IJANS

International Journal of Agricultural and Natural Sciences
E-ISSN: 2651-3617 14(1): 25-32, 2021
Research Article

COLOR AND PHYSICAL RESISTANCE OF TABLE GRAPES AS AFFECTED BY DEFICIT IRRIGATION AND ZN PULVERIZATION AS ADAPTIVE STRATEGIES TO CLIMATE CHANGE

Ali Sabir[1*], Gamze Sari[2], Ferhan Sabir[1], Busra Yildirim[2]
[1]*Selcuk University, Agriculture Faculty, Horticulture Department, 42075, Konya, Turkey*
[2]*Selcuk University, Graduate School of Natural and Applied Science, 42075, Konya, Turkey*

**Corresponding author:*
E-mail: asabir@selcuk.edu.tr

(Received 01[st] February 2021; accepted 18[th] February 2021)

ABSTRACT. Vineyards are generally located in semiarid and arid zones across the world. Water deficit in these regions adversely affects the grape yield and quality. This experiment was designed to reveal the impacts of deficit irrigation and Zn treatment on berry physical characteristics of Alphonse Lavallée (dark black berries) and Italia (white berries) table grapes under glasshouse condition. Six years old vines were drip irrigated with single emitter of 4 L h^{-1} per vine to perform full irrigation (FI) or deficit irrigation (DI)] from bud break to the end of the vegetation season in soilless culture. Irrigations were programmed according to soil water matrix potential (Ψm) levels using soil tensiometers. In Alphonse Lavallée, DI treatment resulted in marked decrease in chroma (color saturation; C) in comparison with FI. However, Zn pulverization alleviated the decrease in C and helped to improve the color saturation of DI-subjected Alphonse Lavallée grapes. Similar effect of Zn pulverization on Hue angle of Alphonse Lavallée berries was also obvious. But, there were no significant differences in color coordinates of Italia cultivar in response to treatments. Zn pulverization significantly improved the berry skin rupture force (SRF) of Alphonse Lavallée subjected to FI, although it did not affect those imposed to DI. In Italia cultivar, Zn pulverization significantly increased the SRF of DI grapes. Berry detachment force (BDF) of DI treated Alphonse Lavallée and Italia grapes were significantly improved by Zn pulverization. This case is particularly important for viticulture under water scarcity conditions since berry quality frequently decreases due to shriveling in drought regions. In Alphonse Lavallée cultivar, SRF displayed a significant and strong correlation with BDF. Zn pulverization could be recommended as a sustainable viticulture practice to mitigate the adverse impacts of water deficit on certain table grape quality features.

Keywords: *Deficit irrigation, Zn treatment, grape quality, berry color, berry resistance*

INTRODUCTION

Global climate change will have adverse impacts on agriculture by increasing water demand, and reducing agricultural water availability. Projections reveal an overall decrease in precipitation and an increase in temperature in arid and semiarid areas. A large proportion of vineyards in the world are located in areas experiencing drought. On the other hand, global climate change with the frequent extreme events forces the growers maximizing food production with less irrigation water, especially in regions having limited water resources [1]. Use of adapted cultivars and rootstocks and sustainable irrigation strategy are essential adaptive managements to cope with ever-increasing water shortage. Irrigations should be applied to avoid water stress in arid and semiarid regions. Also, under protected cultivations such as greenhouses irrigation is compulsory since the vines cannot benefit from precipitation. Water stress may have indirect or direct effects on grape quality and yield. To illustrate, reducing berry size increases the skin to juice ratio, which may increase the concentration of anthocyanins and phenolics in the juice of grape berries. Indirectly, water stress may reduce the shading of fruit. Shading has been shown to decrease fruit color.

Studies have demonstrated that the anthocyanin content in the grape skin increases in a cultivar-dependent pattern under water deficit conditions occurring either before or post-veraison, [2]. Castellarin et al. [3] indicated that water shortage causes an increase in synthesis of organic sugars only if imposed before veraison during ripening Cabernet Sauvignon grapes. In Shiraz, water deficit applied at after veraison leaded to a reduction in sugar concentration and an increase in phenolic compounds content, except for anthocyanins [4]. Our literature investigation revealed that there have been many studies related with the effects of water deficit on biochemical features of grapes. However, certain physical quality parameters such as berry skin color and berry hardness are also important features affecting the market value and storability of table grapes.

