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The Feasibility of Applying Post-Veraison Regulated Deficit Irrigation, Gibberellic Acid and Defoliation on Cracking Phenomena of Autumn Royal Grape Cultivar

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Abstract: A field experiment was performed during the seasons 2019 and 2020, to evaluate the effect of post-veraison regulated deficit irrigation (RDI), Gibberellic acid and defoliation on cracking phenomena of the seedless table grape 'Autumn Royal'. Two irrigation treatments at 60% and 80% were applied post-veraison, GA_3 at 20 mg/L, defoliation at veraison four basal leaves (2 leaves below +2 leaves above the cluster) and a control treatment irrigated at 100% of the net irrigation requirements about 3620 m^3/fed. Results showed that average yield was higher in RDI treatment in at 80% with a water saving in 20% than the control. In addition, berry cracking was less than 10% in RDI at 80% followed by 60%. However, similar yield values were obtained from full irrigation at 100 %, GA_3 and defoliation treatments with no significant differences between them but after eliminating the cracked berry, the net yield was significantly higher than the control. This result suggests that the change in irrigated water amount could have a beneficial effect on berry cracking due to the change in vine canopy microclimate through limiting vegetative growth of vines that enhancing light penetration in the vines.

Key words: Autumn Royal seedless grape · Berry cracking · Deficit irrigation · Fruit quality · Water stress · Microclimate

INTRODUCTION

Autumn Royal is a seedless table grape cultivar with a big berry, purple-black to black in color with a high commercial value, which matures at the last of August. This cultivar is susceptible to berry cracking, which is a serious problem because it increases the labor required since the clusters need to be cleaned during the maturation phase until the harvest. Berries crack some years and others they progress without any cracks.

Berry development has three distinct growth phases: After pollination, grape berry growth is rapid and lasts for 3 to 4 weeks. The second phase of berry development is a lag phase of growth where berries begin to lose chlorophyll and the berries remain very firm. It lasts between 2 to 3 weeks. The third stage is characterized by a period of berry's rapid growth. At this stage the berries begin to soften and sugars accumulate while organic acids decline. Berry growth occurs only by cell enlargement. The veraison takes place in this stage when the berry cracking occurs. It is believed that it was the result of cell enlargement being arrested and the interaction with environmental conditions. Irrigation may play a role in berry cracking. Initial research suggested that heavy irrigation resulted in berry cracking. It is widely known that the internal pressure on berries increases after irrigation [1].

Another problem in this cultivar is the weak attachment of the berries to the rachis, so clusters must be very carefully handled in order to avoid the berry loosening [2].

In vineyards, RDI techniques have been used by applying a reduction in irrigation in the phase of maturation in order to maintain yield and improve the juice quality [3]. However, El-Ansari *et al.* [4] results showed that the severe RDI decreased firmness and acidity and increased total soluble solids of the berries when studying the effects of post-veraison RDI on 'Muscat of Alexandria' grape cultivar quality.

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During fruit development, early stage water deficits after flowering and before veraison result in smaller berries and reduced yields [5]. Furthermore, deterioration of quality in terms of visual appearance of the bunch, berry color and uniformity have been reported [6]. Contrasting behavior was determined for late season limitations, as the sensitivity of grapevines to water limitations after veraison is low [7]

It was found that GA_3 application can reduce the susceptibility to cracking and decay [8] However, Seedless cultivars are routinely treated with GA_3 early in the season to improve berry size and elongate the clusters [9].

On the other hand, Lichter *et al.* [10] indicated that GA_3 did not affect berry size, brix or acidity but had minor effects on berry firmness. Moreover GA_3 reduced the level of peel cracking in some of the experiments and the late application was more effective than early application, suggesting that the process is not at the level of cell division.

Based on the functional relationship between defoliation in the cluster zone and nutrient availability, the removal of leaves near to the basal in florescence, which is the main result of good aeration with lower RH%, restricts the nutrient supply of flowers and thus, berry cracking and cluster compactness are reduced [11].

It was found that relative humidity levels near saturation (100%) can increase the berry cracking [12]. Thus, defoliation or leaf removal in the fruiting zone facilitates air movement and allows air ventilation [13]. Defoliation at pre-bloom caused a slight increase of the width and length per cluster, this could be ascribed to improve ventilation in sparser clusters of pre-bloom vines and this could have caused less cracking of the cluster berries [14].

The theory of the cracking mechanism was based basically on the penetration of water into the berry surface, leading to an increase in its volume and thus to their cracking [15, 16]. Other research on cracking indicated that the water uptake by the fruit from the root system can buildup internal turgor pressure of fruit which also plays an important role in cracking mechanism [17].

The aim of this trial is to ascertain the effect of two strategies of RDI applied from veraison to harvest, defoliation and GA_3 on the yield and berry quality of table grape Autumn Royal cultivar, regarding to berry cracking.

MATERIALS AND METHODS

This study was carried out during two successive seasons 2019 and 2020 in a vineyard located at El-Sadat City, 30° 22' 30" N and 30° 30' 1" E, where this area is characterized by hot to moderate climate. Four year-old seedless table grape "Autumn Royal" spaced 2 x 3 m grown in a sandy soil were used in this investigation. Vines were cane pruned, trellised by Spanish parron system with a bud load of 96 buds/vine (12 canes x 8 buds) in addition to 12 spurs x 2 buds / spur . Pruning was carried on the 15^{th} of January and irrigated via a drip irrigation system.

Seventy five uniform vines were chosen for this study (5 treatments x 3 replicates x 5 vines/replicate). The experiment was carried out on the same vines for both seasons and received common horticultural practices recommended by Ministry of Agriculture. The vineyard was drip irrigated with two lines per row and eight emitters for each vine with 4 L/hr and valves were used for regulating water amounts to the applied water quantity. In the full irrigation treatment 100 %, water requirements was calculated, based upon the potential evapotranspiration (ET_o) according to the modified Penman equation [18].

