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Variation in physiology and vegetative development of different *Vitis* genotypes under the ecological conditions of a continental climate

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Abstract

Multidisciplinary studies have alerted agriculturists to the urgency of implementing mitigation strategies against the pernicious effects of global climate change, which introduces new threats and challenges. The selection of the most suitable genotype is a primary strategy for sustainable agriculture in the face of climate change. This study was conducted to evaluate different grapevine genotypes for their specific physiological and vegetative characteristics in a continental climate region. The genotypes belonging to various *Vitis* species exhibited significant variation in terms of stomatal conductance (gs), leaf temperature (T_{leaf}), chlorophyll content, and shoot growth features. Among the studied genotypes, the autochthonous cultivar Ispitiran was distinguished by its more stable gs and more favorable leaf temperature during the summer period. The 5 BB rootstock stood out with its higher gs and T_{leaf} values. The gs of the cultivars tended to decrease during the hot midsummer, while Ispitiran maintained more stable gs levels. The Isabella cultivar was notable for its greater chlorophyll content in the leaf. Rootstocks demonstrated higher shoot growth compared to the cultivars. The highest shoot diameter was observed in the Ispitiran cultivar. These findings are expected to inform future studies related to genotypic selection for breeding and grape production purposes, contributing to precision viticulture under the adverse effects of climate change.

Keywords: Grapevine germplasm, Climate change, Continental climate, Stomatal conductance, Leaf chlorophyll content, Shoot growth.

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Contents

Contribution of this paper to the literature
The primary contribution of the present study is the finding that genotypes from different genotypic backgrounds showed a wide variation in physiological and developmental features under the continental climate. The autochthonous cultivar, Ispitiran, was divergent from others with its more stable physiology during the summer period.

1. Introduction

The grape production contributes to the economy of many countries across the world. With thousands of cultivars, grapes are among the most valued horticultural products globally, mentioned in rituals and religious activities [1, 2]. Various grape cultivars are used in numerous industrial products, including pressed juice, molasses, vinegar, wine, raisins, jam, seed oil, leaf pickle, as well as for fresh consumption as table grapes [3]. In regions characterized by drought and high temperatures, grape growing is preferred due to the rich germplasm collection of *Vitis*, offering a wide range of genotypic options suitable for specific ecological conditions. For each ecology, certain well-known autochthonous cultivars are closely related to their territories due to their long historical and strong cultural ties with the geographical origin. The productive characteristics of genotypes are directly affected by the connection between the genotypes and the ecological conditions, as well as cultivation traditions, all of which are defined as *terroir viticulture* [4]. The concept of terroir encompasses the topography, climate, geology, soil characteristics, edaphic uniqueness, cultural management, and genotypic demarcation of the viticultural ecosystems. However, recent studies on the global climate change scenario have shown that viticulture faces new threats and challenges. The effects of climate change on grapevines are visible in phenology, grape yield, and quality, and will increase the pressure of pests and diseases in the vineyards due to milder winters [5]. Mediterranean countries, in particular, are forecasted to be exposed to substantial temperature increases, prolonged periods of severe drought, increased levels of ultraviolet radiation, and a heavier occurrence of extreme weather conditions. Studies addressing the mitigation strategies for the adverse effects of climate change on agriculture have been one of the hottest themes in the past few years. One of the mitigation strategies, which is underlined in the most recent research as a promising tool for precision agriculture against climate change, is the selection and use of concrete genotypes in production [6]. Grapevines exhibit vast intervarietal diversity, including the rootstocks [7] and autochthonous cultivars [8]. By investigating the physiology and growth features of the abundant grapevine genotypic diversity, the potential for viticulture adaptation to environmental stressors exacerbated by climate change through varietal selection is immense. Therefore, understanding the physiological attributes and developmental characteristics of different *Vitis* genotypes would guide viticulturists and breeders in selecting concrete genotypes for sustainable viticulture under the adverse effects of global climate change.

2. Materials and Methods

A nursery study was conducted in the Research and Implementation Vineyard of Selcuk University, located at 38°01.785' N, 32°30.546' E, at an elevation of 1158 meters above sea level (Central Anatolia, Turkey) in 2025. The study area has a typical continental climate characterized by significant temperature variations, with warm to hot summers accompanied by low air relative humidity and cold winters. The average annual precipitation in most parts of the Konya closed basin, where the study was performed, is around 300–350 mm, indicative of a semi-arid climate. According to the annual mean values recorded between 1929 and 2024, [9] precipitation, maximum, and minimum temperatures are 327.6 mm, 40.9°C, and -28.2°C, respectively. Most of this area experiences heavy winter freezes, water shortages, lime stress, and salinity [10]. Therefore, this ecology is located within one of the ecosystems susceptible to climate change.