Therefore, the present study addresses the effects of deficit irrigation and Zn treatment on berry physical characteristics of Alphonse Lavallée and Italia table grapes.

MATERIAL AND METHODS

Study layout

This study was designed in the research glasshouse of Selcuk University, Konya, Turkey. Wordwidely popular grape cultivars Alphonse Lavallée and Italia grafted on drought tolerable grapevine rootstock Richter 99 (*Vitis berlandieri* x *V. rupestris*) [5] were selected for the study. The experimental vines were grown in about 7 L pots containing equal amount of peat and perlite. The experiment was a randomized complete block design with two different irrigation levels [Full Irrigation (FI) and Deficit Irrigation (DI)] and two grapevine cultivars. Before bud break prior to the vegetation season, six years old healthy vines grown in equalized pots were chosen depending on homogeneity in vegetative growth. Treatments consisted of three replications in randomized blocks, with three vines per replicate. The vines were subjected to drip irrigation using equipped with irrigation line for per row with single emitter of 4 L h^{-1} for each experimental vine. Black plastic sheets were used under the pots to isolate the vines from the ground. Prior to the bud break, the experimental vines were pruned leaving spurs on arms considering the genetically sufficient fruitfulness of cane nodes of the genotypes to leave four spurs having two buds per spur. At the beginning of the vegetation period, six or seven summer shoots for each vine were provided to elongate to ensure homogenous grapevine development for an objective evaluation of the study treatments. The pH of growth medium, pH: 6.50.

Water applications were programmed depending on the water matrix potential (Ψm) levels of growth medium employing several tensiometers (The Irrometer Company, Riverside, CA). To set up the correct tensiometer reading values for long lasting computing of substrate matrix potential at two variable levels, at the beginning, the peat-perlite substrate water storage at field capacity (water holding capacity of growth medium in the pots) was obtained with using the following the ways described by Satisha et al. [6]. Forty percent of FI was counted as DI [7]. At the beginning of the experiment, these water storage amounts were evaluated for start levels. For each treatment line, two tensiometers were used for a long-term calculation and indication of growth medium water depletion [8], in terms of Ψm using the modified methodology defined by Myburgh and van der Walt [9]. Tensiometers were inserted to the growth medium at a depth of 20 cm and approximately 12 cm away from the grapevine trunk.

Changes in Ψm were continuously recorded with five consecutive daily readings at around 13:00 pm as well as before and after irrigation applications [10]. Repeated records displayed that the midday matrix potential values were persistently around 10 ± 3 cb and 38 ± 4 cb for FI and DI applications, respectively. For this reason, the initial irrometer value of FI application was adjusted to 12 cb, as the lower teshold value of the easily available water in growth medium. To adjust DI application, drip irrigation system was started when Ψm reached 40 cb (the level at which slight wilting occurred at grapevine leaves) and was ended at matrix potential of 34 cb.

The experimental plants of the leaf Zn pulverization treatment were sprayed with an environmentally friendly fertilizer (E-Zn with warranted content 15% zinc in 100% EDTA) two times per summer growth season (prior to inflorescence flowering and at berry set phonological stages). Vine leaves and the newly emerging green clusters were subjected to the Zn pulverized using 1% solution at application rates of approximate 125 mg for each experimental grapevine, following the directions suggested by the produce manufacturer.

Measurements

Eighteen clusters representing each treatment (two clusters for each experimental plant) were employed at the commercial ripening when the berries of the grapevines attain more than 16 °Brix total soluble solid in must (berry juice). Berry skin color of sixty berries gathered form eighteen clusters as indicated in OIV [11] per treatment was measured with a colorimeter (Minolta® CR-400) to record the following parameters from two equatorial zones of grape berries: L* (lightness), C (chroma) and h° (hue). Lightness values may range from 0 (black) 100 (white). Chroma indicates the purity or intensity of color, the distance from gray (achromatic) toward a pure chromatic color and is calculated from the a* and b* values of the CIE Lab scale system, starts from zero for a completely neutral color, and does not have an arbitrary end, but intensity increases with magnitude. Hue means the color wheel and is recorded in angles; green, yellow and red correspond to 180, 90 and 0°, respectively [12,13].

