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Research Article

RESPONSE OF GRAFTED AND OWN ROOTED GRAPEVINES ('ITALIA') TO KNO_3 PULVERIZATIONS IN SOILLESS CULTURE UNDER PROTECTED CULTIVATION ON THE FACE OF CLIMATE CHANGE

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ABSTRACT. Sustainable agricultural techniques are essential strategies to cope with ever-increasing multiple stress factors that restrict agriculture worldwide. KNO_3 pulverization treatment, as one of the common practices performed by farmers, has proven to support plant growth against environmental stressors. The present study was, thus, conducted to reveal the physiological and agronomic responses of grafted and own rooted 'Italia' grapevines to KNO_3 pulverizations in soilless culture under protected cultivation on the face of climate change. Canopy pulverization with KNO_3 (three times per vegetation) did not show adverse effect on stomatal conductance while it regulated the leaf temperature to recommended values at hot period of summer season. Grape berry and cluster features were improved by KNO_3 pulverizations in especially grafted grapevines. KNO_3 strengthened the berry adherence to rachis and affected the berry ripening by increasing the total soluble solid content of the must. The physiological mechanisms driving the accumulation of K^+ though the canopy and into the grape berry compartments is worthy for much more detailed exploration on its mitigating effects of environmental stress factors.

Keywords: *Viticulture, environmental stressors, sustainable practices, leaf fertilizer*

INTRODUCTION

Climate change events show that the increase in extreme weather conditions and water shortage will inevitably cause lower yields and a significant reduction in areas suitable for traditional crop production [1,2]. Extremities in recent weather conditions forced the expansion of protected agriculture, i.e., greenhouses, glasshouses and screen houses, because non-protected systems like forest or pasture are supposed to be more dependent on climate than protected ones. On the other hand, increasing food demands of expanding world population and unforeseeable climatic abnormalities will increase the trend of protected agriculture techniques in warm and temperate areas. Especially, the nutritional quality of horticultural crops is becoming increasingly essential while the ecological conditions are changing for the worse [3]. Protected cultivation provides implementation of sustainable adaptations strategies to mitigate the impact of stress factors. However, surprisingly, few studies have been available in the literature so far regarding the protected cultivation against environmental stressors. Soilless culture in viticulture has recently been gained great attention as it provides controlled cultivation areas against adverse ecological conditions under climate change events. This culture is also suitable for scientific studies in which nutritional [4], palynological or stress physiology [5] subjects are addressed.

In plants, potassium (K^+) plays a key role in cell division processes [6], photosynthesis [7] and is associated with enzymatic reactions which contribute to berry ripening, sugar accumulation and cell turgor maintenance [8,9,10]. K^+ is also involved in solute transportation, partitioning of photosynthetic assimilates, and in the synthesis of several polyphenols required for grape color and aroma [11]. K^+ has direct effect on cell osmotic potential control [12,13,14]), just as other nutrients affect plant physiology. Therefore, foliar potassium nitrate has been recommended in vineyards to support grapevine growth [15].

In the present study, agronomic and growth response of grafted and nongrafted grapevines (‘Italia’) to KNO_3 (very soluble form) pulverizations have been investigated in soilless culture under protected cultivation in which high temperature and low humidity conditions of climate change have been simulated.

MATERIALS AND METHODS

Experiment conditions

The study was carried out at the Research and Implementation Glasshouse (38°01.814 N, 032°30.546E, and 1158 m altitude) and laboratories of Selcuk University Agriculture Faculty. Experimental plants consisted of grafted (on 5 BB rootstock) and nonrafted (own rooted) grapevines of ‘Italia’ table grapes (*Vitis vinifera* L.). The five years old grapevines were grown in a soilless culture established in the glasshouse using approximately 70 L (solid volume) black cylindrical pots containing peat and sterile perlite in equal volume. Each grafting group consisted of fifteen healthy vines divided into three replicates (five vines per treatment). The vines were placed in south-north oriented lines with 1.0 m spacing between rows and 0.5 m spacing on the rows. At the end of the dormant season, the vines were spur pruned to leave 8–10 winter buds on 4–5 canes per plant. The summer shoots during the vegetation period were tied with thread to wires about 2.2 m above the ground to let shoots grow on a perpendicular position to ensure similar benefiting from the sunlight. Similar cultivation practices were applied to the grapevines. The plants were drip irrigated with single emitter per vine on one line for each row. Irrigation amount and intervals were scheduled according to soil water matrix potential (Ψm) levels using several tensiometers (The Irrometer Company, Riverside, CA) placed at a depth of 20 cm and approximately 12 cm away from the trunk for a long-term accurate expression of soil substrate water as previously described by Satisha et al. [16]. Roof and side vent window area of experimental glasshouse was large enough with about 25% of floor area to get good air movement. Inside the experimental glasshouse, the midday temperature was allowed to increase around 36±6 °C during the summer while the relative humidity was around 30% according to data logger records (Ebro EBI 20 TH1). By this way, slightly improper climatic conditions as in temperature and air humidity for agriculture in mild stress were simulated inside the experimental glasshouse as the viticulturists face with today due to global climate change [17].

