Bulgarian Journal of Agricultural Science, 21 (No 2) 2015, 320–324
Agricultural Academy

EFFECTS OF DIFFERENT VINEYARD ALTITUDES AND GRAPEVINE DIRECTIONS ON SOME LEAF CHARACTERISTICS OF CV. GAMAY *VITIS VINIFERA* L.

D. KOK* and E. BAHAR
Namik Kemal University, Faculty of Agriculture, Department of Horticulture, Tekirdag 59030, Turkey

Abstract

KOK, D. and E. BAHAR, 2015. Effects of different vineyard altitudes and grapevine directions on some leaf characteristics of cv. Gamay *Vitis vinifera* L. *Bulg. J. Agric. Sci.*, 21: 320–324

This study was carried out in Ucmakdere Village of Sarkoy County in Tekirdag province of Turkey using cv. Gamay in the course of 2009 growing season. In this research, three levels of vineyard altitude (i.e., low, mid and high) and four different directions of grapevine (i.e., north, south, east and west) were assessed in terms of their effects on some leaf characteristics of cv. Gamay. Based on responses of cv. Gamay to different vineyard altitudes and grapevine directions, strong altitudinal relationships were found out in examined characteristics, including leaf area, stomatal density, stomata length and stomata width. The research results revealed that leaf area and stomatal characteristics were variously affected by vineyard altitudes and also collecting directions of leaves from grapevines. It was observed in research results that leaf stomatal density and stomata length increased with rising vineyard altitude, but leaf area and stomata width reduced with elevating vineyard altitude, regardless of grapevine directions.

Key words: Vitis vinifera L., altitude, grapevine direction, leaf area, stomatal density, stomata length, stomata width

Introduction

Vitis vinifera L. is temperate climate species and the main areas of grape growing are situated between the latitudes of 30° and 50°N and between 30° and 40°S, which approximating to 10–20°C isotherms. Moreover, towards this equator, viticulture can be limitedly performed in areas with higher altitudes under tropical climate zones. Altitude, which is one of the important factors for viticulture can be a limiting factor to successful grape growing (Mullins, 1992).

Plants grown at high altitude are exposed to reducing in air temperature, atmospheric pressure, increasing light intensities, precipitation and wind velocity (Friend and Woodward, 1990; Köerner, 2007); so they must have developed mechanisms, by which to prevent damage caused by chilling, by freezing or by photo destruction. As a consequence, plant species display a wide range of morphological variations along altitudinal gradients (Oleksyn et al., 1998; Köerner, 2003) and alter especially their vegetative growth (Kaska and Kargi, 2007), leaf area (Rost et al., 1984; Fischer, 2000), stomata number (Köerner et al., 1986) and stem and shoots (Balasuriya, 1999; Fischer, 2000) to adapt in different conditions.

Wolfe (1993) stated that among the plant leaf characters and climate relationships, leaf size is one of the best understood and leaf size has been strongly correlated with environmental variables such as soil nutrient level, moisture availability and temperature (Dolph and Dilcher, 1980a; Dolph and Dilcher, 1980b; Wilf et al., 1998; Wolfe, 1993). Leaves on plants of the same species were found to be larger in warm cloud forest habitat, but leaf area decreased at higher elevations where it was much cooler (Ferguson, 1985). As stated, these trends in changing leaf size with altitude are associated with the correlations between leaf size and climatic variables.

Stomata are pore-like structures located on the leaf surfaces of virtually all vascular, terrestrial plant leaves and are responsible for the uptake of photosynthetic CO_2, as well as

**E-mail: dkok@nku.edu.tr; demirkok52@hotmail.com*

for the potentially detrimental water loss from inside the leaf (MacDonald, 2002).

Although stomatal parameters are specific for a particular species, they are affected by multiple ecological factors such as altitude gradient (Beerling and Kelly, 1996), atmospheric CO_2 concentration (Van de Water et al., 1994), temperature, light, irradiance and wind (Lockheart et al., 1998).

Reports concerning influences of altitude on stomatal characteristics of plants are inconsistent. For example, some studies report a tendency for higher stomatal density with altitude (Woodward, 1987). Reports of other research indicate fewer stomata at high elevations (Schoettle and Rochelle, 2000) or no changes in stomatal density (Köerner et al., 1989). Despite the fact that the pattern and frequency of stomata on any leaf surface are under tight genetic control, they may be modified by environmental parameters (Premoli and Brewer, 2007).

The aim of present study is to find out whether various directions of grapevines grown at different altitudes differ in terms of some leaf characteristics.

