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Research Article

VERMICOMPOST, HUMIC ACID AND UREA PULVERIZATIONS AS SUSTAINABLE PRACTICES TO INCREASE GRAPE YIELD AND QUALITY ON THE FACE OF CLIMATIC EXTREMITIES

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ABSTRACT. Sustainable viticulture could enable efficient, cost-effective, environment friendly and low carbon footprint in grape production. Reducing the adverse impact of fertilizers on environment is one of the key issues for sustainable grape growing. The aim of this study was to investigate the effects of cost-effective low-impact leaf fertilizers on grapevines under continental climate condition. In this context, canopy pulverizations with urea, humic acid pulverization, and vermicompost (liquid earthworm manure) were compared with control (no foliar application) using four years old grapevines of 'Alphonse Lavallée'. Treatments significantly increased the shoot length and thickness of grapevines. The highest cluster weights were obtained from vermicompost and humic acid with similar impacts. These treatments also remarkably enhanced the berry detachment and skin rupture forces as essential features determining the market life of table grapes. The findings could provide a practical basis for evaluating precision viticulture applications to support grapevine growth and yield under continental climates where cold damages and degraded soil conditions frequently restrict the agriculture.

Keywords: *Sustainable viticulture, cultivation practices, table grapes, leaf fertilizers*

INTRODUCTION

Growth and productivity of crops are adversely affected by climatic constraints and lime stress in many agricultural lands. In especially arid and semiarid conditions, high amounts of lime in the soil disrupts all physiological and biochemical processes in the plant [1,2]. The imbalance in nutritional elements and the effect of ion toxicity are basic consequences of calcareous condition which has a detrimental effect on the growth of plants. As the plant genotypes and environmental conditions play a decisive role, finding a suitable moderator or stress relievers is one of the duties of growers and researchers. Due to the high cost and hazardous effects of chemical fertilizers, organic compound solutions as foliar fertilizer sprays has been developing. Humic acid is one of the active natural compounds to improve the agro-enviromental performance in farms as plant biostimulants. This organic substance can improve yield and quality parameters of crops, nutrient efficiency, physiological reaction of plants, and abiotic stress tolerance [3]. In spite of these facts, the use of humic acids for grapevines has received insufficient research attention. Recently, vermicompost, produced by digestion of a wide range of organic wastes by earthworms, has been received great interest as an environmentally friendly organic fertilizer. Achieved by earthworms, vermicompost is naturally enriched with essential nutrients, active humic matters, phenolic compounds, and hormones [4]. Studies have been established on the roles of vermicompost, and devise ways of adopting natural farming using eco-friendly soil fauna. One such alternative is the production and utilization of composted organic wastes.

Nitrogen (N), as one of the most important nutrients for plants, stimulates plant growth with a great impact on vine vegetative and reproductive development. Traditionally, in many part of the continental climate areas, grapevines are cultivated on nutrient-poor and non-irrigated soils. Accordingly, throughout the vegetation season, application rates of nitrogen-based fertilizers are typically kept low to control grapevine development and because they can lead to nitrogen leaching and nitrate contamination of groundwater [5]. Foliar N fertilization allows more precise application in crucial periods of grapevine growth due to its high and fast penetration. As the foliar fertilization allows nutrients to pass directly to the grape, a small quantity of fertilizer may be applied. As a result of its intrinsic features, such as small molecular size, non-ionic nature and high solubility, urea is usually taken up rapidly through the leaf cuticule [6].

The present study investigated the effects of urea, humic acid and vermicompost pulverizations on grapevines (‘Alphonse Lavallée’) under continental climate condition with calcareous soil.

MATERIALS AND METHODS

The investigations were carried out in Implementation and Experimental Vineyard of Agriculture Faculty of Selcuk University in 2020. ‘Alphonse Lavallée’, an internationally popular black table grape cultivar (*Vitis vinifera* L.) was used in the study. Four years old grapevines, grafted onto 41 B rootstock, were divided into four experimental groups composed of six plants. Leaf fertilizers were selected on the basis of their various positive effects on plants to compare for their influences on certain agronomic features of grapevines grown on calcareous soil.