For KNO_3 pulverization, each grafting block was further divided into two homogenous parcels. The plants belonging to KNO_3 (13% $N\text{-}NO_3$ plus 46% K_2O) treatment groups were pulverized with potassium nitrate three times per summer period, namely (1) just before flowering, (2) at berry set, and (3) véraison stages. The grapevines canopy including the developing green clusters was pulverized with 1% concentration at application rates of about 250 mg per vine for each application time.

Physiological investigations

Stomatal conductance (gs) and leaf temperature of the leaves at the 4^{th} to 6^{th} nodes from each individual vines were recorded with a steady state porometer (SC-1 Leaf Porometer) from 09:00 to 12:00h [5]. For the measurements, fully expanded, healthy but not senescent sunlit leaves at the grapevine canopy were used [18]. The gs was expressed as mmol H_2O m^{-2} s^{-1}. A portable chlorophyll meter (Minolta SPAD-502, Japan) was used to estimate the chlorophyll contents of the leaves at the 5^{th} or 6^{th} leaf of each shoot.

Grape quality measurements

Twelve representative clusters from each treatment were harvested according to the norms of the Office International de la Vigne et du Vin [19] at commercial maturity (at 15.0±0.2 °Brix). For each treatment, the length, width and mass of the clusters were recorded using an analytical scale. Berry detachment force (BDF) was determined using a total of forty five representative berries for each KNO_3 treatment to assess berry resistance. The berries were randomly used from the top, middle, and bottom of the grape clusters. In the measurement, the rachis section was slowly pulled away from the berry with a force gauge (DPS-11; Imada, Northbrook, IL) until it detached as previously described by Fidelibus et al. [20]. The berry weight was calculated using fifty berries in each of three replicates. The must (berry juice) was obtained with hand press and the supernatants were used for the biochemical investigations. TSS was recorded with a handheld temperature compensated refractometer (Atago 9313). Titratable acidity (TA) was calculated by titrating 10 mL of the must with 0.1 N NaOH to an endpoint of pH 8.1 and expressed as the percentage of tartaric acid [21].

Data analysis

Numerical data were subjected to one-way ANOVA. Statistical differences were considered significant at $P<0.05$, and means were compared with Tukey’s LSD (least significant difference) test using SPSS version 17.0 (SPSS Inc., Chicago, IL, USA).

RESULTS AND DISCUSSION

Physiological changes

The physiological response of the grapevines to KNO_3 treatment under the rootstock effects were investigated on stomatal conductance (gs), leaf temperature and leaf chlorophyll content in midseason in a hottest (36±6 °C) and the driest days (RH ≈ 30%). As illustrated in Fig. 1, the gs, ranging from 405.0 H_2O m^{-2} s^{-1} (KNO_3 treated own rooted vines) to 425.4 H_2O m^{-2} s^{-1} (KNO_3 treated grafted vines), did not show significant variations. The gs values are slightly higher than those obtained from Turkish [5] and Hungarian [22] grapevine cultivars. These indicate that higher temperatures did not remarkably impaire the gs in grafted or own rooted ‘Italia’ grapevines in soilless culture. With very close gs values across the grapevines, the stomatal gas exchange was not affected by the rootstock use and KNO_3 treatment.

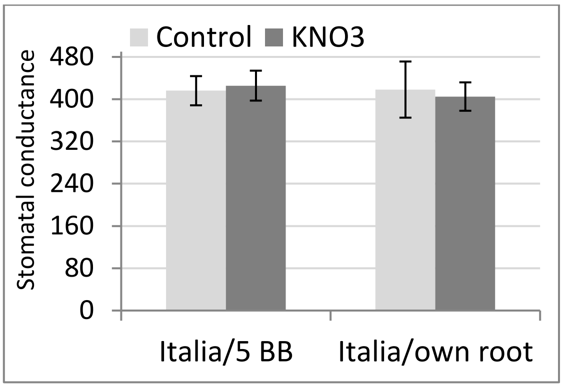

Fig. 1. *Stomatal conductance responses of the grapevines to KNO_3 treatment under the rootstock effect (LSD for grafted and own rooted vine: not significant)*