(WR = Kc x ETo x IE)

where:
Kc = "Crop Coefficient" = A factor that is used to convert ETo to potential vineyard ET (ETc).
ETo = "Reference ET" = The amount of full water use by a well irrigated crop.
IE = Irrigation efficiency of water consumption use

It was found that water requirements were 3620 m^3/fed, which is equivalent to 1.0 ET according to El-Gendy, [19]. This amount was distributed on the growing season stages. The period from veraison till harvest alone required 49% from the overall amount of water.

GA_3 and defoliation treatments were applied at full irrigation (100%). GA_3 was sprayed at late fruit set corresponding to berry diameter of 6 to 8 mm by direct application to the clusters of 20 mg/L, at a rate of 1L/vine. Defoliated vines were subjected to leaf removal of four basal leaves at veraison (two before the cluster and two after the cluster) for both seasons as follow:

- Full irrigation 100% (Control)
- Regulated deficit irrigation at 80% post veraison
- Regulated deficit irrigation at 60% post veraison
- Defoliation at veraison (4 basal leaves; 2 below +2 above the cluster).
- Gibberellin at 20 mg/L (to berry diameter of 6 to 8 mm)

The following measurements were taken to evaluate the effect of the different treatments:

Climatic Data Beneath the Vine Canopy: Data of microclimate was taken inside the vine canopy for each treatment and was recorded weekly at the berry set as follow:

- Sunlight intensity. (1000 Lux)
- Relative humidity. (%)

They were measured on three levels lower, middle and upper branches using "Scheduler Plant Stress Monitor", Standard Oil Engineered Materials Co., Ohio, USA. All the microclimatic measurements were taken using the microprocessor of the apparatus to calculate the average of canopy microclimate to find the relationship between the factors of microclimate and different treatments in order to reduce berry cracking.

Yield: Samples of 15 clusters were collected randomly for each treatment, each treatment (5 clusters from each replicate) when clusters reached their full color and total soluble solids reached about 15-18%, according to Badr and Ramming [20].

- Yield per vine (kg): to calculate the average yield/vine, the random samples were collected and weighed then the mean of cluster weight was multiplied by the number of clusters / vine after being adjusted to 35 clusters per vine after fruit set.
- Average cluster weight (g).
- Average berry weight (g): weight of 10 berries / 10.
- Average berry size (cm^3): by using the measuring cylinder, volume of 10 berries were taken then divided by 10.
- The percentage of cracked berries /cluster (%): At harvest clusters were harvested and the number of cracked berries in each cluster were counted and divided by the total number of berries in each treatment to calculate the percentage of cracked berries as follow:

The percentage of cracked berries = Number of cracked berries / Total number of berries per cluster

- The net yield (Kg): it was calculated for each treatment by the following equation
  Total yield – (Total yield x percentage of cracked berries)
- Berry firmness (g/cm^3) and adherence (g) by using PHSH-PULL (Dynamometer Model DT101).

Chemical Characteristics of Berries: The following determinations were carried out:

- Refractometric total soluble solids (TSS %) and titratable acidity % (one gram of tartaric acid for 100 ml of juice) and TSS / acid ratio were determined according to A.O.A.C., [21].
- Total anthocyanin in berry skin (mg/100g): the spectrocolourimeter is used at 250 nm according to Yilidz and Dikmen [22].

Vegetative Growth Parameters:

- Leaf area (cm^2): Samples of 20 leaves were randomly collected from each treatment for leaf area determination at harvest time (using leaf area meter, Model CI 203, U.S.A.).
- Total leaf area/vine (m^2): The mean leaf area (cm^2) of the basal [5^{th} to 7^{th}] from the shoot tip was multiplied by the average number of leaves / shoot and average number of shoots for each vine at harvest time.
- Shoot length (cm): it was determined by measuring the fruiting shoots before harvest.
- Total chlorophyll content of leaves (SPAD): were measured at harvest time in the mature basal leaves of the sixth and seventh nodes by using the nondestructive Minolta chlorophyll meter model SPAD 502.

Statistical Analysis: The statistical analysis of the present data was carried out according to Snedecor and Cochran [23]. Averages were compared using the new L.S.D. values at 5% level using a randomized complete block.

RESULTS AND DISCUSSION

Climatic Data Beneath the Vine Canopy

Sunlight Intensity (1000 Lux): The data presented in Figure 1 shows the light intensity at the vines canopy as affected by various treatments. There are significant differences among treatments. Data revealed that sunlight intensity values are inversely proportional with the irrigation levels in both seasons, as irrigation at 100% decreased the amount of light reaching the clusters (40.5, 41.6) for both seasons. Sunlight was higher in the

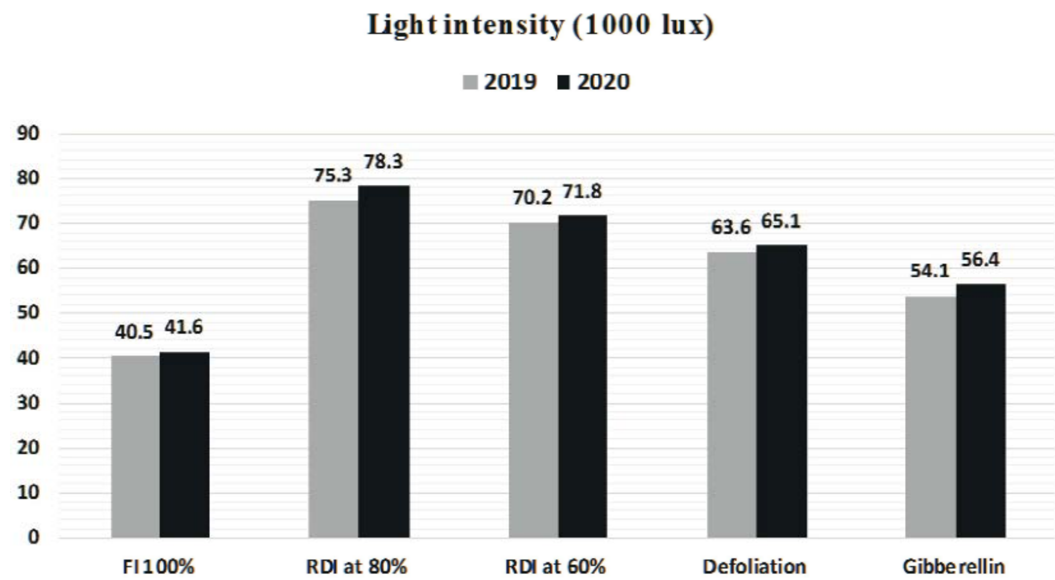

Fig. 1: Feasibility of applying post-veraison RDI, GA_3 and defoliation on canopy Light intensity (1000 lux) of Autumn Royal grape cultivar during the two successive seasons 2019 and 2020