Six different *Vitis* genotypes, including three grapevine rootstocks (1613 C, 5 BB, and 41), two *Vitis vinifera* L. cultivars (Ispitiran and Early Sweet), and a *V. labrusca* cultivar (Isabella), were selected for the study based on their genetic distinctness. The genotypes and their main characteristics are presented in Table 1. Two-year-old own-rooted vines were individually cultivated in approximately 12 L. (solid volume) pots containing an equal mixture of peat and pumice. Before bud break, the vines were spur pruned to provide two buds per vine. A single summer shoot per vine was tied with thread to wires about 2 m above the pots to allow the vines to grow in a perpendicular position, ensuring equal benefit from sunlight. Similar cultivation practices, such as drip irrigation, weeding, and fertigation, were applied to all vines.

Table 1. The genotypes used in the study and their pedigree information.

Genotypes	Pedigree (Genetic origin)
1613 C	Rootstock of *V. solonis* x Othello [*V. vinifera x* (*V. labrusca* x *V. riparia*)]
5 BB	Rootstock of *V. berlandieri* x *V. riparia*
41 B	Rootstock of *V. vinifera* cv. Chasselas x *V. berlandieri*
Ispitiran	Autochthonous Turkish cultivar of *V. vinifera* L. in the Central Taurus Mountains
Early Sweet	Early ripening American cultivar of *V. vinifera* L.
Isabella	Cultivar of *V. labrusca* L. known as fungal resistant with foxy flower

Leaf stomatal conductance (gs) and leaf temperature (T_{leaf}) were determined periodically during the summer period (early, mid-, and late summer) using nine healthy sun-exposed leaves per genotype, born between the 5th and 7th nodes of shoots [11] between 09:00 and 12:00h [12] using a portable Model SC-1 leaf porometer (Decagon Pullman, WA, USA) [13] and was expressed as mmol H_2O m^{-2} s^{-1}. Chlorophyll contents of the same grape leaves (at 5th–7th nodes) were read with a chlorophyll meter (SPAD-502, Minolta, Japan) near the cessation of shoot growth [14]. Shoot length and shoot lignification length were measured with a tape measure having a sensitivity of 1 mm. Shoot diameter was measured with a digital caliper at a point 1 cm above the second node.

2.1. Statistical Analysis

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

3. Results and Discussion

Stomatal conductance (gs), recorded at three different times during the summer, significantly differed among the various *Vitis* genotypes (Figure 1). At the beginning of the summer season, the highest gs was observed in the 5 BB rootstock (549.5 H_2O m^{-2} s^{-1}), followed by the 1613 C rootstock (507.5 H_2O m^{-2} s^{-1}) and the Isabella cultivar (495.2 H_2O m^{-2} s^{-1}). Conversely, the lowest gs values were recorded in the autochthonous cultivar Ispitiran (327.2 H_2O m^{-2} s^{-1}) and the international cultivar Early Sweet (355.2 H_2O m^{-2} s^{-1}). The gs across the cultivars tended to decrease in midsummer, except for Ispitiran, which displayed a slight increase. This decrease in gs may be attributed to an increase in air temperature, leading to stomatal closure [15] because stomatal regulation is a complex physiology involving feedback controls affected by both temperature and water [11, 12]. The rootstocks 5 BB and 1103 P showed the highest gs values for all observations. In late summer, the gs ranged from 301.5 H_2O m^{-2} s^{-1} (41 B) to 482.4 H_2O m^{-2} s^{-1} (5 BB). Ispitiran, the autochthonous cultivar, was distinguished from others by its nearly stable gs course. The gs in plant species varies depending on environmental conditions such as solar irradiance, air temperature, relative humidity, soil, and plant water status. It is generally suggested that cultivars with predominant stomatal regulation tend to be more water-conserving and consequently exhibit a higher adaptation potential to changing conditions [16].