For the investigations on skin rupture force (SRF) and berry detachment force (BDF), thirty representative berries were randomly gathered from the top, middle, and bottom of the grape clusters of each replicates and rachis sections were obtained by cutting the rachis with shears. To record the SRF, a berry from each equatorial section was cradled in a jig attached to a force gauge (DPS-11; Imada, Northbrook, IL) and the gauge was slightly pulled away from the grape berry until the skin puncture. The force to puncture the skin of berry was regarded as the SRF. For BDF, a berry from each section was then cradled in a jig attached to a force gauge and the rachis section was gently pulled away from the berry until it detached from the berry rachis (pedicel). The force required to detach each berry from the rachis in kilogram N (Newton)-force was recorded as the BDF [14].

Data analysis

The recorded numerical data were subjected to statistical analysis using a randomized factorial design. Each treatment was comprised three replications having twelve homogenous grapevines. The mean values were compared using the least significant difference (LSD) test. Statistical tests were performed at $P < 0.05$ using

SPSS 13.0for Windows (SPSS Inc., Chicago, IL, USA). Pearson correlation coefficient was used for regression analysis to evaluate the correlations between certain features.

RESULTS AND DISCUSSION

Variations in lightness (L), chroma (C) and Hue angle of the cultivars are presented in Table 1 and 2. In Alphonse Lavallée cultivar, L was not statistically affected by irrigation or Zn pulverization although there were significant differences in C and Hue angle. Alphonse Lavallee is a dark-skinned grape variety used both as a table grape and as a wine grape [15]. However, this popular table grape cultivar frequently experience berry discoloration in many part of Turkey, because it ripens usually in the middle of summer season when the day temperature is high. As already proven by previous studies, fruit ripening during warm night period had less red skin color than those of cool-night fruit [16]. As the berry color is one of the essential features determining the quality of fruits and table grapes [17]. The lower value of red skin color emergence may affect the acceptance of consumers from a visual quality standpoint. DI treatment resulted in marked decrease in C in comparison with FI. However, Zn pulverization alleviated the decrease in C and helped to improve the chroma (color saturation) of DI-subjected Alphonse Lavallée grapes. Similar effect of Zn pulverization on Hue angle of Alphonse Lavallée berries was also obvious. Minimum quality standards can be generally ensured by applying good cultivation management practices in the vineyard [18], but in the case of grape genotypes such as Alphonse Lavallee which has large-sized black berries, cultural practices can easily lead to overproduction. Under overproduction conditions, berries fail to develop suitable red color [19]. Besides, the production of Alphonse Lavallée grapes in Turkey is conducted in areas with warm climatic conditions. High night temperature associated with water shortage in such areas may inhibit the synthesis of anthocyanins [20], adversely influencing the occurrence of berry skin color.

Table 1. *Lightness (L), chroma (C) and Hue angle response of Alphonse Lavallée to deficit irrigation and Zn pulverization*

Alphonse Lavallée	L	C	Hue
DI	30.3±0.13	1.67±0.02 B	307.7±1.44 C
DI plus Zn	30.8±0.07	2.89±0.13 A	316.8±1.36 B
FI	30.0±0.56	2.85±0.08 A	329.3±5.71 A
FI plus Zn	30.4±0.26	2.62±0.26 A	328.7±3.08 A
	n.s.	0.29	6.39
All values are means ± standard error (n = 60 berries). Means not connected by same letter are significantly different at 5% level by LSD. ns: not significant.			

As for Italia cultivar, there were significant differences in color coordinates of in response to treatments (Table 2). The overall L, C and Hue angle values are near to the proposed values for a wide range of table grape cultivars [21]. The L and C values displayed some decrease in response to FI and Zn pulverization, resulting in slightly darker berries. Changes in C value was similar to that of L, while opposite case was valid for Hue angle. Table grapes are a globally popular produce whose commercial quality is closely related with their visual appearance [22]. The findings here indicated that the cultural practices have considerable influences of berry color.