High temperature condition inside the glasshouse led remarkable increases in grapevine leaves, ranging from 30.2 °C to 32.7 °C (Fig. 2). These values are higher than those suggested by Greer [23] (2012) as optimum (25–30°C) for photosynthesis. A study performed by Greer and Weedon [24] (2013) under vineyard condition revealed that photosynthesis decreased with increasing air temperature after the optimum level of 25 °C. Their results further indicated that such inhibition was as high as 60% when the temperature reaches 45°C. In the present study, KNO_3 treatment provided significant decreases in leaf temperature for both grafted and nongrafted grapevines, although the magnitude of such decrease was influenced by the rootstock use as mentioned by Marguerti et al [25].

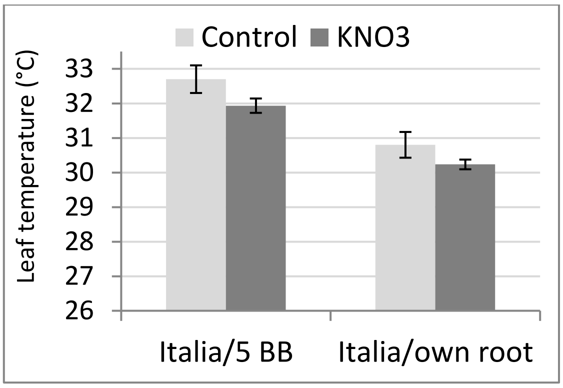

Fig. 2. *Leaf temperature responses of the grapevines to KNO_3 treatment under the rootstock effect (LSD for grafted vines: 0.72; own rooted vines: ns)*

KNO_3 treatment significantly increased the chlorophyll content of the vines with higher effect revealed in own rooted grapevines (Fig. 3). Studying on Cd stresses tomato plants, a positive effect of the K^+ supply treatment (at 310 ppm) due to improved electron transport after K^+ supply was observed on leaf chlorophyll content of stressed plants [26].

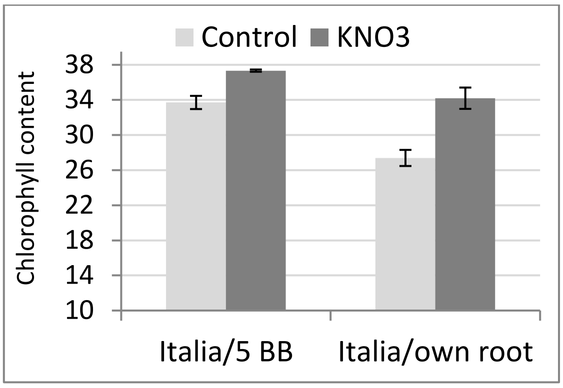

***Fig. 3**. Leaf chlorophyll content responses of the grapevines to KNO_3 treatment under the rootstock effect (LSD for grafted vines: 1.22; own rooted vines: 2.41)*

Quality changes

KNO_3 treatment significantly improved the berry detachment force (BDF) in grafted grapevines from 6.4 N to 6.8 N, although there was no significant effect on this feature in own rooted vines (Fig. 4). Berry shattering, emerging from weak adherence forces between berry and pedicel and/or pedicel and cluster, is one of the prime features determining the postharvest quality life of table and raisin grapes. Therefore, higher BDF is required to prolong market duration of the grapes. With a significant effect found on BDF in the present study, KNO_3 could be proven as effective on maintenance of table grape quality, one of the most important issues in sustainable horticulture to ensure the global food need on the face of climate change. The role of K^+ in biotic and abiotic stress resistance has been well-investigated and K may co-ordinate responses within the berry through control over ROS and osmotic homeostasis [14].

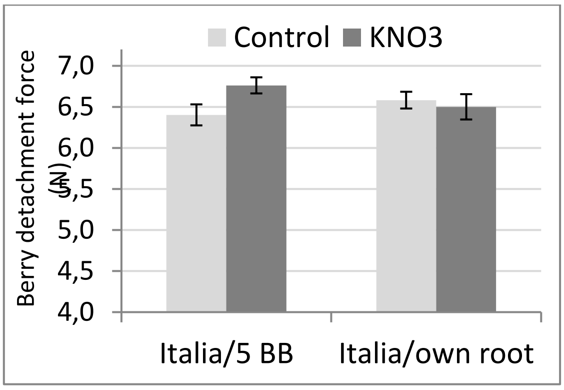

***Fig. 4.** Berry detachment force responses of the grapevines to KNO_3 treatment under the rootstock effect. (LSD for grafted vines: 0.20; own rooted vines: not significant)*

Berry weight was significantly improved by KNO_3 treatment as illustrated in Fig. 5. Improvements on canopy pulverization of KNO_3 were 14.7 % and 4.6% for 'Italia'/5BB and own rooted grapevines, respectively. The extent of K^+ relocation from the leaves to the developing grape berries is one of prime physiologies affecting the berry weight. Vine water statute, leaf microclimate and nutrient availability directly influence the K^+ reserves in leaves through the extent of photosynthesis as well as phloem loading at the source. Liesche [27] revealed the essential role of potassium fertilization to regulation phloem transport and plant growth.

