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Manual Defoliation Treatments Affected Yield and Cluster Quality of Grapevines Cv. Crimson Seedless

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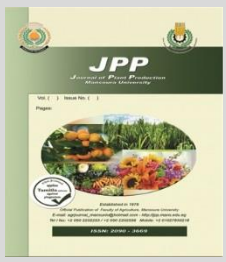

ABSTRACT

This study has proceeded during 2018 and 2019 vintages for resolving the major problems which facing Crimson seedless grapevines production e.g., lack of anthocyanin accumulation at ripening and bunch rot incidence by *Botrytis cinerea*. So, Crimson grapevines were defoliated at pre- and post-blooming by removing eight basal leaves or by removing four leaves before and after blooming (three treatments) in addition to the control. The pre-blooming defoliation of grapevines enhanced vegetative growth conditions and gave a satisfying yield with the good coloring of cluster berries and fewer rot infections.

Keywords: Leaf removal – Crimson – defoliation - Grape – Vines – Anthocyanin.

INTRODUCTION

The Crimson seedless cultivar is red seedless table grape which ripens late (mid-September). The skin is medium thick and its flesh is clear, firm and crisp. The berry's taste is sweet and natural. It has a great market acceptance due to its excellent nutritional properties and its exportable value (Río-Segade *et al.*, 2013). This cultivar faces some production problems like accumulation of anthocyanin and the redundant of set percentage which increasing cluster compactness leading to small berries and cluster rot (Dokoozlian and Peacock, 2001).

Anthocyanin is responsible for the red color of Crimson berries and it was affected by cluster exposure to direct sunlight and leaf removal enhanced anthocyanin (Guidioni *et al.*, 2002). There are several agents affecting grape anthocyanins, of grape, one of these agents is defoliation (Downey *et al.*, 2006). The high leaf density of grape vines impedes the penetration of light into its various parts as well as clusters. So, defoliation is important in vineyards administration especially for high vegetative vigor grapevines such as Crimson Seedless; therefore, exposed clusters by defoliation to sunlight have an increment in phenolics, anthocyanins, and sugars but their titratable acidity decreased compared to shaded clusters (Poni *et al.*, 2006; DiaGo *et al.*, 2012).

Vine leaves (source) photosynthesis is accountable for the formation of carbohydrates and its transmission to clusters (sinks); so, the equilibrium between leaves and clusters is vital for grape quality (Iland *et al.*, 2011).

Defoliation is a unified practice for enhancing source-sink linkages, photosynthetic ability, and quality of crop plants, defoliation can be implemented at all phases of vine growth: pre-blooming, post-blooming, berry setting, pre-véraison and véraison counting on application purpose but early defoliation is unprecedented and innovative viticultural application to adjust yield and enhance clusters quality; hence, pre-bloom defoliation allowed full recovery of the leaf: fruit ratios to that seen in non-defoliated vines due to the improvement of fruit exposure and air circulation (Palliotti *et al.*, 2012; Komm and Moyer, 2015). Also, defoliation could decrease cluster rot infections (Lee and Skinkis, 2013; Feng *et al.*, 2015).

Crimson cultivar needs to regulate its crop load for improving its cluster quality and vine growth (Kurtual *et al.*, 2006). Early defoliation is good vineyard practice for reducing yield and compactness of clusters (Sabbatini and Howell 2010). Therefore, this study aims to choose the optimum time for the defoliation of Crimson grapevines in order to achieve high crop quality.

MATERIALS AND METHODS

1. Plant Material and Vineyard Site:

The present investigation was studied during the 2018 and 2019 vintages to set the appropriate defoliation timing of Crimson seedless grapevines for achieving high crop quality. The grapevines used were 3-year-old, planted at 2 m between vines and 3.5 m between rows, irrigated by a drip system, grown in clay soil and pruned on 15th February (8 canes with 10 to 12 nodes for fruiting and 5 to 6 renewal spurs with 2 nodes at the head) under Gable trellis system at a commercial vineyard at El-Mahalla El-Kobra, Gharbia Governorate, Egypt.

