness in 2009 of the cvs. 'Ferrovia' and 'Early Lory' was higher in the covered trees than the control, of the cv. 'Van' lower, whereas that of the cv. 'Early Star' was not altered (Table 5). In 2010, fruit firmness of the cv. 'Ferrovia' was higher in the covered trees than the control, whereas that of the other cultivars was not significantly different between the treatments (Table 6). In 2011, fruit firmness of all cultivars was not significantly affected between the treatments (Table 7). Blanke and Balmer (2008) reported that the early-ripening 'Earlise', 'Burlat' and 'S. de Charmes' cultivars grown under cover developed fruit of similar firmness as the control. On the contrary, fruits of 'Samba' and 'Vlone M', were considerably softer than the control. However, these results were taken in a fully enclosed polytunnel.

Total soluble solids of fruits of all cultivars for all years were not significantly different with only exception that of the cv. 'Early Lory' which were lower in the covered trees than the control (Tables 5, 6, 7). Total soluble solids of fruits under cover were higher than the control as reported by Borve et al. (2003) in Norway for the cv. 'Van'. Concentrations of sugars (sucrose, glucose, fructose and sorbitol) and organic acids (citric, malic, shikimic and fumaric acid) were not significantly different among control and fruits under covers in the research of Usenik et al. (2009). Blanke and Balmer (2008) in a trial with the cvs. 'Burlat', 'Earlise', 'Samba', and 'Souvenir des Charmes' reported that fruit ripened 12 to 19 days earlier than those from uncovered control trees, indicating a shorter or enhanced fruit development and maturation. The cover had no adverse effect on fruit colouration. However, their experimental trees were grown in a fully enclosed polytunnel. Both delayed and advanced ripening under plastic covers were reported by other authors (Borve et al., 2003). Borve and Meland (1998b) stated that climatic conditions during the covering period may influence the plastic covering effects on fruit ripening and the effects of plastic covering may also change between years and locations.

In 2009, ascorbic acid content of the cvs. 'Ferrovia' and 'Van' was higher in the covered trees whereas that of the cv. 'Early Lory' lower than the control (Table 5). In 2010, ascorbic acid content of the cvs. 'Early Lory' and 'Ferrovia' was higher in the covered trees than the control, whereas that of the cultivars 'Van' and 'Early Star' was not significantly different (Table 6). Ascorbic acid content of all cultivars in 2011 was not significantly different between the treatments. Regarding acidity, in 2009 values of covered trees of the cultivars 'Early Lory' and 'Ferrovia' were higher than the control (Table 5), however in 2010 there were no significant differences found between treatments (Table 6). In 2011, acidity of the cultivars 'Early Lory' and 'Early Star' of covered trees were higher than the control (Table 7). In 2009, total phenolics of fruits under cover were higher in the cultivars 'Ferrovia', 'Early Star' and 'Van' compared to the control (Table 5), however in 2010 there were no significant differences found between treatments (Table 6). In 2011, total phenolics of fruits of the cv. 'Van' under cover were lower than the control, whereas those of the rest cultivars were not significantly different (Table 7). Usenik et al. (2009) reported that there was no significant effect of covering on the concentrations of phenolics of the cultivars 'Hedelfinger', 'Kordia', and 'Regina'. In 2009, total antioxidant capacity of fruits under cover were higher in the cultivars 'Ferrovia', 'Early Star' and 'Van' compared to the control (Table 5). In 2010, total antioxidant capacity of fruits under cover were higher in the cultivars 'Ferrovia', 'Early Star' and 'Van' compared to the control, whereas that of the cv. 'Early Lory' lower (Table 6). In 2011, total antioxidant capacity of fruits of all cultivars were not different between treatments (Table 7).

Photosynthetic rate of the cultivars 'Early Star' and 'Van' in 2010 were not affected by the covering, however that of 'Ferrovia' decreased under cover (Table 8). In 2011, photosynthetic rate of all cultivars were not significantly different among treatments (Table 9). Transpiration rate of all cultivars were not significantly different among treatments in 2010. However, in 2011 transpiration rates of the cultivars 'Early Star' and 'Ferrovia' were decreased under cover (Tables 8, 9). Stomatal conductance of all cultivars were not significantly different among treatments in 2010. The same was measured in 2011 for the cultivars 'Early Star' and 'Ferrovia', whereas that of 'Van' increased under cover (Tables 8, 9). The lower transpiration in the covered treatments was most probably the result of a lower leaf-to-air vapor pressure deficit under the plastic covering, since stomatal conductance was not affected by covering. The lower transpiration of the covered trees, led to a higher water use efficiency in 2011 (and a similar trend was also observed in 2010 except for 'Ferrovia').