Study design. The experimental vineyard is located at 38°01.785 N, 032°30.546 E and 1158 m altitude (Central Anatolia, Turkey). The long-term meteorological data proven that the predominating climatic condition in the research vineyard is semi-arid with cold winters, hot and dry summers. According to Turkish State Meteorological Service data [7], annual mean temperature, measured between 1929-2020, is 11.7 °C, with the highest and lowest mean values of 18.0 and 5.4 °C among the years. In this period the highest temperature was 40.6 °C, while the lowest one was -28.2 °C. These data indicate the existence of cold injury incidence in the city. The coldest and the hottest months are January and July, respectively. The Konya Closed Basin usually has a relative humidity below 50%, probably because the prevailing north wind and common south wind are dry. Average precipitation value of the years between 1950 and 2015 is 320 mm. The four years old grapevines in east-west oriented rows (1.25 × 3.00 m) were trained to a typical bilateral, thin vertical shoot positioned canopy. According to the bud fruitfulness aptitude of the cultivar, the experimental vines were cane pruned by leaving five or six spur canes (10 to 12 buds) per a vine. To investigate the effect of foliar spraying of different fertilizers on certain leaf attributes of the grapevine, an experiment in factorial format based on randomized complete block design with three replications was conducted. Treatments were, (i) control (no foliar application), (ii) urea pulverization, (iii) humic acid pulverization, and (iv) vermicompost (liquid earthworm manure) pulverization. The application concentration of each product was prepared according to the company instructions. Each of the treatments was performed three times during the vegetation period. The first applications for each experimental group were performed when the shoots were about 40-50 cm. The others were carried out at berry set while the final application was done at véraison. Cultivation practices were performed as commonly practiced by the local growers. The vines were subjected to drip irrigation using equipped with irrigation line for per row with single emitter for each experimental vine. Shoot positioning was vertical shoot positioned trellis system. The experimental vines received the same cultural practices such as weed control. The pH value of the experimental vineyard was 7.5±0.1 (alkaline).

In order to investigate the effects of treatments on grapevine physiology, vegetative development, yield and quality, certain measurements and analyses have been performed. The stomatal conductance (gs) and temperature (Tl_{eaf}) of leaves were obtained using the 5th or 6th leaf of the shoot tip from each shoot of vines from 09:30 to 11:30 h [8] (with a steady state porometer (SC-1 Leaf Porometer) [9] and was expressed as mmol H_2Om^{-2} s^{-1}. For these measurements, fully expanded but not senescent sun-exposed leaves at the outer canopy were used. Shoot length (all the scion shoots were measured with a sensitivity of 1 mm) and shoot diameter (internodes between the second and third nodes of shoots were measured with digital caliper) were measured at the end of growth period around the cessation of shoot elongation [10].

Eleven clusters of each treatment were sampled at the commercial ripening when the berries of the grapevines attain more than about 15 °Brix total soluble solid (SSC) in must (berry juice). At laboratory, cluster weight was recorded with precision balance. Berry skin color of sixty berries form all 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) [12]. To investigate skin rupture force (SRF) and berry detachment force (BDF), thirty berries of clusters of each treatment were used. 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 pedicel. The force required detaching each berry from the rachis was recorded as the BDF [13]. The length and diameter of the sixty berries randomly collected from the middle of fifteen clusters per treatment were recorded using digital caliper. SSC (°Brix) was determined with a portable temperature compensated refractometer (Atago 9313). Titratable acidity (TA) was quantified by titrating 10 mL of the homogenized berry flesh must with 0.1 N NaOH to an endpoint of pH 8.1 and expressed as the percentage of tartaric acid. All assays were performed in triplicate.

The collected data were subjected to statistical analysis. The mean values were compared using the least significant difference (LSD) test. Statistical tests were performed at $P < 0.05$ using SPSS 13.0 for Windows (SPSS Inc., Chicago, IL, USA).

RESULTS AND DISCUSSION

Analyzing the physiological response of grapevines to cultivation practices may help growers in evaluating their effects in viticulture management. Stomatal conductance (gs) is one of the essential physiological measures indicating the photosynthesis efficiency of the plants. The gs ranged from 125.7 mmol H_2O m^{-2} s^{-1} (control) to 135.7 mmol H_2O m^{-2} s^{-1} (humic acid) among the treatments with statistically insignificant level (Fig. 1). These values were slightly lower than those of Zsófi et al. [14] (2014)

who investigated the gs range between 197 and 269 mmol H_2O m^{-2} s^{-1} for the Hungarian grapevine cultivar. Stomatal regulation plays a key role in plant response to environmental stress because the stomatal regulation causes rapid variation in water use efficiency [15]. However, there is still insufficient experimental knowledge on the stomatal regulation in grapevines, except for few studies [8, 16].