Sixty-three grapevines, with high vitality and symmetrical in growth were picked out for the destination of this study utilizing a completely randomized design with three replicates (each replicate is represented by three vines) to perform the following treatments in both vintages:

T_1 Pre-blooming defoliation by removing eight basal leaves.
T_2 Post-blooming defoliation by removing eight basal leaves.
T_3 Defoliation by removing four leaves before and after blooming.
T_4 non-defoliated (control).

Defoliation was formed by manually detaching leaves and laterals from the eight basal nodes on all shoots at different timings as mentioned above. Pre-bloom defoliation was performed on 25 April in 2018 and on 30

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April in 2019. Fruit-set defoliation was carried out on 12 May in 2018 and on 20 May in 2019.

2. Crop load (m^2/kg), Leaf area per vine (m^2) and Yield per vine (kg):

Crop load was calculated as the total leaf area per vine divided by yield per vine (m^2/kg). Leaf area per vine was determined as m^2 at harvest by removing 30 leaves/replicate (6th or 7th leaf) which was expressed as cm^2 utilizing this equation: Leaf area (cm^2) = 0.587 (L×W). Where L= length of the leaf blade and W= width of leaf blade according to **Montero *et al.* (2000)** and multiplying by the mean number of leaves per shoot and the obtained results were multiplying by the mean number of shoots per vine. Yield per vine was determined at harvest time (13 August in 2018 and 23 August in 2019) by counting clusters per vine, then multiply by the cluster's average weight.

3. Clusters morphology and Berries properties and composition:

When SSC % reached about 19-20% (Abd El-Razek *et al.*, 2011), we harvested six clusters from each replicate and taken them to Pomology Department for measuring clusters morphology {average of cluster weight (g), length and width (cm), number of berries per cluster and their weight}. Also, 70 berries of each cluster were taken randomly from each replicate to estimate average berry diameter (mm) and its composition{SSC % by a refractometer and percentage of total titratable acidity as a tartaric acid (AOAC, 1995)}. And total anthocyanin was measured in berry skin extract (mg/100g fresh weight) according to Mazumadar and Majumder (2003).

Regarding the cluster coefficient of compactness, it was indexed as a ratio between the number of berries per cluster and cluster length (cm) (Fawzi *et al.*, 2019).

Referring to Botrytis incidence, it was determined as a percentage between the number of incidence clusters with rot and clusters number per vine. Botrytis severity was assessed as a percentage between the number of diseased berries and berries number per cluster.

4 .Statistical analysis

Data were statistically analyzed by variance analysis (ANOVA) as illustrated by Snedecor and Cochran (1994), using the statistical package program SAS (SAS Institute Inc. Cary, NC, USA) as a randomized complete design. Comparisons between means were made using the Least Significant differences Test (LSD) as indicated by Waller and Duncan (1969) at 5% probability level.

RESULTS AND DISCUSSION

1. Leaf area, Yield and Crop load Per Vine

Data in Table 1 illustrate that all utilized applications significantly affected the leaf area, yield, and crop load per vine. Early leaf removal at pre-blooming (T1) presented the highest leaf area per vine closely to control (T4) during both vintages; hence, it resulted in 29.75& 34.30 and 28.58 & 33.13 m^2 in the two vintages of study, respectively. That not astonishing because pre-bloom defoliation allowed full recovery of leaf area per vine which was not happened by late defoliation (T2) or defoliation by removing four leaves before and after blooming (T3) and that was confirmed by Tardaguila *et al*. (2010) on Graciano and Carignan grape cultivars.