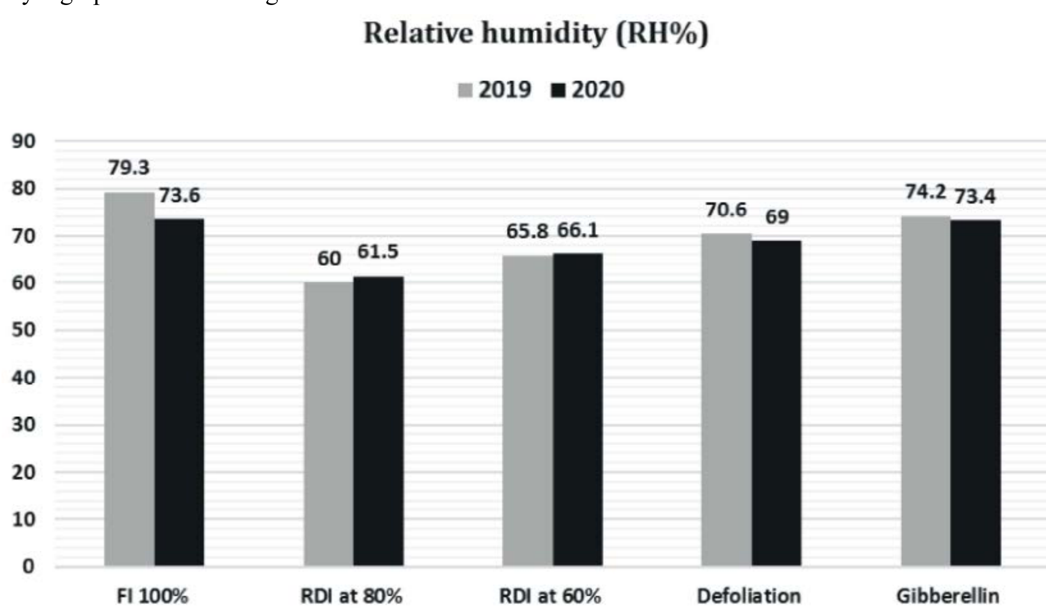

Fig. 2: Feasibility of applying post-veraison RDI, GA_3 and defoliation on canopy Relative humidity % of Autumn Royal grape cultivar during the two successive seasons 2019 and 2020

vines irrigated at level 80 % and 60 % RDI (75.3, 78.3 & 70.2, 71.8) in both seasons respectively. These results were noticed during both seasons and can be explained according to the fact that, reducing of irrigation plays an important role in limiting vegetative growth of vines that enhancing light penetration in vine microclimate (1).

Moreover, leaf removal of four leaves (two basal under cluster + two above cluster) led to an increase in light intensity inside the canopy of the vines.as stated by Bedrech and Mostafa, [24] that the highest light intensity in the canopy was recorded by the treatments of defoliation in comparison with the control.

It was found that GA_3 has the lowest values of light intensity after the control. According to different investigators, GA_3 treatment improved vegetative growth and leaf area which led to a decrease in light penetration within the canopy [25].

Relative Humidity (%): There were significant proportions between the canopy density and levels of irrigation, as it is obvious in Figure 2. Relative humidity (RH %) is higher in the dense canopies of the control (irrigated at 100 %) vines than any other treatments. Bertin *et al.* [26] observed the clear interaction between RH% on fruit cracking where increasing RH% increases the occurrence of fruit cracking. Humidity can build up slightly in dense canopies as mentioned before by Ramteke *et al.* [1] that reducing of irrigation plays an important role in limiting vegetative growth of vines that in turn reduces the relative humidity in vine microclimate. It is probably the factors such as irrigation and sunlight that may affect the plant response to RH%.

Similarly, defoliation is an important parameter affecting canopy RH% which shows an opposite pattern (Figure, 2). Consequently, defoliated vines has a lower RH% than the control as found by Bedrech and Mostafa [24] who stated that relative humidity were observed in the treatments of defoliation than the foliate vines.

It was found that GA_3 has the higher values of relative humidity after the control. On other words, RH% is high in vines that showed a very high canopy growth. According to different investigators, GA_3 treatment improved vegetative growth and leaf area which in turn led to an increase in the canopy RH% [9].

Yield

Average Yield per Vine (Kg) and Cluster Weight (g): It could be observed that, vines irrigated at level 80 % and 60 % RDI respectively produced a higher significant yield than 100% in both seasons (Table 1). By calculating the overall loss of yield we can notice that the net yield in the vines irrigated at 100% gave the least values of the mentioned parameters in both seasons, because of the berry cracking effect which leads to a significant commercial loss in the grape production by decreasing yield [1].

In a previous study, it was found out that the overall results during three study years showed that high grape yields of very good quality can be obtained with moderate RDI in the post veraison phase without affecting grape quality [27]. Also, Romero *et al.* [28] stated that, the moderately irrigated vines of "Tempranillo" cv. gave greater yield than that severed irrigated.

Similar yield values were obtained from full irrigation at 100 %, GA_3 and defoliation treatments with no significant differences between them in the second season. On the other hand, by calculating the overall loss and the net yield by eliminating the cracked berries, we can find that they differ significantly with a superior values obtained from GA_3 followed by defoliation treatments compared with the control in both seasons.

Similarly, data revealed that four leaves removal (2 below + 2 above the cluster) at fruit zone may be sufficient to improve ventilation which make them less susceptible to berry cracking. These findings are in linear with those obtained from Poni *et al.* [29] who stated that leaf removal, led to reducing cluster compactness for all defoliation treatments as compared to non-defoliated shoots.