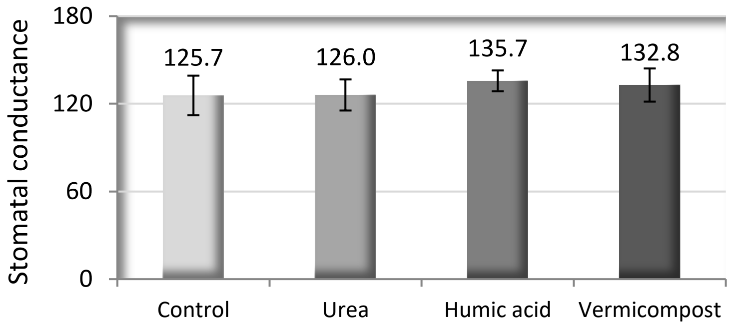

Fig. 1. *Stomatal conductance variations of the grapevines in response to the leaf treatments*

Similar to gs response, leaf temperature (T_{leaf}) did not show significant variation in response to the treatments (Fig. 2). T_{leaf} changed from 28.5 °C (control) to 29.4 °C (humic acid). Overall T_{leaf} values across the studied grapevines were within thethreshold values for optimum photosynthesis (25–30°C) suggested by Greer [17] for grapevine.

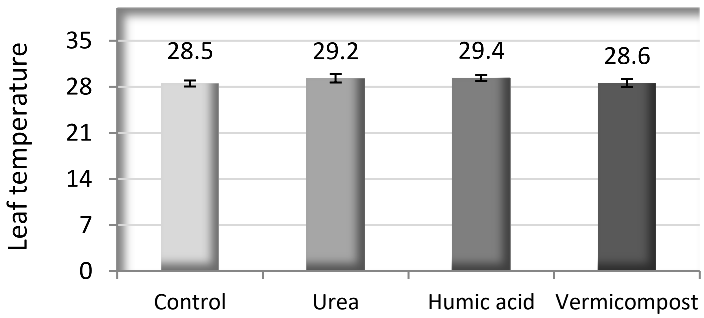

Fig. 2. *Leaf temperature variations of the grapevines in response to the leaf treatments.*

Shoot length significantly varied in response to leaf treatments (Fig. 3). Humic acid and vermicompost significantly improved the shoot elongation while urea had no significant effect in comparison to control vines. Humic acid and vermicompost pulverizations resulted in 22.7 and 15.3% increase in shoot growth, respectively. In shoot diameter, urea pulverization led to the highest value (8.2 mm), followed by humic acid (8.1 mm) and vermicompost (7.9 mm) all of which had significant and similar effects on thickness of shoot (Fig. 4). Shoot diameter, as a vegetative growth feature affecting the cold resistance of grapevines in continental climates like Konya Basin is one of the prime parameters. Leaf pulverizations might improve the cold hardiness of the vines as they led to increase in shoot thickness.

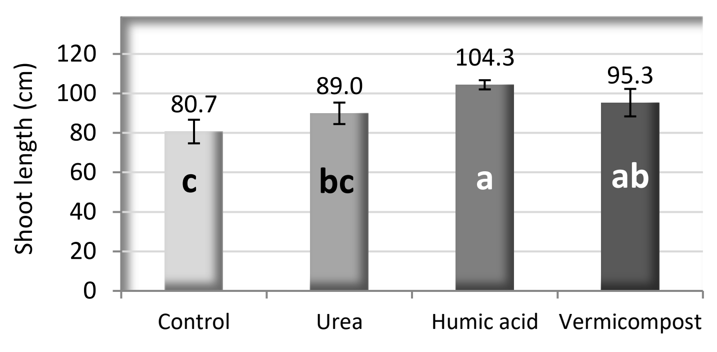

Fig. 3. *Shoot length variations of the grapevines in response to the leaf treatments. Means with distinct letters are significantly different (P < 0.05, LSD: 10.27).*