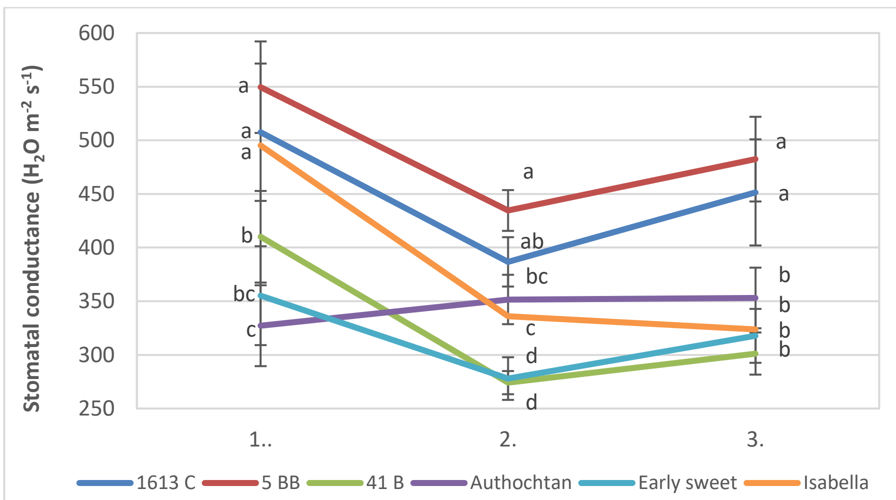

Figure 1. Variation in stomatal conductance (H_2O m^{-2} s^{-1}) of different *Vitis* genotypes.

Note: Each bar represents the mean±standard error. Different letters within the same measurement date denote significant differences ($p<0.05$).

Leaf temperature (T_{leaf}) changes during the summer period displayed significant differences among the genotypes (Figure 2). T_{leaf} changes figured out the opposite of gs in general. In the early season, the highest T_{leaf} was determined in 5 BB rootstock (32.7 °C), followed closely by 41 B rootstock (32.6 °C), while the lowest T_{leaf} values were determined in autochthonous cultivar Ispitiran (31.5 °C) and Isabella (31.6 °C). In mid-summer, the T_{leaf} across the cultivars increased. However, the increase in Ispitiran was remarkably lower than others, probably due to the adaptation capability of this genotype to continental climate conditions, because this cultivar also differed from others with its more stable gs during the summer, including the hottest date in mid-season. Greer [17] suggested a range of T_{leaf} between 25 and 30°C as the threshold values for optimum photosynthesis by grapevine. Overall, T_{leaf} values recorded over the genotypes during the summer period are higher than the mentioned optimum values, except for the T_{leaf} of Ispitiran at the 3rd measurement. This local cultivar, in fact, diverged from others with its relatively lower T_{leaf} values approaching the upper level of the optimum range. T_{leaf} affects the adaptation of a genotype to changing conditions as it regulates the transpiration rate of the grapevine leaves, as previously stated by Marguerit et al. [18].

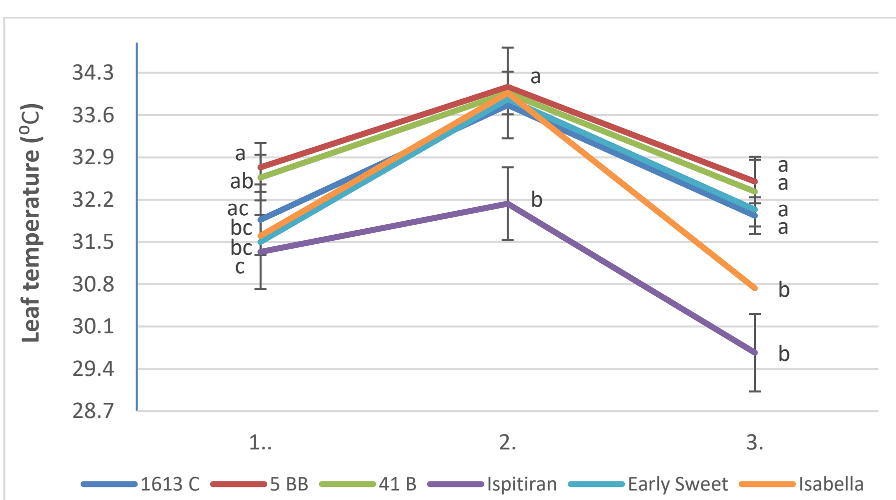

Figure 2. Variation in leaf temperature (^0C) of different *Vitis* genotypes.

Note: Each bar represents the mean ± standard error. Different letters within the same measurement date denote significant differences ($p<0.05$).