Average Berry Weight (g): It is accepted that one of the main results of irrigation treatments is an increase in berry weight and size [30], as it found in our results. It could be observed that, vines irrigated at level 80 % produced the highest significant berry weight compared with 60 % RDI and 100% respectively in both seasons (Table 1). These results are in harmony with De la Hera-Orts *et al.* [31] finding that berry weight was greatest in moderate than severe irrigation treatments. The increase was very fast during the first days of Stage III (defined as the period of time from veraison to maturity). Moreover, Romero *et al.* [28] and Shahidian *et al.* [32] summarized that, reducing irrigation had a negative effect on berry weight, length and diameter.

Berry weight was higher in clusters of vines treated by GA_3 and defoliation treatments respectively than the other treatments in both seasons. These results are similar to those of Sidahmed and Kliewer [33] who found that gibberellic acid (GA_3) applied to defoliated vines produced significantly heavier berries than the not defoliation vines.

Average Berry Size (cm): Full irrigation is not recommended since it increases the berry size (Table 1) and this produces a decrease of the skin pulp ratio which is detrimental for the grape quality [34]. Our results indicated that RDI had a significant effect on the grape berry size and the largest berry size was obtained under 80% RDI, while the smallest berry size was obtained under the full irrigated treatment application in the same season.

However, Seedless cultivars are routinely treated with GA_3 has a great effect on improving berry size and elongate the clusters [9].

The Percentage of Cracked Berries: In our study, the Autumn Royal cultivar showed high berry cracking levels in vines irrigated at 100% irrigation, (Table 1) whereas in 80% followed by 60% of RDI, the level of damage, in term

Table 1: Feasibility of applying post-veraison RDI, GA_3 and defoliation on yield and morphological measurement of Autumn Royal grape cultivar during the two successive seasons 2019 and 2020

	Yield/vine (Kg)		Cluster weight (g)		Berry weight (g)		Berry size (cm^3)		Cracked berries (%)		Net yield/vine (Kg)	
Treatments	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
FI 100%	23.5	23.2	684.4	664.4	6.0	5.9	5.8	5.7	20.4	19.3	18.7	18.7
RDI at 80%	30.5	28.9	873.3	828.2	7.7	7.2	7.5	7.4	5.2	5.6	28.9	27.2
RDI at 60%	27.7	26.8	793.2	766.5	7.4	6.9	7.3	6.6	6.4	7.8	25.9	24.7
Defoliation	23.0	23.6	657.7	675.8	6.3	6.3	6.0	6.1	13.3	14.7	19.9	20.2
Gibberellin	24.6	24.7	728.8	706.5	6.7	6.6	6.6	6.5	12.1	13.2	21.6	21.4
New L.S.D. at 0.05	2.0	2.0	15.0	10.0	0.2	0.2	0.1	0.2	1.0	1.0	0.9	0.8

of cracked berries, was negligible in both seasons. The changes in irrigation management and the application of RDI in the post veraison phase can maintain yield and improve berry quality and especially decrease berry cracking in the Autumn Royal cultivar. This problem is attributed to an excess water application in the maturation phase [35].

The reduction in berry cracking phenomena as a result of reducing or regulating the amount of irrigation can be ascribed to the fact that, decreasing irrigation plays an important role in limiting the vines vegetative growth which in turn enhances the light penetration and reduced the relative humidity within the vine canopy as cleared by Ramteke *et al.* [1].

However, GA_3 application reduced the susceptibility to berry cracking [8]. Moreover, GA_3 applied after berry set was more effective in reducing the level of peel cracking than earlier application as it was indicated by Lichter *et al.* [10] suggesting that the process is not at the level of cell division.

Defoliation treatment played an important role in limiting the cracked berries percentage by providing good aeration and decreasing the canopy RH% as it was found by Bedrech and Mostafa [24] that humidity can build up in dense canopies of the control vines than defoliated treatment. Also the severity of leaf removal (two basal before cluster + two after cluster) led to an increase in light intensity inside the canopy of the vines.

Relative humidity levels near saturation (100%) can increase the berry cracking [12]. Moreover, based on the functional relationship between leaf removal in the cluster zone of the shooting process and nutrient availability, the defoliation near to the basal in florescence restricts the nutrient supply of flowers and thus, berry cracking and cluster compactness are reduced [11]. Yield components were also markedly affected by defoliated vines treatment which showed a smaller clusters and berries, leading to improved cluster looseness and to higher relative skin growth which has greater effect on reducing the number of cracked berries per cluster [36].

Berry Firmness (g/cm^2) and Adherence (g): The significantly beneficial effect of the moderate RDI at 80% on berry firmness and berry adherence strength than the other treatments is clear in Figures 2 and 3. Data revealed that berry firmness values are directly proportional with the irrigation levels in both seasons, as irrigation at 100% increase berry firmness which results in increasing its ability to cracking. On the other hand, severe RDI at 60% showed the lowest firmness which made the berries more susceptible to shatter. Several studies investigating the effects of water deficits on table grapes observed that the treatment receiving the highest irrigation volume gave highest firmness values. Oppositely, the severe RDI decreased berry firmness [4].

Larson *et al.* [37] indicated that GA_3 effects on berry firmness appear to act by making the skin more elastic. It is a generally found that firm fleshed cultivars have higher trend to fruit cracking than soft-fleshed cultivars. Fruit cracking is caused by excess water uptake resulting in bursting of the skin [38].

Chemical Characteristics of Berries

Total Soluble Solids (TSS %) and Titratable Acidity (%) and TSS / Acid Ratio: Deficit irrigation can be of interest to improve some of the quality parameters of the berries such as color, total dissolved solids and aromas [4]. Results showed that the moderate RDI had an effect on berry juice quality at harvest. However the severe at 60% RDI increased total soluble solids of the berries recording the highest values (Table 2) followed by 80% RDI, GA_3, defoliation and full irrigation 100% treatments respectively.