Materials and Methods

Site description and plant material

The study was conducted in three commercial vineyards situated at three different altitudes (180, 280 and 405 m above sea level) in Ucmakdere Village of Sarkoy County of Tekirdag province in Turkey during the vegetation period of 2009. This region is one of the most important wine producing regions in Turkey and vineyards in here are generally situated at heights ranging from 110 to 500 m a.s.l.

All vineyards' altitudes and co-ordinates are summarized in Table 1 and mean values of some climatic characteristics belonging to Sarkoy County were also given in Table 2 (Bahar et al., 2010).

Table 1
Vineyards altitudes and coordinates

Vineyard level	Vineyard altitude m a.s.l.	Vineyard co-ordinate
Low altitude	180	35T 0529386 UTM 4517320
Mid altitude	280	35T 0529448 UTM 4517091
High altitude	405	35T 0529237 UTM 4516543

In present research, Gamay, which is a famous wine grape cultivar and well adapted to growing conditions of Sarkoy County was used for research material. Grapevines of cv. Gamay were grafted onto Rupestris du Lot rootstock and trained to a goblet system with no trellis at spacing of 1.6 x 1.6 m.

Measurement and counting performed in research

At the end of research, some leaf characteristics such as leaf area (cm^2), stomatal density ($no.mm^{-2}$), stomata length (μm) and stomata width (μm) were determined for cv. Gamay. For this purpose, it was paid attention to leaves from 6^{th} nodes at shoots from different directions (i.e., north, south, east and west) of grapevines grown at various altitudes (i.e., low, mid and high).

After leaves from four directions of grapevines grown at three different altitudes were collected, they were scanned with a pc scanner and these scanned images were processed with a pc packing program to calculate mean leaf area (Kraft, 1995).

In order to determine stomatal characteristics, leaf epidermal imprints were obtained from the places near the central main vain that are located underside of mature leaves. For this goal, nail polish was applied to underside surfaces of leaves and waited up to nail polish completely dried. Afterwards, nail polish patches were gently peeled from leaves by pulling to obtain leaf impressions and placed on a macroscopic slide. Stomatal characteristics of leaves were examined under a light microscope to 40×. While stomatal frequency was expressed as stomata number per mm^2; stomata length (μm) and stomata width (μm) were measured as μm using ocular ruler (Kok, 2011).

Statistical analysis

The study was arranged according to completely randomized parcel design with 4 replicates, including 4 grapevines per replicate. All data concerning related criterion were means of 8 observations per replicate. Statistical analysis

Table 2
Some climatic values for Sarkoy County (as means of long terms)

	Months											
Monthly	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
Mean temperature, ºC	5.5	5.6	7.9	12.5	17.1	22.0	24.0	23.7	20.5	15.5	11.0	7.4
Max. temperature, ºC	19.5	20.7	24.5	28.0	31.0	35.0	36.7	35.5	32.8	31.5	25.5	19.5
Min. temperature, ºC	-8.0	–9.9	–9.5	1.0	4.5	10.0	13.0	12.9	7.6	0.4	–5.3	–7.8
Mean precipitation, mm	77.1	35.8	44.8	45.8	37.1	30.7	14	9.7	19.6	47	87.9	84.9
Mean sun duration, h	4.4	4.5	6.7	8.5	10.0	11.5	12.5	11.8	10.1	8.1	6.9	4.5

was performed with TARIST software and interaction analysis were carried out using MSTAT-C software. In order to compare mean differences among the directions of grapevines grown at various altitudes, Fisher's L.S.D. test was used at $P \leq 0.05$.

Results and Discussion

In current research, some characteristics of leaves from various directions of grapevines grown at different altitudes were assessed. As a result of statistical analysis, the main effects of vineyard altitudes and grapevine directions are presented in Table 3 and interactions of vineyard altitude and grapevine direction were also shown in Figures 1, 2, 3 and 4.

Leaf characters such as leaf area and stomatal characteristics are known to be determined by genetic factors (He et al., 1998).However, these can be affected by variations of environmental factors like atmospheric CO_2 concentration (Van de Water et al., 1994), temperature, light, irradiance and wind (Lockheart et al., 1998). In present study, the variable of leaf area was found to be significant in relation to main effects of vineyard altitude and interactions of vineyard altitude and grapevine direction ($P \leq 0.05$). Grapevines grown at vineyard with low altitude have higher leaf area (147.20 cm^2) than grown at mid altitude (109.77 cm^2) or at high altitude (85.47 cm^2) (Table 3). With respect to interactions of vineyard altitude and grapevine direction, while the highest value of leaf area were obtained from interaction of low altitude and west direction (163.39 cm^2); the lowest mean value was 74.59 cm^2 for interaction of high altitude and west direction (Figure 1). This is consistent with findings of Tanner and Kapos (1982) and Köerner (1989) that plant leaf size generally reduces and leaf mass per area increases with increasing altitude levels.