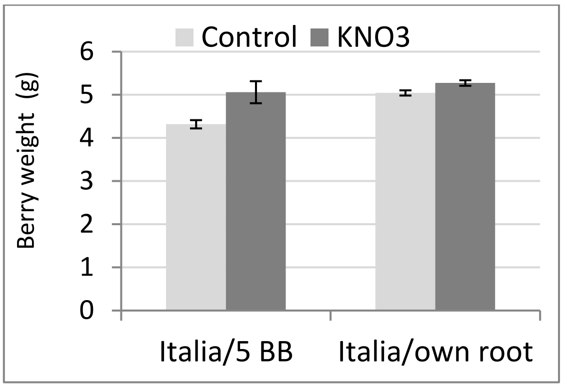

Fig. 5. *Berry weight force responses of the grapevines to KNO_3 treatment under the rootstock effect (LSD for grafted vines: 0.43; own rooted vines: 0.14)*

KNO_3 treatment had significant effects on cluster features of grafted grapevines, although it did not affect such features in own rooted grapevines (Table 1). Canopy pulverization with KNO_3 resulted in 19.8%, 2.6% and 21.4% improvements in weight, length and width of the berries of grapevines belonging to ‘Italia’/5 BB grafting. This indicates that KNO_3 treatment increase the grape yield by improving the berry and cluster features in grafted grapevines.

Table 1. *Changes in weight, length and width of grape clusters in response to KNO_3 treatment under the rootstock effect*

Genotype	Treatment	Weight	Length	Width
Italia/5 BB	Control	225.8±12.9 B	16.5±1.19	11.2±0.85 B
Italia/5 BB	KNO_3	281.7±18.0 A	16.9±0.40	14.2±0.20 A
Italia/own root	Control	252.8±19.4	16.8±0.25	12.2±0.21
Italia/own root	KNO_3	255.6±20.7	16.7±0.82	12.0±0.29
LSD for Italia/5 BB vines		*35.2*	*ns*	*1.38*
LSD for own rooted vines		*ns*	*ns*	*ns*

Means with different letters in a column are significantly different according to Student’s t-test ($P < 0.05$), ns: not significant.

Biochemical features of grape must such as TSS, TA and pH were affected by KNO_3 treatment (Table 2). KNO_3 pulverization resulted in increases in TSS and pH, while it led to decrease in TA, indicating its effect on accelerating the grape ripening process. K^+ has a strong effect on juice biochemical composition and thus is also significant for berry must acidity and color [28]. TSS significantly increased due to K^+ supply, indicating the effect of potassium cation on early ripening of grapes. Therefore, potassium pulverization could be beneficial for earlier harvest in grape growing.

Table 2. *Changes in TSS, TA and pH of grape must in response to KNO_3 treatment under the rootstock effect*

Genotype	Treatment	TSS	TA	pH
Italia/5 BB	Control	15.2±0.15 B	0.40±0.003 A	4.03±0.02 B
Italia/5 BB	KNO_3	15.8±0.06 A	0.36±0.004 B	4.14±0.03 A
Italia/own root	Control	15.9±0.12 B	0.34±0.003	4.16±0.01
Italia/own root	KNO_3	16.8±0.20 A	0.31±0.011	4.30±0.09
LSD for Italia/5 BB vines		*0.26*	*0.008*	*0.05*
LSD for own rooted vines		*0.36*	*0.170*	*ns*

Means with different letters in a column are significantly different according to Student's t-test ($P < 0.05$), ns: not significant.

CONCLUSION

KNO_3 supply in this study modulated the grapevine physiology and alleviated the negative effect of high temperature and low humidity condition with decreasing the leaf temperature to optimum level and increasing the chlorophyll content. Berry and cluster features were improved by K^+ pulverizations in especially grafted grapevines. K^+ also increased the total soluble solid content of the must across the grapevines. Given the essential role of K^+ to plant physiology as well as grape quality, the mechanisms driving the accumulation of K though the grapevine plant and into the grape berry compartments is worthy of much more detailed exploration with further investigations focusing on its mitigating effects of environmental stress factors.

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