It was concluded that most of the negative effects accompanied to irrigation on berry sugar are probably due to excess water supply. The reduction of sugar content during maturity is caused mainly by changing the tartaric acid to salt forms, along with the decrement of sugar concentration as an effect of increasing berry volume [39]. The sugar content may also diminish due to competition between vegetative growth obtained from full irrigated

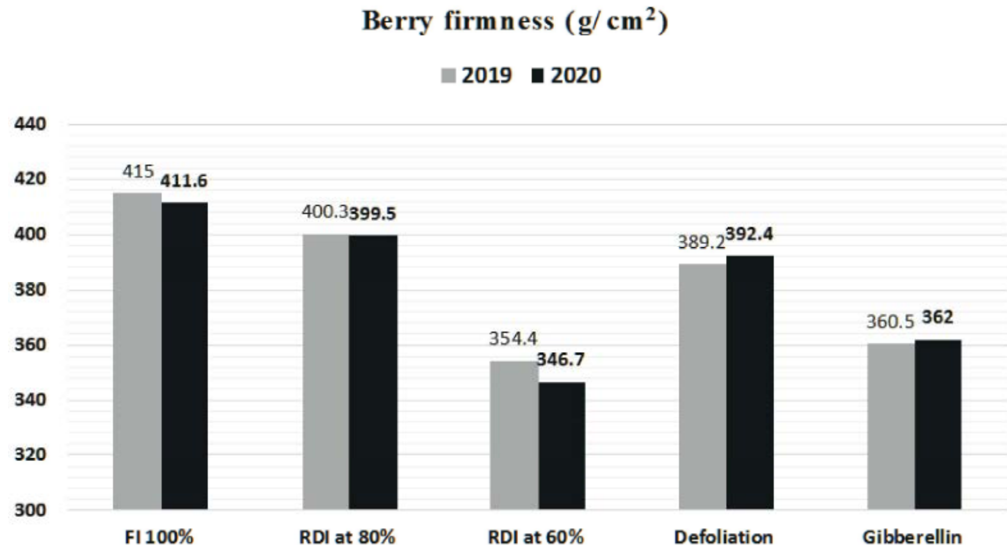

Fig. 3: Feasibility of applying post-veraison RDI, GA_3 and defoliation on berry firmness (g/cm^2) of Autumn Royal grape cultivar during the two successive seasons 2019 and 2020

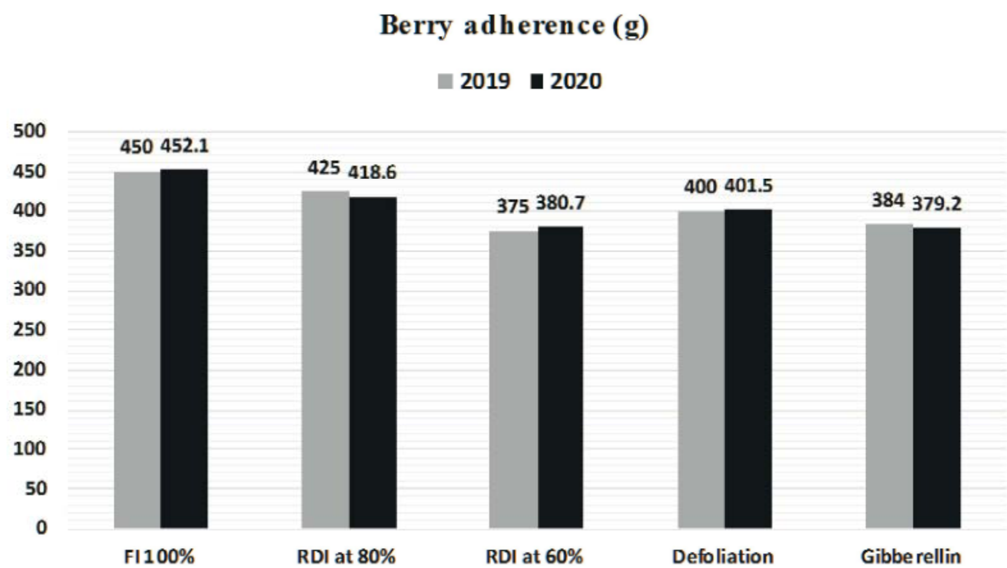

Fig. 4: Feasibility of applying post-veraison RDI, GA_3 and defoliation on berry adherence (g) of Autumn Royal grape cultivar during the two successive seasons 2019 and 2020

vines and fruit development. Thus, severe water stress tends to decrease vigor but also the sugar and acid content since photosynthetic activity may be compromised [31]. Similarly, Opazo *et al.* [40] concluded that, moderate and severe water stress significant increased soluble solids grapevines cv. Cabernet Sauvignon.

Titratable acidity is of great importance for grape juice and commonly used as indicators of quality. At the time of harvest in both seasons, significant differences were found among all treatments. The values shown in Table 2 indicates that titratable acidity was higher in full irrigated treatment grapes starting from the onset of stage III (defined as the period of time from veraison to maturity) till harvest time, while decreasing irrigation experienced a faster decrease in titratable acidity during the same period. Al-Khafaji, [41] mentioned that GA_3 had reduced the breathing of fruits thereby increasing the accumulation of organic acids and might have inhibited the chlorolytic enzymes and chlorinated bacterium, which increased the total acidity in the grape.

Table 2: Feasibility of applying post-veraison RDI, GA_3 and defoliation on chemical characteristics of berries of Autumn Royal grape cultivar during the two successive seasons 2019 and 2020

	Total soluble solids (TSS %)		Titratable acidity (%)		TSS / acid ratio.		Total anthocyanin (mg/100g fw)	
Treatments	2019	2020	2019	2020	2019	2020	2019	2020
FI 100%	15.1	15.2	1.1	0.9	13.7	16.8	34.5	34.0
RDI at 80%	16.8	16.7	0.5	0.4	33.6	41.7	44.2	43.8
RDI at 60%	17.2	17.5	0.3	0.3	57.3	58.3	46.1	48.7
Defoliation	15.5	15.6	0.7	0.7	22.1	22.2	41.8	42.5
Gibberellin	16.4	16.1	0.6	0.6	27.3	26.8	39.0	37.1
New L.S.D. at 0.05	0.3	0.3	0.04	0.02	5.0	4.0	1.0	1.0

The TSS/acid ratio basically showed a downward trend with the increasing of the irrigation rate post-veraison due to the increasing of TSS % (Table 2).

