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The Effects of Altitude on Stomata Number and Some Vegetative Growth Parameters of Some Apple Cultivars

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Abstract: This study was carried out to determine the effects of altitude on stomata number, shoot length, shoot thickness, shoot number and leaf area of Starking Delicious, Granny Smith, Starkspur Golden Delicious, Starkrimson Delicious and Golden Delicious apple cultivars grown in Erzurum and Tortum district. As altitude increased, all parameters investigated decreased. It was found that shoot length and stoma number were measured as 25.2 cm in Erzurum and 36.15 cm in Tortum, and 191.3 units per mm^{-2} in Erzurum and 348.8 units per mm^{-2} in Tortum district, respectively. Starkspur Golden Delicious cultivar had the highest shoot number by average of 46.0 and 48.5 units and Granny Smith cultivar had the highest leaf area by 31.1 cm2 and 34.2 cm2 in Erzurum and Tortum, respectively. Significant correlations were obtained among some climatic parameters pertaining to vegetation period and the vegetative growth parameters, as well as among all growth parameters in both locations. Positive significant correlations were found between the shoot number and temperature, precipitation and relative humidity (r = 0,633*; r = 0.684*; r = 0.656*, respectively), and between the leaf area and temperature, precipitation and relative humidity (r = 0,689*; r = 0.688*; r = 0.768*, respectively). Also, a negative significant correlation was found between the stomata number and the shoot number (r = -0.624*).

Key words: altitude, stoma number, vegetative growth, apple, Erzurum-Tortum.

INTRODUCTION

The agricultural activities in all over the world change depending on different climatic factors caused by distance to equator, proximity to water masses, topography, altitude, etc. The deciduous fruit species favorably grow in temperate zones. However, the fruit also grow in areas with higher altitudes under tropical and subtropical climate zones. As gone farther away from equator, the climatic conditions become severe in the temperate zone[2]. With changes in climatic conditions, the level of altitude may affect on plant growth and quality of fruit species grown in the zone. For instance, as altitude increases; the precipitation also increases, however, the temperature, O2 and CO2 contents decrease. The rise of CO2 concentration in lower altitude causes increasing in atmosphere temperature and therefore, it affects on increasing photosynthesis rate[22,27,28]. The plants alter especially their vegetative growth [15], such as leaf area[24,9], stoma number[18] and stem and shoots [3,9,22] to adapt in different conditions. Water balance in plants is important for protecting plants from frost and drought, and regulating biological processes[15,17,28]. The small pores called as stomata distributed in upper and nethe epidermises of plant leaves conduct physiological functions of plants such as transpiration and photosynthesis[16,17,24,13,7,19]. In general, there are more stomata on the bottom of a leaf than that of the top. This helps to limit water loss through the stomata since the bottom side of a leaf is cooler [28].

Open and closure mechanisms of stomata are very complicated in terms of physiological and ecological process. It is modulated by water, temperature, light[19,5], starch and sugar changing mechanism and CO2 inside leaf Rost *et al*.,[24]. In some leaves, moderate water stress causes to produce ABA, which signals the stomata to close before dehydration is severe. Then, the hormone is gradually destroyed[24]. As soil moisture is depleted, stomata of leaves close earlier in the day, therefore, fruit growth goes down. This event leads to reduction in both fruit growth and total carbohydrate production[28].

This study was carried out to determine the effects of altitude, the relations between stomata number on leaf and vegetative growth parameters (shoot length,

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shoot thickness, shoot number and leaf area) and also to evaluate reactions to different ecologies of apple cultivars grown in the different altitudes.

MATERIAL AND METHODS

Plant Samples: Starking Delicious (SD), Granny Smith (GS), Starkspur Golden Delicious (SSGD), Starkrimson Delicious (SCD) and Golden Delicious (GD) five-year old apple cultivars were used as plant material in this study. Trees (spacing, 3.0 x 2 m) grafted on MM106 rootstocks were used as plant in both the Research and Application Orchard of Department of Horticulture of Agriculture Faculty in Atatürk University (1900 m) and Tortum district of Erzurum province (1200 m) in 2005 year. The study was carried out on 3 trees randomly selected from each cultivar (2 location x 5 cultivars x 3 trees = 30 trees in total). Some climate parameters of the locations are presented in Table 1.