Leaf chlorophyll content significantly varied among the genotypes (Figure 3). The highest chlorophyll content was found in the Isabella cultivar (33.3 mg/kg), followed by the 1613 C rootstock (31.4 mg/kg) and the Early Sweet cultivar (31.1 mg/kg). Conversely, the lowest chlorophyll content was observed in the 41 B rootstock (27.6 mg/kg), which was closely followed by the Ispitiran cultivar (27.9 mg/kg) and the 5 BB rootstock (28.4 mg/kg). The chlorophyll contents across the genotypes are similar to those recorded by Zengin and Sabir [19], who studied the effects of organic and synthetic mulch applications on the physiological and growth responses of different grapevine rootstocks in arid ecology. This may indicate that the grapevines synthesized adequate chlorophyll pigments in their leaves under the continental climate conditions.

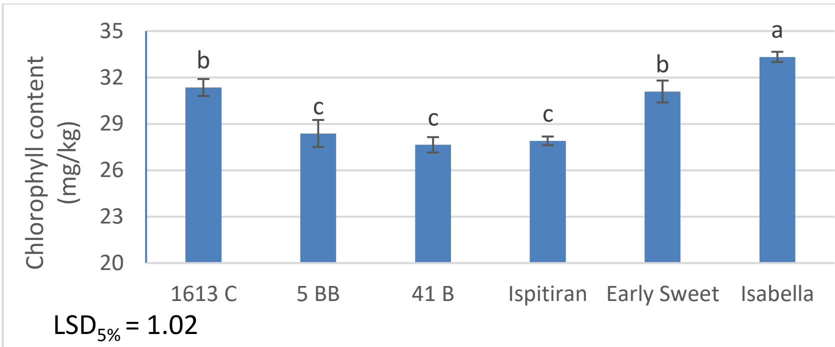

Figure 3. Variation in leaf chlorophyll content (mg/kg) of different *Vitis* genotypes.

Note: Each bar represents the mean ± standard error. Different letters among the genotypes denote significant differences ($p<0.05$).

Shoot length showed significant variation among the *Vitis* genotypes (Figure 4). The highest shoot length was measured in 1613 C rootstock (123.7 cm), which was followed closely by 5 BB rootstock (121.0 cm) at the same statistical level. In contrast, the lowest shoot length was recorded in Early Sweet (77.0 cm), followed closely by Isabella (77.7 cm) and Ispitiran (81.5 cm) cultivars. Under stressful environmental conditions of the continental climate zone, adequate shoot development is one of the primary issues determining the resistance of young vines against drought and winter cold, which can be as low as –20°C for several winter days [9], although biochemical features are also effective in coping with the stressors [20].

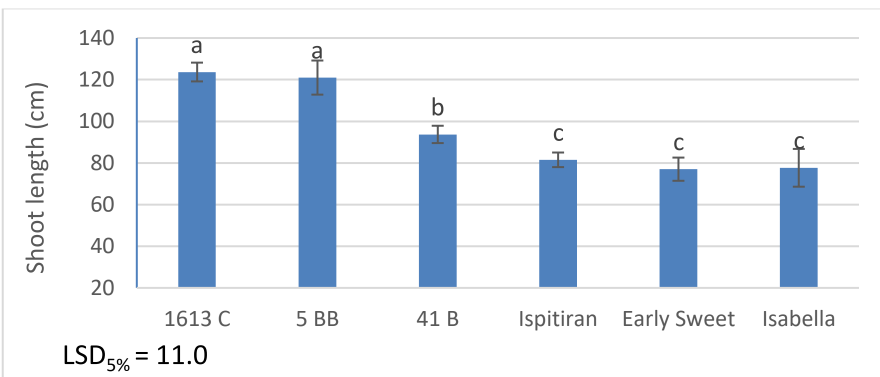

Figure 4. Variation in shoot length (cm) of different *Vitis* genotypes.

Note: Each bar represents the mean ± standard error. Different letters among the genotypes denote significant differences ($p<0.05$).