Table 2. *Lightness (L), chroma (C) and Hue angle response of Italia to deficit irrigation and Zn pulverization*

Italia	L	C	Hue
DI	45.4±0.27 A	12.73±0.17 A	107.6±0.84 C
DI plus Zn	44.0±0.34 B	11.77±0.47 B	108.2±0.86 C
FI	43.8±0.33 B	11.98±0.06 B	110.0±0.42 B
FI plus Zn	42.4±1.15 C	11.49±0.44 B	112.8±0.07 A
	1.20	0.63	1.20
All values are means ± standard error (n = 60 berries). Means not connected by same letter are significantly different at 5% level by LSD.			

Even though grape is a one of non-climacteric fruits, necessarily perishable texture of the berry as indicated by weight loss, softening, browning, skin color degradation, berry shatter, rachis cracking and decay development negatively influence its long term storage, transporting and marketing [23]. Moreover, as harvesting of grapes in certain parts of Turkey coincides with rainy season a bulk of the products arrives at the market within short course of time resulting a glut which decrease the price. For this reason, it is imperative to enhance a sustainable strategy that would improve visual and physical quality features of grape cluster and berries, more importantly berry color and firmness, alongside maintaining postharvest quality during subsequent long term cold storage. In the present study, effects of DI and Zn treatment on physical hardness of berries were evaluated by measuring skin rupture force (SRF) while shatter resistance was determined using berry detachment force (BDF). As can be seen in Fig. 1A and B, SRF of both Alphonse Lavallée and Italia cultivars was not significantly affected by irrigation treatments. But, Zn pulverization significantly improved the SRF of Alphonse Lavallée subjected to FI, although it did not affect those imposed to DI. In Italia cultivar, Zn pulverization significantly increased the SRF of DI grapes. BDF of DI treated Alphonse Lavallée and Italia grapes were significantly improved by Zn pulverization (Fig 2A and B). This case is particularly important for viticulture under water scarcity conditions since berry quality frequently decreases due to shriveling in drought regions. According to regression analysis as illustrated in Fig. 3, A and B, SRF and BDF displayed linear relationship with different magnitudes depending on genotypic aptitudes. In Alphonse Lavallée cultivar, SRF displayed a significant and strong correlation with BDF. Such correlation was also significant in Italia cultivar although it was not as high as that of Alphonse Lavallée.

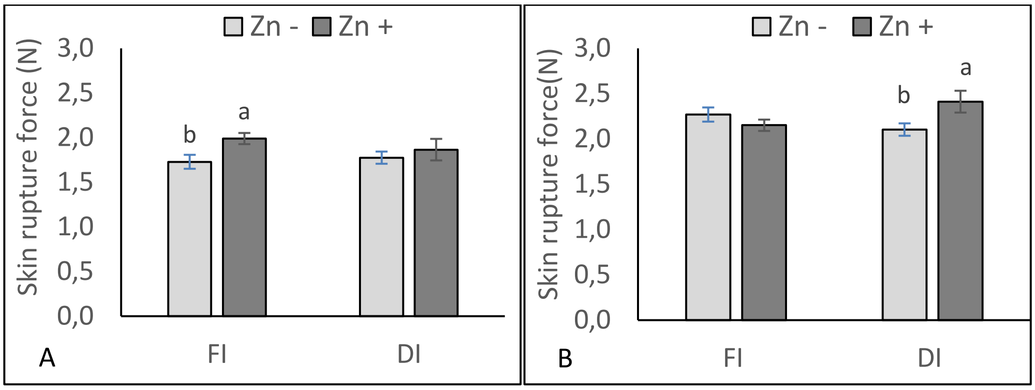

Fig. 1. *Skin rupture force responses of Alphonse Lavallée (A) and Italia (B) cultivars to deficit irrigation and Zn pulverization*