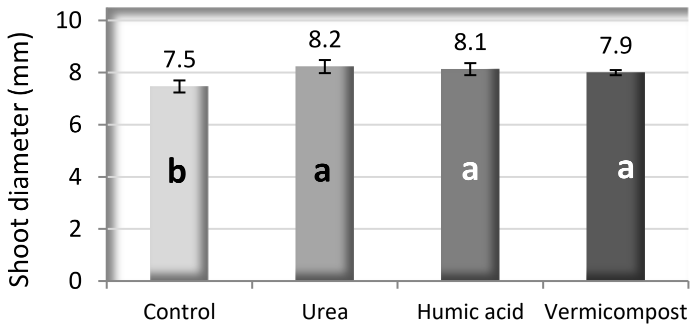

Fig. 4. *Shoot diameter variations of the grapevines in response to the leaf treatments.* Means with distinct letters are significantly different (P < 0.05, LSD: 0.39).

As depicted in Fig. 5, treatments significantly affected the cluster weight with the highest value obtained from vermicompost (242.0 g) which was followed by humic acid (240.1 g) and urea (200.8 g). The increase levels were 13.8, 9.7 and 5.3% for humic acid, vermicompost and urea respectively. Increase in cluster growth are like those of shoot growth. Therefore, the high leaf area and net photosynthesis likely contributed to increase the cluster mass which directly affects the yield per area. Using different grapevine cultivars, Mohamadineia et al. [18] evaluated the impact of foliar application at concentrations of 2.5 $mg.L^{-1}$ to 7.5 $mg.L^{-1}$ on yield and berry attributes in grapevine. Similar to our findings, they reported that the humic acids enhanced the yield, berry weight and volume, compared to the untreated vines.

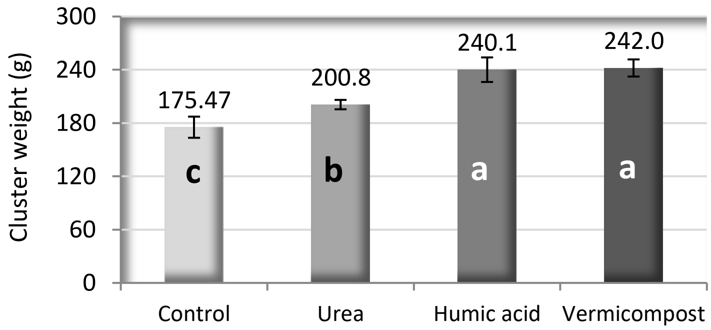

Fig. 5. *Cluster weight (g) variations of the grapevines in response to the leaf treatments. Means with distinct letters are significantly different (P < 0.05, LSD: 20.1).*

Berry detachment force significantly improved by the treatments with their similar effects (Fig. 6). The force to abscise the berries varied from 2.67 N (control) to 3.04 N (vermicompost). There were 12.3, 10.7 and 9.7% improvements in berry detachment forces of vermicompost, urea and humic acid treatments, respectively. Berry abscission during storage [19] and transport [20] represents a frequent serious problem in the marketing of table grapes. The treatments in this study obviously strengthened the berry adherence to rachis.

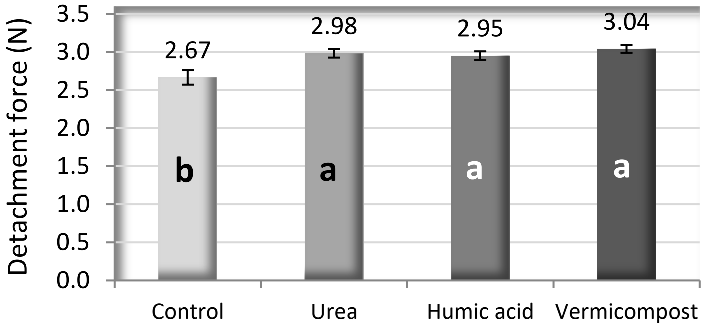

Fig. 6. *Berry detachment force (N) variations of the grapevines in response to the leaf treatments. Means with distinct letters are significantly different (P < 0.05).*

Berry skip rupture force was significantly improved by the treatments with the highest effect of vermicompost which resulted in as high as 21.2% increments in comparison to control berries (Fig. 7). Urea and humic acid pulverizations also provided increases in skin resistance with their 12.9 and 9.7%, respective values. Skin resistance is one of the prime features determining the postharvest life of table grapes. Certain treatments such as calcium can help preserve the membrane integrity of plant cell by retarding senescence-related membrane lipid changes and enhancing membrane restructuring physiology [21], thereby conferring the rigidity to the cell wall and protecting the wall from hydrolytic enzymes produced by decay-causing microorganisms.