## IV. Conclusion

Covering of the trees with the plastic polyethylene films increased marketable yield and did not have any adverse effect on fruit quality. In addition, covering tended to increase water use efficiency of cherry trees by reducing transpiration rates. Moreover, climatic conditions during the covering period may influence the fruit quality attributes and the effects of plastic covering may also change between years.

## Acknowledgement

This research was financed by the Greek Organization of Agricultural Assurance.

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International Journal of Agriculture Innovations and Research
Volume 2, Issue 6, ISSN (Online) 2319-1473

Table 1: Precipitation from the beginning of May till the end of harvest

| 2009 | Precipitation (mm) | 2010 | Precipitation (mm) | 2011 | Precipitation (mm) |
|---|---|---|---|---|---|
| 24 May | 10 | 16 May | 18 | 4 May | 15 |
| 28 May | 33 | 21 May | 3 | 5 May | 20 |
| 29 May | 8 | 22 May | 13 | 7 May | 3 |
| 30 May | 12 | | | 10 May | 11 |
| | | | | 11 May | 7 |
| | | | | 20 May | 15 |
| | | | | 28 May | 9 |
| | | | | 30 May | 7 |
| Total | 63 | | 34 | | 87 |

Table 2: Productivity, mean fruit weight, percentage of cracking and fruit colour parameters in 2009.

| Treatment | Productivity (kg tree-1) | Fruit weight (g) | Cracking (%) | Harvest date | L | a | C |
|---|---|---|---|---|---|---|---|
| **Early Star (Control)** | 18.2 a* | 8.46 a | 0 a | 15 May | - | - | - |
| **Early Star (Covered)** | 18.6 a | 8.51 a | 0 a | | -- | - | - |
| | | | | | | | |
| **Early Lory (Control)** | 18.3 b | 6.96 b | 0 a | 9 May | - | - | - |
| **Early Lory (Covered)** | 22.2 a | 9.57 a | 0 a | | - | - | - |
| | | | | | | | |
| **Ferrovia (Control)** | 26.2 a | 9.21 a | 22 a | 1 June | 34.60 b | 39.01 a | 39.53 a |
| **Ferrovia (Covered)** | 27.6 a | 10.39 a | 6 b | | 37.67 a | 38.24 a | 38.82 a |
| | | | | | | | |
| **Van (Control)** | 25.9 a | 8.19 a | 9 a | 2 June | 32.88 b | 36.68 b | 36.97 b |
| **Van (Covered)** | 26.7 a | 8.73 a | 0 b | | 35.06 a | 39.62 a | 40.24 a |

*Means followed by the same letter in the same column, for each cultivar, are not significantly different (Duncan's multiple range test, P≤0.05)

Table 3: Productivity, mean fruit weight, percentage of cracking and fruit colour parameters in 2010

| Treatment | Productivity (kg tree-1) | Fruit weight (g) | Cracking (%) | Harvest date | L | a | C |
|---|---|---|---|---|---|---|---|
| **Early Star (Control)** | 17.5 a* | 8.40 a | 34.4 a | 17 May | 31.57 a | 31.52 a | 22.00 a |
| **Early Star (Covered)** | 17.0 a | 8.60 a | 1.8 b | | 32.47 a | 33.09 a | 23.10 a |
| | | | | | | | |
| **Early Lory (Control)** | 16.9 a | 8.60 a | 29.7 a | 13 May | - | - | - |
| **Early Lory (Covered)** | 17.1 a | 8.65 a | 2.2 b | | - | - | - |
| | | | | | | | |
| **Ferrovia (Control)** | 22.1 a | 12.00 a | 48.0a | 27 May | 30.16 a | 28.77 a | 29.77 a |
| **Ferrovia (Covered)** | 20.9 a | 12.20 a | 4.1 b | | 33.44 a | 30.81 a | 30.89 a |
| | | | | | | | |
| **Van (Control)** | 23.2 a | 7.43 a | 35.4 a | 2 June | 31.30 a | 27.00 b | 28.02 b |
| **Van (Covered)** | 24.1 a | 7.79 a | 5.5 b | | 32.48 a | 30.89 a | 32.91 a |

*Means followed by the same letter in the same column, for each cultivar, are not significantly different (Duncan's multiple range test, P≤0.05)

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Volume 2, Issue 6, ISSN (Online) 2319-1473