Total Anthocyanin in Berry Skin (mg/100g): Berry skin anthocyanin of Autumn Royal cultivar at harvest time was determined for all treatments (Table 2). However deficit irrigation can be of interest to improve some of the quality parameters of the berries such as color [4]. Results shows that moderate water deficits play a direct role in promoting grape composition by improving grape color, with signi?cantly higher values for 60% followed by 80% RDI than the other treatments [42]. Besides, post-veraison water deficit can stimulate the direct accumulation of anthocyanins [43].

Since the anthocyanins are synthesized in the skin, larger berry weight results in a lower skin-to-flesh ratio as anthocyanins are diluted [44]. Thus, defoliation, GA_3 and full irrigated treatment were found to be significantly less effective in increasing anthocyanin.

Vegetative Growth Parameters

Leaf Area (cm^2), Total Leaf Area/Vine (m^2) and Shoot Length (cm): Data illustrated in Table 3 showed that, deficit irrigation had a significant effect on the vegetative traits of the vines on both seasons. Results showed that in the irrigation treatments, full irrigation at 100% had a positive trend on leaf area followed by the moderate RDI at 80% treatment than severe irrigation at 60% RDI which records the lowest values of all treatments. These results may be ascribed to the fact that water stress significantly limits plant growth and its development, resulting in reductions in shoot elongation and leaf area [45]. Additionally, in the two other treatments defoliation and GA_3. Sanchez and Dokoozlian [46] postulate that the positive effects of defoliation on leaf area are related to the improved light microclimate within the renewal zone of the canopy, besides the Gibberellic acid which played an important factor for increasing leaf area [47]. Overall, our results agree with the previous studies that full irrigation at 100% gave the highest values of leaf area followed by defoliation treatment.

In respect to total leaf area, defoliation conducted around the cluster zone had an opposite trend; it reduced the total leaf area resulting in increasing sunlight exposure of grape clusters. Our findings are linear with those obtained from Fuentes *et al.* [48] who stated that basal defoliation decreases the total leaf area in the central part of the canopy and increase light penetration.

Similar to our results Mohsen and Ali [25] found that the GA_3 treatments increased the leaf area in Red globe.

Moreover, Dodd [49] previously mentioned that the shoot length significantly decreased, with increasing deficit irrigation, which is similar to the present results, due to the higher sensitivity of vegetative growth to deficit irrigation conditions.

Total Chlorophyll Content (SPAD): Total chlorophyll content (Table 3) showed higher values in the defoliated plants as mentioned before by Peña and Casierra [50].

In agreement with the data obtained in the present study, as the chlorophyll in leaves of the defoliated plants was higher than in the control plants, Hunter and Visser [51] explained that the remaining leaves in the defoliated vines, seek to lengthen their life trying to compensate the lost leaf area, through modifying the leaves chemical composition such as chlorophyll which raise the leaf photosynthetic capacity. However, leaves of defoliated vines are exposed to a higher light intensity which affects positively the development of photosynthetic capacity [52]. In this sense, it is possible that the vines of the present study modified their photosynthetic capacity in response to defoliation, resulting in raising total chlorophyll content. In addition, also Gibberellic acid had played an important factor for increasing chlorophyll content as mentioned by Korkutal *et al.* [48].

Table 3: Feasibility of applying post-veraison RDI, GA_3 and defoliation on Vegetative growth parameters of Autumn Royal grape cultivar during the two successive seasons 2019 and 2020

	Leaf area (cm^2)		Total Leaf area (m^2)		Shoot length (cm)		Total chlorophyll (SPAD)	
Treatments	2019	2020	2019	2019	2020	2020	2019	2020
FI 100%	217.3	215.6	16.29	16.17	182.4	185.2	37.2	36.8
RDI at 80%	205.6	206.4	15.42	15.48	188.5	189.3	30.6	29.2
RDI at 60%	193.5	195.7	14.51	14.67	184.7	186.1	29.3	28.7
Defoliation	210.2	211.3	14.95	15.05	199.8	201.4	28.8	28.2
Gibberellin	199.4	200.7	15.76	15.84	193.1	193.6	31.2	30.2
New L.S.D. at 0.05	0.5	0.4	0.75	0.74	6.0	5.0	4.0	4.0

Total chlorophyll content is slightly increased under regulated deficit irrigation (RDI) but with no significant results among all treatments. Similarly, Xu and Leskovar [53] stated that both deficit irrigation treatments had no significant effect on the content of chlorophyll a, b and carotenoid based on either leaf area or dry weight. These results are consistent with recent reports by Somayeh *et al.* [54] finding that deficit irrigation at 75% ETc had no significant effect on chlorophyll index as compared to 100% ETc irrigation.

CONCLUSION

The overall results during the study years showed that it is economically feasible to change the irrigation schedule which had a beneficial effect on berry cracking. The results showed that regulated deficit irrigation at 80% post veraison gave the highest yield in respect to decreasing the percentage of cracked berries besides improving the berry quality demonstrating that the use of moderate water doses in semiarid regions may improve the physiological status of the vine and, therefore, economic benefit with no significant loss in grape quality. Thus, it is possible to decrease irrigation amount from 3620 m^3/fed to 2900 m^3/fed by nearly 20%, when applied post veraison without adversely affecting berry physical quality and productivity.