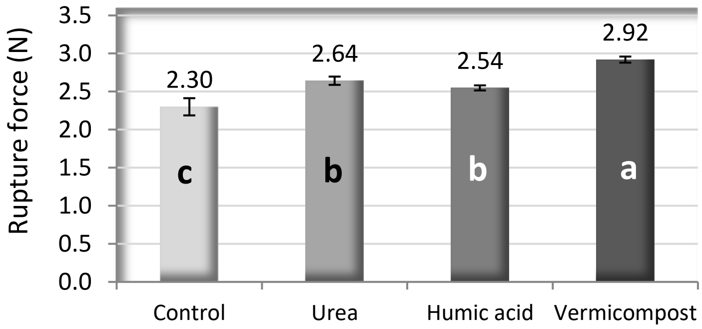

Fig. 7. *Berry skin rupture force (N) variations of the grapevines in response to the leaf treatments. Means with distinct letters are significantly different (P < 0.05, LSD: 0.126)*

As presented in Table 1, treatments were ineffective on lightness of the berry skin (L). However, urea and humic acid treatments significantly affected the chroma and

Hue angle values. The highest C value was obtained from humic acid, followed by urea. Poor coloration substantially reduces the market value of table grapes [22]. Therefore, exogenous applications such as humic acid and urea could be considered as strategies to improve the berry color, a globally common problem seen in colored table grapes.

Table 1. *Variations in L, C and Hue angle of the grape berries in response to the leaf treatments. Means with distinct letters are significantly different (P < 0.05).*

Treatments	L	C	Hue
Control	29.2±0.17	2.12±0.04 c	292.7±3.3 c
Urea	29.6±0.14	2.48±0.02 b	332.0±2.4 a
Humic acid	29.2±0.39	2.68±0.02 a	321.0±3.3 b
Vermicompost	29.3±0.20	2.07±0.05 c	291.7±2.2 c
LSD (%5)	ns	0.07	5.41

ns: Not significant

Physical features of grape berries displayed significant differences in response to the treatments (Table 2). The highest weight, length and width values of berries were obtained from vermicompost pulverization, resulting 19.6, 6.0 and 9.1% increases, respectively. Berry size is one of the visual quality features determining the market prize of table grapes. The canopy pulverization treatments, vermicompost in particular, let to improvements in visual quality by increasing the berry size.

Table 2. *Variations in weight, length and width of the grape berries in response to the leaf treatments. Means with distinct letters are significantly different (P < 0.05).*

Treatments	Weight	Length	Width
Control	4.01±0.14 c	18.9±0.14 b	16.7±0.21 c
Urea	4.50±0.17 b	18.8±0.19 b	17.4±0.28 b
Humic acid	4.59±0.11 b	18.7±0.28 b	17.1±0.06 b
Vermicompost	4.98±0.19 a	20.1±0.22 a	18.3±0.16 a
LSD (%5)	0.29	0.41	0.37

ns: Not significant

Biochemical properties of grape must varied due to leaf pulverizations (Table 3). The highest SSC level was determined in control grapes while the lowest value was obtained from humic acid. Treatments led to decreases in SSC probably due to increases in berry physical features and cluster weight. The highest maturity index was obtained from control and was followed by vermicompost within the same statistical group.