Table 4: Productivity, mean fruit weight, percentage of cracking and fruit colour parameters in 2011.

| Treatment | Productivity (kg tree-1) | Fruit weight (g) | Cracking (%) | Harvest date | L | a | C |
|---|---|---|---|---|---|---|---|
| **Early Star (Control)** | 23.5 a* | 11.96 a | 27.5 a | 15 May | 33.01 a | 32.89 a | 22.14 b |
| **Early Star (Covered)** | 24.0 a | 12.14 a | 5.0 b | | 32.78 a | 33.17 a | 24.15 a |
| | | | | | | | |
| **Early Lory (Control)** | 19.9 a | 9.31 a | 18.3 a | 7 May | - | - | - |
| **Early Lory (Covered)** | 23.5 a | 9.46 a | 7.8 b | | - | - | - |
| | | | | | | | |
| **Ferrovia (Control)** | 31.9 a | 10.56 a | 19.0 a | 26 May | 31.21 a | 26.59 b | 28.55 a |
| **Ferrovia (Covered)** | 29.1 a | 10.21 a | 3.1 b | | 32.42 a | 31.61 a | 29.61 a |
| | | | | | | | |
| **Van (Control)** | 31.2 a | 8.7 a | 22.0 a | 1 June | 32.41 a | 28.14 b | 29.17 b |
| **Van (Covered)** | 32.1 a | 9.0 a | 4.5 b | | 32.17 a | 32.91 a | 33.61 a |

*Means followed by the same letter in the same column, for each cultivar, are not significantly different (Duncan's multiple range test, P≤0.05

Table 5: Fruit quality attributes at harvest in 2009

| Treatment | Firmness (kg/cm2) | Total soluble solids (0Brix) | Ascorbic acid (mg 100g-1 f.w.) | Acidity (% malic acid) | Total phenolics (mg gallic acid eq. g-1 f.w.) | Total antioxidant capacity (μM g-1 f.w.) |
|---|---|---|---|---|---|---|
| **Early Star (Control)** | 0.553 a* | 14.4 a | 11.00 a | 1.23 a | 2.32 b | 19.40 b |
| **Early Star (Covered)** | 0.585 a | 14.8 a | 9.30 b | 1.22 a | 3.00 a | 24.80 a |
| | | | | | | |
| **Early Lory (Control)** | 0.322 b | 11.46 a | 7.17 a | 0.53 b | 1.42 a | 10.50 a |
| **Early Lory (Covered)** | 0.426 a | 11.57 a | 7.25 a | 0.62 a | 1.35 a | 9.80 a |
| | | | | | | |
| **Ferrovia (Control)** | 0.558 b | 13.20 a | 6.10 b | 0.88 b | 1.98 b | 16.90 b |
| **Ferrovia (Covered)** | 0.649 a | 14.20 a | 6.90 a | 1.00 a | 2.24 a | 18.01 a |
| | | | | | | |
| **Van (Control)** | 0.753 a | 15.48 a | 7.80 b | 1.35 b | 2.78 b | 29.11 b |
| **Van (Covered)** | 0.558 b | 15.62 a | 8.80 a | 1.52 a | 3.22 a | 32.29 a |

*Means followed by the same letter in the same column, for each cultivar, are not significantly different (Duncan's multiple range test, P≤0.05)

Table 6: Fruit quality attributes at harvest in 2010

| Treatment | Firmness (kg/cm2) | Total soluble solids (0Brix) | Ascorbic acid (mg 100g-1 f.w.) | Acidity (% malic acid) | Total phenolics (mg gallic acid eq. g-1 f.w.) | Total antioxidant capacity (μM g-1 f.w.) |
|---|---|---|---|---|---|---|
| **Early Star (Control)** | 0.694 a* | 13.4 a | 14.9 a | 0.85 a | 2.27 a | 23.1 b |
| **Early Star (Covered)** | 0.690 a | 13.5 a | 14.7 a | 0.78 a | 2.11 a | 25.7 a |
| | | | | | | |
| **Early Lory (Control)** | 0.678 a | 13.6 a | 10.3 b | 0.82 a | 1.57 a | 16.5 a |
| **Early Lory (Covered)** | 0.672 a | 13.3 b | 12.1 a | 0.84 a | 1.41 a | 14.6 b |
| | | | | | | |
| **Ferrovia (Control)** | 0.687 b | 17.3 a | 12.2 b | 0.86 a | 1.78 a | 16.7 b |
| **Ferrovia (Covered)** | 0.69 a | 16.8 a | 13.4 a | 0.89 a | 1.60 a | 19.3 a |
| | | | | | | |
| **Van (Control)** | 0.624 a | 15.7 a | 14.3 a | 0.97 a | 1.72 a | 27.6 b |
| **Van (Covered)** | 0.606 a | 15.5 a | 13.4 a | 1.02 a | 1.87 a | 29.8 a |