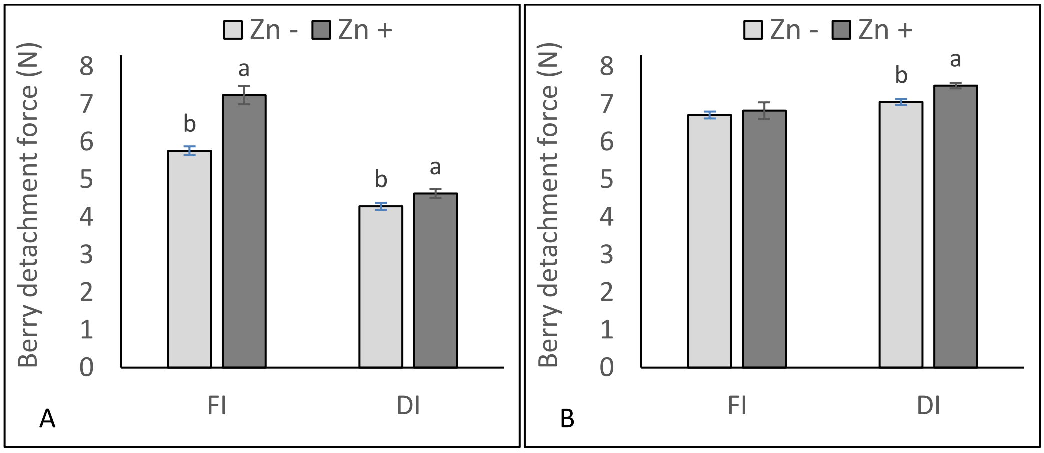

Fig. 2. *Berry detachment force responses of Alphonse Lavallée (A) and Italia (B) cultivars to deficit irrigation and Zn pulverization*

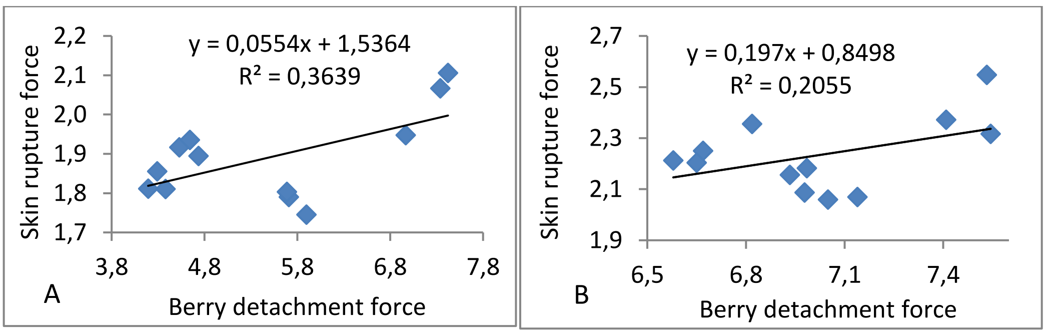

Fig. 3. *Correlation of skin rupture force and berry detachment force in Alphonse Lavallée (A) and Italia (B) cultivars*

CONCLUSION

Under deficit irrigation condition, generally Zn pulverization resulted in certain remarkable improvements in berry skin color as well as berry skin and pedicel hardness of grapes, although the response of cultivars was partially different. On the face of ever-increasing adverse effect of global climate change, Zn pulverization could be recommended as a sustainable viticulture practice that may mitigate the negative impacts of water deficit on certain table grape quality features.

REFERENCES

[1] Mushtaq, S., Maraseni, T. N. (2011): Technological Change in the Australian Irrigation Industry: Implications for Future Resource Management and Policy Development. National Water Commission (NWC) Waterlines Report Series No. 53. NWC, Canberra, ACT.

[2] Intrigliolo, D. S., Castel, J. R. (2011: Interactive effects of deficit irrigation and shoot and cluster thinning on grapevine cv. Tempranillo. Water relations, vine performance and berry and wine composition. Irrigation Science, 29: 443−454.

[3] Castellarin, S. D., Matthews, M. A., Di Gaspero, G., Gambetta, G. A. (2007): Water deficits accelerate ripening and induce changes in gene expression regulating flavonoid biosynthesis in grape berries. Planta, 227: 101−12.

[4] Petrie, P. R., Cooley, N. M., Clingeleffer, P. R. 2004): The effect of post-veraison water deficit on yield components and maturation of irrigated Shiraz (*Vitis vinifera* L.) in the current and following season. Australian Journal of Grape and Wine Research, 10: 203−215.