Table 3. *Variations in SSC, acid and pH of the grape berries in response to the leaf treatments. Means with distinct letters are significantly different (P < 0.05).*

Treatments	SSC	Acid	pH
Control	16.8±0.38 a	0.43±0.01	4.11±0.06
Urea	15.6±0.40 b	0.44±0.02	4.30±0.04
Humic acid	14.9±0.12 b	0.43±0.02	4.16±0.05
Vermicompost	15.5±0.58 b	0.41±0.01	4.20±0.06
LSD (%5)	0.76	ns	ns

ns: Not significant

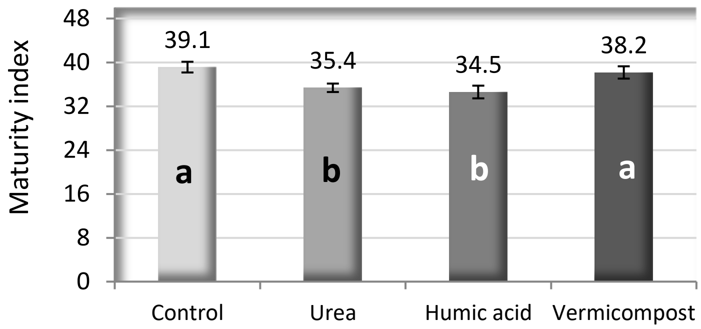

Fig. 8. *Berry maturity index (N) variations of the grapevines in response to the leaf treatments. Means with distinct letters are significantly different (P < 0.05, LSD: 2.01).*

As illustrated in Fig. 9, findings about the yield per vine were just similar to the berry and cluster weight values. Treatments significantly increased the vine yield with the highest effect of humic acid (3181.7 g) and were closely followed by vermicompost (3166.5) within the same statistical group. Under continental climate conditions, as experienced in the study area, weather and soil conditions considerably govern the grapevine development, as it requires suitable temperatures, radiation intensities, as well as specific levels of water availability throughout its growth cycle, ultimately influencing yield, berry attributes, and must structure [23]. In stressful ecologies, sustainable practices like humic acid and vermicompost have particular importance to induce grapevine development and yield for mitigating the adverse effects of the stressful conditions.

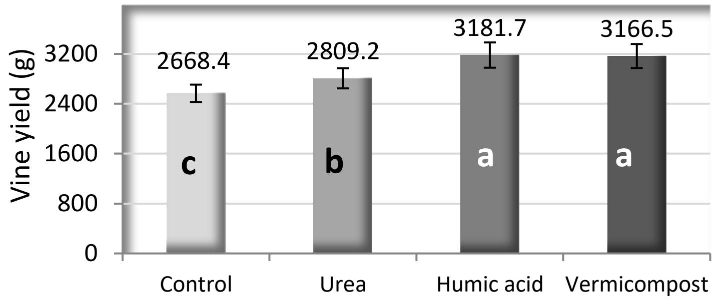

Fig. 9. *Vine yield (g) variations of the grapevines in response to the leaf treatments. Means with distinct letters are significantly different (P < 0.05, LSD: 117.6).*

CONCLUSION

Vermicompost, humic acid and urea pulverizations as sustainable agricultural practices were examined for their effectiveness on grapevine physiology, development and yield under continental climate condition. The vegetative growth of grapevines, determined as shoot length and thickness, improved by the treatments. The highest weights in berry and cluster were obtained from vermicompost pulverization, followed by humic acid. These treatments also improved the berry detachment and skin rupture forces. The findings of present study could provide a practical basis for evaluating precision viticulture applications to enhance grapevine development, yield and berry quality under continental climates where cold damages and degraded soil conditions commonly restrict the agriculture.

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REFERENCES

[1] Bavaresco, L., Poni, S. (2003): Effect of calcareous soil on photosynthesis rate, mineral nutrition and source-sink ratio of table grape. Journal of Plant Nutrition, 26: 1451–1465.
[2] Karaca, U., Sabir, A. (2018): Sustainable Mitigation of Alkaline Stress in Grapevine Rootstocks (*Vitis* spp.) by Plant Growth-Promoting Rhizobacteria. Erwerbs-Obstbau, 60: 211–220.
[3] Calvo, P., Nelson, L., Kloepper, J. W. (2014): Agricultural uses of plant biostimulants. Plant and Soil, 383: 3-41.
[4] Benazzouk, S., Djazouli, Z.E., Lutts, S. (2018): Assessment of the preventive effect of vermicompost on salinity resistance in tomato (*Solanum lycopersicum* cv. Ailsa Craig). Acta Physiologiae Plantarum, 40: 121 https://doi.org/10.1007/s11738-018-2696-6
[5] Pérez-Álvarez, E.P., Garde-Cerdán, T., García-Escudero, E., Martínez-Vidaurre, J.M. (2017): Effect of two doses of urea foliar application on leaves and grape nitrogen composition during two vintages. Journal of the Science of Food and Agriculture, 97: 2524–2532.
[6] Lasa, B., Menendez, S., Sagastizabal, K., Cervantes, M.E.C., Irigoyen, I., Muro, J., Aparicio-Tejo, P. M. Ariz, I. (2012): Foliar application of urea to 'Sauvignon blanc' and 'Merlot' vines: doses and time of application. Plant Growth Regulation, 67: 73–81.