REFERENCES

1. Ramteke, S., V. Urkude, S.D. Parhe and Sh. Bhagwat, 2017. Berry Cracking; Its Causes and Remedies in Grapes -A Review. Trends in Biosciences, 10: 549-556.
2. Dokoozlian, N.K., B. Peacock, D. Luvisi and S. Vasques, 2000. Cultural practices for 'Autumn Royal' table grapes. Pub TB17-00. Cooperative Extension. Tulare County. University of California, pp: 3.
3. Ferreyra, R., G. Selles, J. Peralta and J. Valenzuela, 2004. Effect of water stress applied at different development periods of 'Cabernet Sauvignon' grapevine on production and wine quality. Acta Hort (ISHS) 646: 27-33.
4. El-Ansari, D.O., O. Oakayama, K. Hirano and G. Okamoto, 2005. Response of Muscat of Alexandria table grapes to post-veraison regulated deficit irrigation in Japan. Vitis, 44(1): 5-9.
5. Conesa, M.R., J.M. De la Rosa, F. Artés-Hernández, I.C. Dodd, R. Domingo and A.P. Pastor, 2015. Long-term impact of deficit irrigation on the physical quality of berries in "Crimson Seedless" table grapes. J. Sci. Food Agric., 95: 2510-2520.
6. Perniola, R., P. Crupi, R. and D. Antonacci, 2016. Cultivar and rootstock interaction affects the physiology and fruit quality of table grape with different water management—Preliminary results. Acta Hortic., 1136: 129-136.
7. Conesa, M.R., N. Falagán, J.M. De La Rosa, E. Aguayo, R. Domingo and A.P. Pastor, 2016. Post-veraison deficit irrigation regimes enhance berry coloration and health-promoting bioactive compounds in "Crimson Seedless" table grapes. Agric. Water Manag., 163: 9-18.
8. Zoffoli, J.P., B.A. Latorre and P. Naranjo, 2009. Preharvest applications of growth regulators and their effect on postharvest quality of table grapes during cold storage. Rev., 19: 217-262.
9. Gao, X.T., W. Ming-Hui, S. Dan, L. Hui-Qing, Ch. Wei-Kai, Y. Hang-Yu, L. Fan-Qi, W. Qiu-Chen, W. Yu-Ya and H. Fei, 2020. Effects of gibberellic acid (GA_3) application before anthesis on rachis elongation and berry quality and aroma and flavour compounds in *Vitis vinifera* L. 'Cabernet Franc' and 'Cabernet Sauvignon' grapes. J. Sci. Food Agric., 100: 3729-3740.

10. Lichter, A., T. Kaplunov, Y. Zutahy, A. Daus, I. Maoz, D. Beno-Mualem and S. Lurie, 2015. Effects of gibberellin on cracking and postharvest quality of the seeded table grape 'Zainy'. Acta horticulturae 1079(1079): 265-271.
11. Sabbatini, P. and G.S. Howell, 2010. Effects of early defoliation on yield, fruit composition and harvest season cluster rot complex of grapevines. HortScience, 45(12): 1804-1808.
12. Schwarz, A., 1994. Relative humidity in cool store: measurement control and influence of discreet factors. Acta Horticulturae, 368: 687-692.
13. Stefano, P., F. Bernizzoni, S. Civardi and N. Libelli, 2008. Effects of Pre-bloom Leaf Removal on Growth of Berry Tissues and Must Composition in Two Red *Vitis vinifera* L. Cultivars. Australian Journal of Grape and Wine Research, 15: 185-193.
14. Kaya, Ö., 2019. Effect of manual leaf removal and its timing on yield, the presence of lateral shoots and cluster characteristics with the grape variety Karaerik'. Mitteilungen Klosterneuburg 69: 83-92.
15. Christensen, J.V., 1972. Cracking in Cherries III Determination of cracking susceptibility. Acta Agric. Scand, 22: 128-136.
16. Christensen, J.V., 1976. Cracking in cherries. Danish Journal of Plant and Soil Science, 80: 289-324.
17. Yamamoto, T., M. Kudo and S. Watanabe, 1990. Fruit cracking and characteristics of fruit thickening in 'Satonishiki' cherry. Journal Japanese Soc. Hort. Sci., 59(2): 325-332.
18. Allen, R., L.A. Pereira, D. Raes and M. Smith, 1998. Crop evapotranspiration. Guidelines for computing crop water requirements, Irrigation and Drainage Paper 56, Food and Agric. Organization of the United Nations, Rome, Italy, pp: 300.
19. El-Gendy, R.S., 2012. Water Requirements of Grafted Grapevines under Desert Land Conditions. Journal of Horticultural Science & Ornamental Plants, 4(3): 345-364.
20. Badr, S.A. and D.W. Ramming 1994. The development and response of Crimson Seedless cultivar to cultural practices. Proceeding of International Symposium on Table Grape Production, California, U.S.A., 29: 219 -222.
21. A.O.A.C., 1985. Association of official Agriculture Chemists. Official methods of analysis. Washington D.C., U.S.A.
22. Yildiz, F. and D. Dikmen, 1990. The extraction of anthocyanin from black grapes and black grape skins. Doga Derigisi, 14 (1): 57 – 66, .
23. Snedecor, G.W. and W.G. Cochran, 1990. Statistical Methods. 7th Ed. The Iowa State Univ. Press, Ames. Iowa, USA, pp: 393.
24. Bedrech, S.A. and F.A. Mostafa, 2017. Influence of modifying canopy microclimate on grapevines growth and powdery mildew incidence. J. Biol. Chem. Environ. Sci., 12(1): 281-299.
25. Mohsen, F.S. and A.A. Ali, 2019. Foliar spray of Gibberellin (GA_3) and Urea to improve growth, yield, bunch and berry quality of Red globe grapevine. Curr. Sci. Int., 8(1): 193-202.
26. Bertin, N., S. Guichard, C. Leonardi, J.J. Longuenesse and D. Langlois, 2000. Seasonal evolution of the quality of fresh glass house tomatoes under Mediterranean conditions, as affected by airvapour pressure deficit and plant fruit load. Ann. Bot., 85: 741-750.
27. Facia, J.M., O. Blancoa, E.T. Medina and A. Martínez-Cobb, 2014. Effect of post veraison regulated deficit irrigation in production and berry quality of Autumn Royal and Crimson table grape cultivars. Agricultural Water Mangement Elsevier, 134(C): 73-83.
28. Romero, P., R.G. Munoz, J.I. Fernández-Fernández, F.M. Amor and J. García-García, 2015. Improvement of yield and grape and wine composition in field-grown Monastrell grapevines by partial rootzone irrigation, in comparison with regulated deficit irrigation. Agric. Water Manage., 149: 55-73.
29. Poni, S., L. Casalini, F. Bernizzoni, S. Civardi and C. Intrieri, 2006. Effects of Early Defoliation on Shoot Photosynthesis, Yield Components and Grape Composition. American Journal of Enology and Viticulture, 57: 397-407.
30. Matthews, M.A. and M.M. Anderson, 1988. Fruit ripening in Vitis vinifera L.: Responses to seasonal water deficits. Am. J. Enol. Viticult., 39: 313-320.
31. De La Hera-Orts, M.L., A. Martínez-Cutillas, J.M. López-Roca and E. Gómez-Plaza, 2004. Effects of moderate irrigation on vegetative growth and productive parameters of Monastrell vines grown in semiarid conditions. Spanish Journal of Agricultural Research, 2(2): 273-281.
32. Shahidian, S., P. Valverde, R. Coelho and A. Santos, 2016. Leaf water potential and sap flow as indicators of water stress in Crimson,, seedless? grapevines under different irrigation strategies. Theor. Exp. Plant Physiol., 28: 221-239.