Non and post-blooming defoliated vines (T4 and T2) achieved the highest yield following by pre-blooming defoliation (T1) but defoliation by removing four leaves before and after blooming (T3) yielded the lowest yield per vine in this study. This reduction in yield due to T1 and T3 is mainly due to these treatments reduce fruit set percentage and therefore decrease berries cluster number (Table 2); hence, pre-blooming defoliation minimizes the obtainability of carbohydrates; consequently, the fruit set is substandard (Poni *et al.*, 2006; Tardaguila *et al*., 2010).

Table 1. Effect of different treatments on leaf area, yield and crop load per vine of Crimson seedless grapevines during the 2018 and 2019 vintages.

Treatment	Leaf area / vine (m^2)		Yield / vine (kg)		Crop load (leaf area/yield) (m^2/ kg)	
	2018	2019	2018	2019	2018	2019
1	29.75 A	34.30 A	9.12 B	11.13 B	3.29 A	3.09 A
2	20.54 C	25.09 C	10.83 A	12.99 A	1.89 C	1.94 C
3	23.99 B	28.54 B	6.96 C	8.69 C	3.46 A	3.29 A
4	28.58 A	33.13 A	10.88 A	13.05 A	2.63 B	2.54 B
LSD at 5%	2.63	2.61	1.29	1.41	0.54	0.46

The larger lopsidedness in vegetative productive occurred in non-defoliated vines (T4) and those defoliated during post blooming (T2) but it was sharply in T2 which presented the lowest crop load in this study. This is associated with the decrease in leaf area per vine which induced by T2, concomitantly with the higher yields observed in its vines and that was in accordance with Würz *et al.* (2017). In general, pre-bloom defoliation allowed full recovery of leaf area: yield ratios than the non-defoliated vines and this is very logic because the fact we induce by defoliation is reducing yield and the reduction in yield is always more than proportional to the reduction in leaf area though at the end of the season leaf area to yield ratio was increased in pre-blooming defoliation treatment (T1).

However, We might assume that the increment in the leaf area due to defoliation at harvest was the result of a compensative response that motivates stretching in leaf area, probably through lateral shoots (Poni *et al.*, 2006; Pastore *et al*., 2013). This response emerged a leaf area-to-defoliated vine yield ratio which was greater than control when measured at harvest (Table 1).

2. Clusters and Berries morphology

The concerning data in Table 2 indicate that defoliation applications significantly reduced cluster weight, and berries morphology (number, weight, and diameter of berries) but showed an increase in clusters length and width than the control. Moreover, pre-blooming defoliation (T1) presented more pronounced effect in this concept; hence, it presented the highest cluster length and width compared to other treatment under this study but it reduced berries morphology (number, weight, and diameter of berries) and cluster weight compared to non-defoliated vines (T4) which showed the highest cluster weight and berries morphology (number, weight, and diameter of berries) during both vintages under this study. These results are in agreement with those recorded by Intrieri *et al.* (2008) who mentioned that defoliation reduced berries number per cluster due to the reduction in fruit set of the defoliated vines, as the number of flowers that set during anthesis is physiologically related to assimilating shoot-leaf area.

Table 2. Effect of different treatments on clusters and berries morphology of Crimson seedless grapevines during the 2018 and 2019 vintages.

Treatment	Cluster weight (g)		Cluster length (cm)		Cluster width (cm)		Berries number		Berries weight (g)		Berry diameter (mm)	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
1	426.9 B	456.9 B	24.7 A	27.2 A	15.8 A	18.4 A	102.7 C	105.7 C	417.5 B	447.5 B	16.4 CB	16.2 CB
2	451.4 BA	481.4 BA	25.0 A	27.6 A	17.0 A	19.6 A	119.0 B	122.0 B	442.9 BA	472.9 BA	16.6 B	16.4 B
3	348.1 C	378.1 C	21.8 B	24.4 B	16.0 A	18.6 A	95.3 C	98.3 C	338.0 C	368.0 C	16.2 C	15.9 C
4	459.8 A	489.8 A	21.2 B	23.7 B	13.9 B	16.5 B	132.7 A	135.7 A	450.4 A	480.4 A	16.8 A	16.6 A
LSD at 5%	31.49	31.48	1.47	1.46	1.79	1.77	11.02	11.01	31.71	31.70	0.22	0.21