[5] Carbonneau, A. (1985): The early selection of grapevine rootstocks for resistance to drought conditions. American Journal of Enology and Viticulture, 36: 195–198.

[6] Satisha, J., Prakash, G.S., Venugopalan, R. (2006): Modeling of the effect of physio-biochemical parameters in water use efficiency of grape varieties, rootstocks and their stionic combinations under moisture stress conditions. Turkish Journal of Agriculture and Forestry, 30: 261–271.

[7] Sabir, A. (2016): Physiological and morphological responses of grapevine (*V. vinifera* L. cv. 'Italia') leaf to water deficit under different rootstock effects. Acta Scientiarum Polonorum Hortorum Cultus, 15: 135–148.

[8] Young, M.H., Sisson, J.B. (2002): Tensiometry. In: Methods of soil analysis, Part 4, Physical Methods, Dane JH, Topp GC (Eds.), SSSA Book Series No. 5, Soil Science Society of America: Madison: 575-608.

[9] Myburgh, P.A., van der Walt, L.D. (2005): Cane water content and yield responses of *Vitis vinifera* L. cv. Sultanina to overhead irrigation during the dormant period. South African Journal of Enology and Viticulture, 26: 1–5.

[10] Okamoto, G., Kuwamura, T., Hirano, K. (2004): Effects of water deficit stress on leaf and berry ABA and berry ripening in Chardonnay grapevines. Vitis, 43: 15–17.

[11] O.I.V. (1983): Le code des caracte`res descriptifs des varie´te´s et espe´ces de Vitis. Office International de la Vigne et du Vin. Dedon, Paris.

[12] McGuire, R. (1992): Reporting of objective color measurements. HortScience, 27: 1254–1255.

[13] Peppi, M. C., Fidelibus, M. W., Dokoozlian, N. (2006): Abscisic acid application timing and concentration affect firmness, pigmentation and color of 'Flame Seedless' grapes. HortScience 41: 1440–1445.

[14] Fidelibus, M. W., Cathline, K. A., Burns, J. 2007): Potential abscission agents for raisin, table, and wine grapes. HortScience, 42: 1626–1630.

[15] Anonymous (2007): Catalogue des variétés et clones de vigne cultivés en France. Collectif, Ed. IFV, Le Grau-du-Roi.

[16] Faragher, J. D. (1983): Temperature regulation of anthocyanin accumulation in apple skin. Journal of Experimental Botany, 34: 1291-1298.

[17] Clydesdale, F. M. (1993): Color as a factor in food choice. Critical Review in Food Science and Nutrition, 33: 83-101.

[18] Sabir, A., Kucukbasmaci, A., Taytak, M., Bilgin, O. F., Jawshle, A. I. M. (2018): Sustainable Viticulture Practices on the Face of Climate Change. Agricultural Research and Technology: Open Access Journal; 17: 556033. DOI: 10.19080/ARTOAJ.2018.17.556033.

[19] Kliewer, W. M., Weaver, R. J. (1971): Effect of crop level and leaf area on growth, composition, and coloration of ‘Tokay’ grapes. American Journal of Enology and Viticulture, 22: 172–177.

[20] Mori, K., Sugaya, S., Gemma, H. (2005): Decreased anthocyanin biosynthesis in grape berries grown under elevated night temperature condition. Scientia Horticulturae, 105: 319–330.

[21] Martinez, J. C., Almela, L., Fernandez-Lopez, J. A. (1998): Measuring the color of table grapes. Color Research and Application, 21: DOI: 10.1002/(SICI)1520-6378(199602)21:1<50::AID-COL5>3.0.CO;2-4

[22] Sabir, F. K., Sabir, A., Unal, S., Taytak, M., Kucukbasmaci, A., Bilgin, O. F. 2019): Postharvest Quality Extension of Minimally Processed Table Grapes by Chitosan Coating. International Journal of Fruit Science, (19): 347–358.

[23] Sabir, A., Sabir, F. K., Kara, Z. (2011): Effects of Modified Atmosphere Packing and Honey Dip Treatments on Quality Maintenance of Minimally Processed Grape cv. Razaki (*V. vinifera* L.) during Cold Storage. Journal of Food Science and Technology, 48(3): 312-318.