Studies like Woodward (1987), Schoettle and Rochelle (2000), Köerner et al. (1989) have shown that stomatal density is variously affected by altitude gradients. In this study, there were significant differences in the stomatal density for main effects of vineyard altitude and grapevine direction and interactions of vineyard altitude and grapevine direction ($P \leq 0.05$). Among the different vineyard altitudes, the highest value of

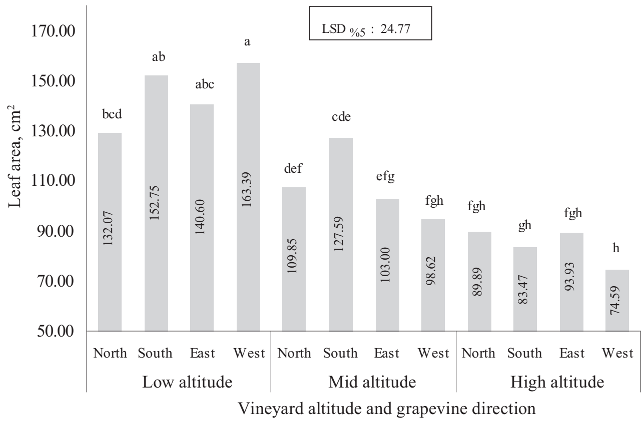

Fig.1. Interaction effects of different vineyard altitude and grapevine direction on leaf area of cv. Gamay

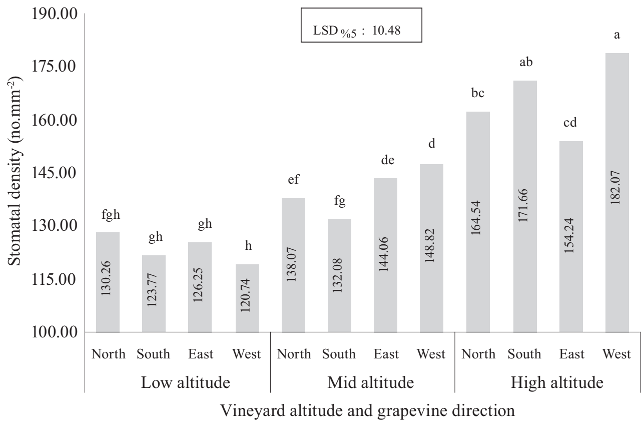

Fig. 2. Interaction effects of different vineyard altitude and grapevine direction on stomatal density of cv. Gamay

stomatal density in leaves were observed in grapevines grown at high altitude vineyard (168.13 $no.mm^{-2}$) than grown at mid altitude vineyard (140.76 $no.mm^{-2}$) or at low altitude vineyard (125.25 $no.mm^{-2}$). With reference to various grapevine directions presented in Table 3, west direction led to the highest stomatal density (150.54 $no.mm^{-2}$) and other grapevine direc-

Table 3
The main effects of different vineyard altitudes and grapevine directions on some leaf characteristics of cv. Gamay

Leaf characteristics	Vineyard Altitude				Grapevine Direction				
	Low	Mid	High	$LSD_{\%5}$	North	South	East	West	$LSD_{\%5}$
Leaf area, cm^2	147.20a	109.77b	85.47c	12.36	110.60	121.27	112.51	112.20	N.S.
Stomatal density, no. mm^{-2}	125.25c	140.76b	168.13a	5.24	144.29b	142.50b	141.52b	150.54a	6.05
Stomata length, µm	73.51c	86.83b	102.46a	6.63	87.34	85.48	86.00	91.19	N.S.
Stomata width, µm	42.14a	33.23b	26.43c	2.43	33.68	35.69	33.48	32.88	N.S.