Shoot lignification length findings revealed a pattern quite similar to that of shoot length, with significant variations among the genotypes (Figure 5). The highest shoot length was found in 1613 C rootstock (93.3 cm), which was followed closely by 5 BB rootstock (91.7 cm) at the same statistical level. In contrast, the lowest shoot length was measured in Early Sweet (40.3 cm), followed by Ispitiran (51.0 cm) and Isabella (54.0 cm) cultivars. The cane quality properties of grapevines are highly dependent on the lignification level of the fibrous cell wall, which follows lignin biosynthesis and deposition in the cell wall. Lignification is important for stressful ecologies as it helps to improve the mechanical properties of the grape shoot [21]. Good lignification allows the vine to better withstand abiotic and biotic stresses [22], and it also affects the vine's reproductive cycle in the following year. Bud sprout performance in the spring season is also affected by cane lignification quality [23].

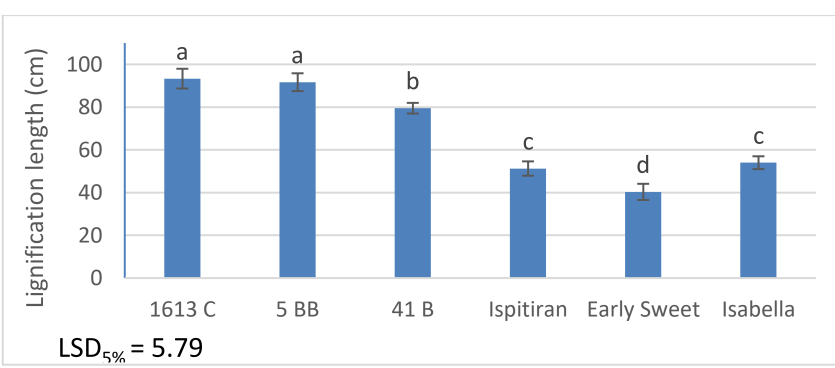

Figure 5. Variation in shoot lignification length (cm) of different *Vitis* genotypes.

Note: Each bar represents the mean ± standard error. Different letters among the genotypes denote significant differences ($p<0.05$).

Shoot diameter findings differed from shoot length findings, with significant variations among the genotypes (Figure 6). The highest shoot diameter was measured in the Ispitiran cultivar (6.12 mm), followed by the Early Sweet cultivar (5.12 mm). The lowest shoot diameter was observed in the 5 BB rootstock (4.04 mm), followed by the Isabella cultivar (4.65 mm). Shoot diameter has been reported to influence cold hardiness in grapevines [24]. Therefore, a well-lignified thick shoot can usually better survive under the effects of multiple stress factors such as winter cold and summer drought. Nonetheless, it should be underlined that shoot diameter alone is not sufficient to judge the stress tolerance of a given genotype, as there are several additional factors that indirectly affect the ability to withstand stressors [25].

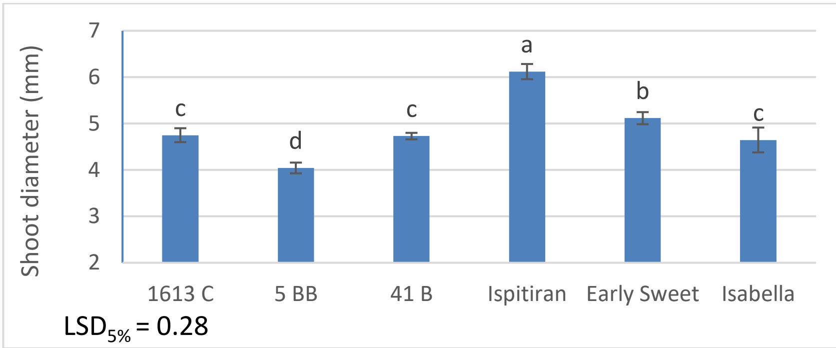

Figure 6. Variation in shoot diameter (mm) of different *Vitis* genotypes.

Note: Each bar represents the mean ± standard error. Different letters among the genotypes denote significant differences ($p<0.05$).

4. Conclusion

The present study was performed to comparatively evaluate certain physiological and vegetative characteristics of different grapevine genotypes under the continental climate conditions. The studied genotypes belonging to different *Vitis* species showed significant variation in terms of grapevine physiology, recorded as stomatal conductance, leaf temperature, chlorophyll content, and vegetative growth features. The local cultivar Ispitiran had more stable stomatal conductance and more consistent leaf temperature than others during the summer period. On the other hand, the rootstock 5 BB was pioneering with its higher stomatal conductance and leaf temperature values. The findings could aid viticulturists in terms of genotypic selection for breeding and/or grape production purposes for sustainable viticulture under the continental climate conditions.

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