33. Sidahmed, O.A. and W.M. Kliewer, 1980. Effects of Defoliation, Gibberellic Acid and 4-Chlorophenoxyacetic Acid on Growth and Composition of Thompson Seedless Grape Berries. Am J Enol Vitic., 31: 149-153.
34. Ruiz Sánchez, M., A. Ricardo, M. Yaumara, P. Ricardo and J. Ruiz-Lozano, 2010. The arbuscular mycorrhizal symbiosis enhances the photosynthetic efficiency and the antioxidative response of rice plants subjected to drought stress. Journal of Plant Physiology, 167: 862-9.
35. Opara, L.U., C.I. Studman and N. Banks, 1997. Fruit skin splitting and cracking. Hort. Postharvest Biol. Technol., 51: 183-192.
36. Matteo, G., F. Bernizzoni, S. Civardi and S. Poni, 2012. Effects of Cluster Thinning and Preflowering Leaf Removal on Growth and Grape Composition in cv. Sangiovese. American Journal of Enology and Viticulture, 63: 325-332.
37. Larson, F.E., R.J. Fritts, K. Patten and M.E. Patterson, 1983. Sequential sprays of gibberellic acid and calcium may reduce cherry cracking. Good fruit Grower, 34: 26-28
38. Khadivi-Khub, A., 2007. Evaluation of genetic diversity in sweet cherry cultivars using morphological and molecular markers. MSc Thesis, University of Tehran, Iran.
39. García-Escudero, E., J. Baigorri, R. Lissarraguej and V. Sotés Ruiz, 1995. Influencia del riego sobre laacidez de mostos en cv. Tempranillo (*Vitis vinifera* L.). ITEA91, 175-185.
40. Opazo, C.A., S.O. Farias and S. Fuentes, 2010. Effects of grapevine (*Vitis vinifera* L.) water status on water consumption, vegetative growth and grape quality: An irrigation scheduling application to achieve regulated deficit irrigation. Agricultural Water Management, 97: 956-964.
41. AL-Khafaji, M.A., 2014. Plant growth regulators, applications and utilization in horticulture. University of Baghdad. Ministry of Higher Education and Scientific Research, Iraq.
42. Chaves, M.M., O. Zarrouk, R. Francisco, J.M. Costa, T. Santos and A.P. Regalado, 2010. Grapevine under deficit irrigation: hints from physiological and molecular data. Annals of Botany, 105(5): 661-676.
43. Casassa, L.F., R.C. Larsen, C.W. Beaver, M.S. Mireles, M. Keller and W.R. Riley, 2013. Impact of extended maceration and regulated deficit irrigation (RDI) in Cabernet Sauvignon wines: characterization of proanthocyanidin distribution, anthocyanin extraction and chromatic properties. Journal of Agricultural and Food Chemistry, 61(26): 6446–6457.
44. De La Hera Orts, M.L., A. Martínez-Cutillas, J.M. López-Roca and E. Gómez-Plaza, 2005. Effect of moderate irrigation on grape composition during ripening. Spanish Journal of Agricultural Research, 3(3): 352-361
45. Chaves, M.M., J.S. Pereira, J. Maroco, M.L. Rodrigues, C.P.P. Ricardo, M.L. Osori, I. Carvalho and T. Faria, 2002. How Plants Cope with Water Stress in the Field. Photosynthesis and Growth. Oxford Journals, Life Sci. Annals of Bot., 89: 907-916.
46. Sanchez, L. and N. Dokoozlian, 2005. Bud Microclimate and Fruitfulness in *Vitis vinifera* L. American Journal of Enology and Viticulture, 56(4).
47. Korkutal, I., E. Bahar and Ö. Gökhan, 2008. The characteristics of substances regulating growth and development of plants and the utilization of gibberellic acid (GA3) in viticulture. World J. Agric. Sci., 4: 321-25.
48. Fuentes, S., C. Poblete-Echeverría, S. Ortega-Farias, S. Tyerman and R. De Bei, 2014. Automated estimation of leaf area index from grapevine canopies using cover photography, video and computational analysis methods. Aust. J. Grape Wine Res., 20: 465-473.
49. Dodd, I.C., 2005. Root-to-shoot signalling: assessing the roles of 'up' in the up and down world of long-distance signalling in planta. Plant Soil., 274: 251-70.
50. Peña, J.E. and F. Casierra, 2013. Chlorophyll Fluorescence in Partially Defoliated Grape Plants (*Vitis vinifera* L. cv. Chardonnay). Rev. Fac. Nal. Agr. Medellín, 66(1): 6881-6889.
51. Hunter, J.J. and J.H. Visser, 1989. The effect of partial defoliation, leaf position and developmental stage of the vine on leaf chlorophyll concentration in relation to the photosynthetic activity and light intensity in the canopy of *Vitis vinifera* L. cv. Cabernet Sauvignon. South African Journal of Enology and Viticulture, 10(2): 67-73.
52. Richards. J.H., 1993. Physiology of plants recovering from defoliation. pp: 85-94. In: Proceedings of the XVII International Grassland Congress. New Zealand Grassland Assoc., Palmerston North, N.Z., pp: 186.
53. Xu, C. and D.I. Leskovar, 2014. Growth physiology and yield responses of cabbage to deficit irrigation. Hort. Sci. (Prague), 41: 138-146.
54. Somayeh, F., Z. Zabihollah, F. Reza and L. Abdolmajid, 2019. Effects of deficit irrigation and kaolin application on vegetative growth and fruit traits of two early ripening apple cultivars. Biological Research, 52: 43.