Significant at $P \leq 0.05$; N.S.: Not significant

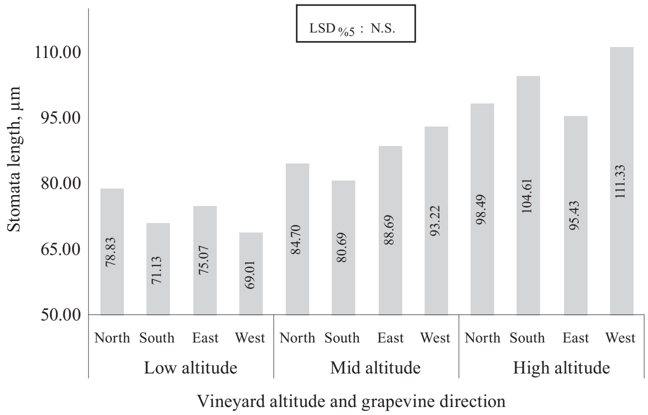

Fig. 3. Interaction effects of different vineyard altitude and grapevine direction on stomata lenght of cv. Gamay

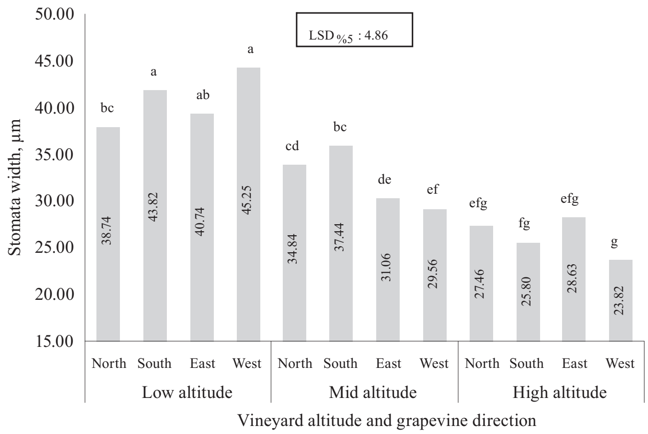

Fig. 4. Interaction effects of different vineyard altitude and grapevine direction on stomata width of cv. Gamay

tions such as north, south and east followed it (144.29, 142.50 and 141.52 no.mm^{-2}, respectively). In terms of interactions of vineyard altitude and grapevine direction, the highest values of stomatal density were obtained from interaction of high altitude and west direction (182.07 no.mm^{-2}) and the lowest value of stomatal density were 120.74 no.mm^{-2} for interaction of low altitude and west direction (Figure 2).

As given in Table 3, there are statistically significant differences among main effects of vineyard altitude based on stomata length ($P \leq 0.05$). Results from the present study revealed that mean values of stomata length of leaves from grapevines grown at high altitude were higher (102.46 µm) than grown at mid altitude (86.83 µm) or at low altitude (73.51 µm).

In current research, increasing vineyard altitudes from low to mid and from mid to high altitude levels resulted in a decrease of stomata width (42.14, 33.23 and 26.43 µm, respectively) in grapevine leaves in terms of main effects of vineyard altitude ($P \leq 0.05$, Table 3). However, interactions of vineyard altitude and grapevine direction shown that low altitude vineyard and west grapevine direction brought about an increase in stomata width (45.25 µm) and the lowest mean value was 23.82 µm for interaction of high altitude vineyard and west grapevine direction ($P \leq 0.05$, Figure 4).

Conclusions

Leaf area and stomatal characteristics of plants are plastic in their response to climate manipulation and plants may be capable of adapting to a changing climate through changes in their leaf characteristics. Climatic conditions of vineyards situated at various altitudes differ along altitudinal gradients. The results of current study presented in here indicate that leaf area, stomatal density, stomata length and stomata width in cv. Gamay were changing not only with increasing altitude levels, but also influencing by grapevine directions exposed to different climatic factors with reference to temperature, light, irradiance and wind. In conclusion, despite the fact that leaf characteristics of cv. Gamay varied according to grapevine directions, various vineyard altitudes from low to high caused an increase stomatal density and stomata length and a decrease leaf area and stoma width.

References

Bahar, E., I. Korkutal and Y. Boz, 2010. Assessment of sarkoy county in terms of terrior. In: Valuables Symposium of Tekirdag Province (October 14, 2010, Tekirdag), pp. 156–177 (Tr).

Balasuriya, J., 1999. Shoot population density and shoot weight of colonal tea (*Camellia sinensis)* at different altitudes in Sri Lanka. *European Journal of Agronomy*, 2: 123–130.

Beerling, D. J. and C. K. Kelly, 1996. Evolutionary comparative analysis of the relationship between leaf structure and function. *New Phytologist*, **134**: 35–51.

Dolph, G. E. and D. L. Dilcher, 1980a**.** Variation in leaf size with respect to climate in the tropics of the western hemisphere. *Bulletin of the Torrey Botanical Club*, **107**: 154–162.

Dolph, **G. E. and D. L. Dilcher**, 1980b. **Variation**in **leaf size-**with**respect**to **climate**in Costa Rica. *Biotropica,* **12:** 91–99.