Furthermore, early defoliation caused a reduction in berries' weight and diameter and that is mainly due to a decreased assimilative inflow in the period of rapid berry development (Mullins *et al.*, 1992). This stage lasted between 3 and 4 weeks after flowering and during this phase berries grew both through a cell division and cell enlargement (Coombe, 1992). No further cell division occurs after this period. At this stage, berry enlargement is very sensitive to assimilative supply because it requires intense biosynthesis of structural and osmotic compounds and enzymatic machinery, which are energy-dependent (Ollat and Gaudillere, 1998). Berry development followed a typical double sigmoid curve; hence, berries develop in two phases, separated by a phase of slow growth – lag phase (Coombe, 1992).

Moreover, all defoliated vines enhanced cluster length and width compared to no defoliated once, especially pre-blooming defoliation (T1) which allowed full recovery of leaf area and achieved the highest leaf area per vine compared to other treatments (Table 1) and therefore enhanced photosynthesis of vines which assimilate cluster development. These results are in agreement with those on 'Chardonnay' and 'White Riesling' grapevines (Zoecklein *et al.*, 1992) and on 'Pinot noir' vines (Vasconcelos and Castagnoli, 2000).

3. Berries composition and Anthocyanin content

Data in Table 3 reveals that all defoliation treatment showed an increment in SSC%, but a reduction in titratable acidity% of Crimson berries juice compared to the control (T4) during both vintages. Moreover, pre-blooming defoliation (T1) showed the most pronounced effect on SSC%; it recorded 19.8 & 20.2 %, but had the lowest titratable acidity %; it recorded 0.50 & 0.55 % during the two vintages, respectively. That is because this application increased leaf area compared to control (Table 1). This is supported by the results of Abd El-Razek *et al.* (2010) who demonstrated that the soluble solid content (SSC %), and SSC/acid ratio were increased by defoliation but the acidity was decreased in the berries of 'Crimson Seedless' grapes and that was in agreement with many investigators who found that sunlight-exposed fruits are generally rich in soluble solid content and show reduced titratable acidity, compared to non-exposed or canopy shaded (Reynolds *et al.*, 2006; Fox, 2006). Also, Gatti *et al.* (2012) found similar results, which may be related to increased sun exposure in the cluster zone.

Also, early defoliation, correlated with a high incidence of solar radiation, allows a decrease in titratable acidity percentage (Intrigliolo *et al.*, 2014; Risco *et al.*, 2014). Also, Conde *et al.* (2007) mentioned that the exposed cluster to sunlight increased its temperature, leading to an increment in respiration rate in cells which caused a deterioration in titratable acidity.

Table 3. Effect of different treatments on Berries composition and Anthocyanin content of Crimson seedless clusters during the 2018 and 2019 vintages.

Treatment	Soluble solids concentration (SSC %)		Titratable acidity (%)		Anthocyanin (mg/100g fresh weight)	
	2018	2019	2018	2019	2018	2019
1	23.8A	24.2A	0.50B	0.55B	41.43A	43.98A
2	21.2C	21.5C	0.60A	0.65A	26.50C	29.05C
3	22.5B	22.8B	0.52B	0.57B	39.94A	42.49A
4	20.6C	20.9C	0.59A	0.64A	34.16B	36.71B
LSD at 5%	1.18	1.16	0.04	0.03	3.07	3.06

Concerning to the effect of different treatments on berries content of anthocyanin (Table 3), it is obvious that pre-blooming defoliation (T1) and defoliation by removing four leaves before and after blooming (T2) gave the highest value of anthocyanin but (T1) was higher, and the lowest value of anthocyanin content was obtained by post-blooming defoliation (T2). In this respect, Lee and Skinkis (2013) and Sternad Lemut *et al.* (2011) found that early defoliation, compared to non-defoliated vines of Pinot noir, produced higher anthocyanin accumulation. And that may be because anthocyanin content is highly contingent by the amount of solar radiation, both in the vegetative canopy and directly in the clusters (Sun *et al.*, 2012). Our results are compatible with those mentioned by Ferree *et al.*, 2004; Kliewer and Dokoozlian, 2005; Sabbatini and Howell, 2010 who found that fruits exposed to sunlight achieved a high accumulation of anthocyanin compared to non-exposed.