*Means followed by the same letter in the same column, for each cultivar, are not significantly different (Duncan's multiple range test, P≤0.05)

Table 7: Fruit quality attributes at harvest in 2011

| Treatment | Firmness (kg/cm2) | Total soluble solids (0Brix) | Ascorbic acid (mg 100g-1 f.w.) | Acidity (% malic acid) | Total phenolics (mg gallic acid eq. g-1 f.w.) | Total antioxidant capacity (µM g-1 f.w.) |
|---|---|---|---|---|---|---|
| **Early Star (Control)** | 0.70 a* | 14.9 a | 14.9 a | 1.04 b | 1.39 a | 23.05 a |
| **Early Star (Covered)** | 0.75 a | 14.1 a | 15.3 a | 1.20 a | 1.48 a | 22.06 a |
| | | | | | | |
| **Early Lory (Control)** | 0.66 a | 10.90 a | 9.3 a | 0.67 b | 0.88 a* | 13.5 a |
| **Early Lory (Covered)** | 0.60 a | 9.55 b | 8.6 a | 0.78 a | 0.94 a | 12.9 a |
| | | | | | | |
| **Ferrovia (Control)** | 0.60 a | 14.9 a | 9.7 a | 1.11 a | 1.04 a | 15.8 a |
| **Ferrovia (Covered)** | 0.70 a | 14.4 a | 9.7 a | 1.15 a | 1.03 a | 15.7 a |
| | | | | | | |
| **Van (Control)** | 1.05 a | 18.6 a | 8.6 a | 1.54 a | 1.43 a | 26.60 a |
| **Van (Covered)** | 0.94 a | 17.4 a | 8.2 a | 1.46 a | 1.30 b | 26.90 a |

*Means followed by the same letter in the same column, for each cultivar, are not significantly different (Duncan's multiple range test, P≤0.05)

Table 8: Photosynthetic rate, transpiration and stomatal conductance in 2010

| Treatment | Photosynthetic rate (µmol CO2 m-2 s-1) | Transpiration (mmol H2O m-2 s-1) | Stomatal conductance (mol H2O m-2 s-1) | Water use efficiency (µmol CO2 mol H2O-1) |
|---|---|---|---|---|
| **Early Star (Control)** | 10.65 a* | 5.28 a | 0.14 a | 2,01 b |
| **Early Star (Covered)** | 9.34 a | 3.81 a | 0.18 a | 2,45 a |
| | | | | |
| **Ferrovia (Control)** | 7.07 a | 4.39 a | 0.11 a | 1,61 a |
| **Ferrovia (Covered)** | 3.87 b | 3.69 a | 0.23 a | 1,05 b |
| | | | | |
| **Van (Control)** | 10.33 a | 6.19 a | 0.19 a | 1,67 b |
| **Van (Covered)** | 10.94 a | 5.10 a | 0.27 a | 2,15 a |

*Means followed by the same letter in the same column, for each cultivar, are not significantly different (Duncan's multiple range test, P≤0.05

Table 9: Photosynthetic rate, transpiration, and stomatal conductance in 2011

| Treatment | Photosynthetic rate (µmol CO2 m-2 s-1) | Transpiration (mmol H2O m-2 s-1) | Stomatal conductance (mol H2O m-2 s-1) | Water use efficiency (µmol CO2 mol H2O-1) |
|---|---|---|---|---|
| **Early Star (Control)** | 11.73 a* | 5.78 a | 0.24 a | 2.03 b |
| **Early Star (Covered)** | 9.34 a | 3.73 b | 0.28 a | 2.53 a |
| | | | | |
| **Ferrovia (Control)** | 12.60 a | 5.66 a | 0.22 a | 2.23 b |
| **Ferrovia (Covered)** | 10.43 a | 3.36 b | 0.35 a | 3.11 a |
| | | | | |
| **Van (Control)** | 9.55 a | 6.07 a | 0.21 b | 1.57 b |
| **Van (Covered)** | 10.34 a | 5.09 a | 0.91 a | 2.03 a |

*Means followed by the same letter in the same column, for each cultivar, are not significantly different (Duncan's multiple range test P≤0.05).