Ferguson, D. K., 1985. The origin of leaf-assemblages – new light on an old problem. *Reviews in Palaeobotany and Palynology*, **46**: 117–188.

Fischer, G., 2000. Eco-physiological Aspects of Fruit Growing in Tropical Highlands. *Acta Horticulturae,* **531:** 91–98.

Friend, A. D. and F. I. Woodward, 1990. Evolutionary and ecophysiological responses of mountain plants to the growing season environment. *Advances in Ecological Research*, **20:** 59–124.

He, X-Q, Y-H Lin and J-X Lin, 1998. Research on correlation between stomata density and variation of atmospheric carbon dioxide during a century (in Chinese). *Chinese Science Bulletin,* **43**: 860–862 (Ch).

Kaska, N. and S. P. Kargı, 2007. The Physiology of Horticultural Plants. Growth and Development. *Nobel Press*, Adana (Tr).

Kok, D., 2011. Involvement of peroxidase activity in various sensitivity to gamma irradiation in scions of Cabernet Sauvignon and Merlot cvs. (*Vitis vinifera* L.). *Journal of Food, Agriculture & Environment*, **9** (2): 392–396.

Köerner, C., 2003a. Alpine Plant Life: Functional plant ecology of high mountain ecosystems. *Springer-Verlag*, Berlin, *Heidelberg*, New York.

Köerner, C., 2007b. The use of 'altitude' in ecological research. *Trendsin Ecology & Evolution***, 22**: 569–574.

Köerner, C., P. Bannister and A. F. Mark, 1986. Altitudinal variation in stomatal conductance, nitrogen content and leaf anatomy in different plant life forms in New Zealand. *Oecologia*, **69**: 4.

Köerner, C., M. Neumayer, S. P. Menendez-Reidl and A. Smeets-Scheel, 1989. Functional morphology of mountain plants. *Flora,* **182**: 353–383.

Kraft, A., 1995. FlachenberechnungEiner SW-GrafikFlaeche Packing Programme.

Lockheart, M. J., I. Poole, P. F. Van Bergen and R. P. Evershed, 1998. Leaf carbon isotope composition and stomatal characters: important consideration for palaeoclimate reconstructions. *Organic Geochemistry*, **29**: 1003–1008.

MacDonald, G. M., 2002. Conifer stomata. *Tracking Environmental Change Using Lake Sediments*, **3**: 33–47.

Mullins, M. G., A. Bouquet and L. E. Williams, 1992. Biology of the Grapevine. *Cambridge University*, Cambridge, UK, pp. 239.

Oleksyn, J., J. Modrzynski, M. G. Tjoelker, R. Zytkowiak, P. B. Reich and P. Karolewski, 1998. Growth and physiology of *Piceaabies* populations from elevational transects: common garden evidence for altitudinal ecotypes and cold adaptation. *Functional Ecology*, **12**: 573–590.

Premoli, A. C. and C. A. Brewer, 2007. Environmental *v.* genetically driven variation in ecopysiological traits of *Nothofaguspumilio* from contrasting elevations. *Australian Journal of Botany*, **55**: 585–591.

Rost, T. L., M. G. Barbour, R. M. Thornton, T. E. Weier and C. R. Stocking, 1984. Botany. A Brief Introduction to Plant Biology, *California*, USA.

Schoettle, A. W. and S. G. Rochelle, 2000. Morphological variation of *Pinusflexilis* (Pinaceae), a bird-dispersed pine, across arrange of elevations. *American Journal of Botany*, **87**: 1797–1806.

Tanner, E. V. J. and V. Kapos, 1982. Leaf structure of Jamaican upper Montane rain forest trees. *Biotropica***, USA, 14**: 16-24.

Wilf, P., S. L. Wing, D. R. Greenwood and C. L. Greenwood, 1998. Using fossil leaves as palaeoprecipitation indicators: An Eocene example. *Geology*, **26**: 203–206.

Wolfe, J. A., 1993. A Method of Obtaining Climatic Parameters from Leaf Assemblages. *U. S. Geological Survey Bulletin*, **2040**: 1-71.

Woodward, F. I., 1987. Stomatal numbers are sensitive to increase in CO_2 from pre-industrial levels. *Nature*, **18**: 617–618.

Van de Water, P. K., S. W. and J. L. Leavitt Betancourt, 1994. Trends in stomatal density and 13C/12C ratio of *Pinusflexilis* needles during last glacial-interglacial cycle. *Science,* **264**: 239–243.

Received January, 8, 2014; accepted for printing December, 2, 2014.