4. Compactness, Botrytis incidence and severity of clusters

Defoliation of Crimson seedless grapevines generally reduced the compactness, botrytis incidence and severity of clusters during both vintages of the study (Table 4). It is obvious pre-blooming defoliation (T1) gave a superior reduction than the other defoliation treatments or the control; it recorded 4.16 & 3.88 for cluster compactness, 8.25 & 9.60 for botrytis incidence percentage and 2.35 & 2.68 for botrytis severity percentage in the two vintages, respectively. While the non-defoliated Crimson vines topped the scene for these parameters; hence, it gave the highest rate of compactness and botrytis incidence and severity of grapevines clusters than the others; it recorded 6.26 & 5.72 for cluster compactness, 21.31 & 22.66 % for botrytis incidence and 6.69 & 7.02A % in the two vintages, respectively.

Table 4. Effect of different treatments on cluster compactness, botrytis incidence and severity of Crimson seedless grapevines during the 2018 and 2019 vintages.

Treatment	Cluster compactness		Botrytis incidence (%)		Botrytis severity (%)	
	2018	2019	2018	2019	2018	2019
1	4.16C	3.88C	8.25D	9.60D	2.35D	2.68D
2	4.76B	4.43B	13.27B	14.61B	4.42B	4.75B
3	4.37CB	4.03C	10.35C	11.69C	3.33C	3.66C
4	6.26A	5.72A	21.31A	22.66A	6.69A	7.02A
LSD at 5%	0.43	0.38	0.96	0.94	0.06	0.063

The reduction in cluster compactness due to defoliation treatments referring to the increment in cluster length and the reduction in cluster berries number which occurred in defoliated vines and these results are supported by Poni *et al*. (2006) and Beslic *et al.* (2013). Furthermore, defoliation treatments resulted in a reduction of bunch rot incidence e.g., *Botrytis cinerea* (Molitor *et al*., 2011; Mosetti *et al.*, 2016) and that could be explained by the looser clusters with better penetration of light, air and higher cluster exposure that provided better ventilation and more effective spray treatments from flowering to harvest (Tardaguila *et al.*, 2010; Frioni *et al.*, 2017).

In summary, the grape quality was quite high for the defoliation treatments of Crimson Seedless grapevines; therefore, the decision upon defoliation timing is precisely based on vineyardists planning for grape quantity/quality ratio at harvest. Favorable yield with good cluster quality of cv. Crimson Seedless could be accessed through pre-blooming defoliation at the Gable trellis system.

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أثر معاملات التوريق اليدوي على محصول وجودة عنقود كرمات العنب صنف الكريمسون عديم البذور

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تم المضي قدما في هذه الدراسة خلال عامي ٢٠١٨ و ٢٠١٩ من أجل حل المشاكل الرئيسية التي تواجه إنتاجية كرمات العنب الكريمسون عديم البذور مثل نقص تراكم الأنثوسيانين عند النضج وتعفن العنقود عن طريق البوتريتس. لذلك ، تم توريق كرمات العنب الكريمسون في مرحلة ما قبل وبعد التزهير عن طريق إزالة ثماني أوراق قاعدية أو عن طريق إزالة أربع أوراق قبل وبعد التزهير (ثلاثة معاملات) بالإضافة إلى الكنترول. عزز توريق الكرمات قبل التزهير حالة النمو الخضري وأعطى محصول مرضي مع تلوين جيد لحبات العنقود وإصابات أقل للتعفن.