[7] Anonymous, (2021): Turkish State Meteorological Service. https://www.mgm.gov.tr/eng/forecast-cities.aspx [Accession date: 31.08.2021].

[8] Sabir, A., Yazar, K. (2015): Diurnal dynamics of stomatal conductance and leaf temperature of grapevines (*Vitis vinifera* L.) in response to daily climatic variables. Acta Scientiarum Polonorum Hortorum Cultus, 14: 3–15.

[9] Zufferey, V., Cochard, H., Ameglio, T., Spring, L., Viret, O. (2011): Diurnal cycles of embolism formation and repair in petioles of grapevine (*Vitis vinifera* cv. Chasselas). Journal of Experimental Botany, 62: 3885–3894.

[10] Sabir, A. (2013): Improvement of grafting efficiency in hard grafting grape Berlandieri hybrid rootstocks by plant growth-promoting rhizobacteria (PGPR). Scientia Horticuturae, 164: 24–29.

[11] O.I.V. (1983): Le code des caractéres descriptifs des variétés et espéces 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] Fidelibus, M. W., Cathline, K. A., Burns, J. (2007): Potential abscission agents for raisin, table, and wine grapes. HortScience, 42: 1626–1630.

[14] Zsófi, Z., Villangó, S., Pálfi, Z., Tóth, E., Bálo, B. (2014): Texture characteristics of the grape berry skin and seed (*Vitis vinifera* L. cv. Kékfrankos) under post-veraison water deficit. Scientia Horticulturae, 172: 176–182.

[15] Kaiser, H., Kappen, L. (2000): In situ observation of stomatal movements and gas exchange of *Aegopodium podagraria* L. in the understorey. Journal of Experimental Botany, 51: 1741–1749.

[16] Rogiers, S.Y., Greer, D.H., Hatfield, J.M., Hutton, R.J., Clarke, H.S. (2011): Stomatal response ofan anisohydric grapevine cultivar to evaporative demand, available soil moisture and abscisic acid. Tree Physiology, 32: 249–261.

[17] Greer, D.H. (2012): Modelling leaf photosynthetic and transpiration temperature-dependent responses in *Vitis vinifera* cv. Semillon grapevines growing in hot, irrigated vineyard conditions. AoB Plants, DOI:10.1093/aobpla/pls009.

[18] Mohamadineia, G., Farahi, M. H. and Dastyaran, M. (2015): Foliar and soil drench application of humic acid on yield and berry properties of ‘Askari’ grapevine. Agricultural Communications, 3: 21–27.

[19] Sabir, F.K., Sabir, A. (2019): Pre-harvest Micronized Calcium and Postharvest UV-C Treatments Extend the Quality of ‘Crimson Seedless’ (*Vitis vinifera* L.) Grapes. Erwerbs-Obstbau 61(Suppl 1): S25–S32

[20] Li, M., Huang, Z., You, X., Zhang, Y., Wei, P., Zhou, K., Wang, Y. (2020): Relationships between cell structure alterations and berry abscission in table grapes. Frontier in Nutrition, 7: doi: 10.3389/fnut.2020.00069.

[21] Picchioni, G.A., Watada, A.E., Conway, W.S., Whitaker, B.D., Sams, C.E. (1998): Postharvest calcium infiltration delays membrane lipid catabolism in apple fruit. Journal of Agriculture ans Food Chemistry, 46: 2452–2457.

[22] 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.

[23] van Leeuwen, C., Darriet, P., (2016): The impact of climate change on viticulture and wine quality. Journal of Wine Economics 11: 150–167.