Vegetative Parameters: Average shoot length, shoot thickness, shoot number and leaf area (cm^2) were determined. All measurements were taken in the last vegetative growth period[1].

Stomata Counting: The full developed leaf samples were boiled in ethyl alcohol (70 %) for 10 minutes and thus provided chlorophyll degradation. After these samples taking a filmy shape were boiled in lactic acid (90 %), than they were kept in the cold lactic acid solution for 4-5 minutes. In the last stage; stomata number were determined by using light microscope. Stomata numbers appeared in vision area were counted by using 5 microscope slides with 3 repetitions for each leaf sample[25].

Data Analysis: Data were analyzed with the SPSS software program and the means were separated by Duncan's multiple range tests, and the correlation analyses were performed for all variables.

RESULTS AND DISCUSSION

The change in shoot length and stomata number of apple trees grown in two locations were found statistically significant ($P < 0.01$). Average shoot length and stomata number of apple cultivars were measured as 25.2 cm and 191.3 units per mm^{-2}, in Erzurum; while they were 36.15 cm and 348.8 units per mm^{-2} in Tortum district, respectively. Leaf areas were measured as 23.81 cm2 and 30.14 cm2 in Erzurum and Tortum, respectively. Leaf area decreased with altitude increased. The SSGD cultivar had the highest shoot number with 46.0 units in Erzurum and 48.5 units in Tortum. The highest stomata number and leaf area were determined as 243.8 units per mm^{-2} and 475.0 units per mm^{-2}; 31.1 cm2 and 34.2 cm2 on GS cultivar in Erzurum and Tortum, respectively (Table 2). A significant negative relation between stomata number and shoot number ($r = -0.624^*$) were obtained (Table. 3).

Positive significant relations ($P < 0.05$) were also found between the shoot number and temperature, precipitation and relative humidity ($r = 0{,}633^*$; $r = 0.684^*$; $r = 0.656^*$, respectively), and between the leaf area and temperature, precipitation and relative humidity ($r = 0{,}689^*$; $r = 0.688^*$; $r = 0.768^*$, respectively) (Table. 3).

The reactions of apple cultivars to the climatic factors were different in the both locations. As seen in Table 1; Tortum district has warmer climatic condition, more precipitation and more relative humidity as compared to Erzurum. This situation leads to be longer vegetation period and provides higher vegetative growth in Tortum. The apple cultivars grown in Tortum ecological conditions with lower altitude had higher stomata number and vegetative growth parameter values than those of the apple cultivars grown in Erzurum.

The plants grown in the higher altitudes are subject to harsher environmental conditions during their growth and development periods. Usually, these locations are colder, more drought, and have more UV light intensity. Thus, the plants exposed to these tough conditions have to take some prevention to stand and maintain their vitalities such as narrowing leaf area[9,24], lessening stomata number to prevent water loss [18]. Furthermore, the plants grown in those regions have more spur stem and shoots due to more UV light intensity [3,9,21]. Previous studies carried out by Hokanson *et al*[11,23] in strawbery and Chandra [6] in some alpine plants showed that leaf area decreased along with hoisted altitude. Mısırlı and Aksoy [20] in fig, Gönüz and Özgürücü[10] in thyme found that stomata number on both up and low epiderm layers of leaves decreased with altitude. Gönüz and Özgürücü[10] in thyme found that leaf and cuticle thickness, stomata length increased but stomata number and width decreased in higher altitudes. Similar results were obtained from apples[29], walnuts [7] and begonias[12]. Our results are agreed with the previous reports. Granny Smith cultivar had the highest stomata number and leaf area values in the both locations. Average temperature, total precipitation and relative humidity factors had the positive effects on all vegetative growth parameters in both locations. These relations may change depending on species, cultivar and regional differences. The ecological conditions such as water, temperature, and light intensity affect directly on the

Table 1: The climatic data for locations during vegetation period in 2005 (DM~, 2007).

Locations/Months		May	June	July	August	September	Average
TORTUM (1200 m)	Minimum Temperature (°C)	-0.4	3.4	10.1	6.8	3.8	4.74
	Maximum Temperature(°C)	25.2	28.5	34.4	35.4	29.4	30.58
	Avarage Temperature (°C)	12.3	15.6	21.6	20.8	14.4	16.94
	Precipitation (mm)	111.1	47.0	57.7	64.5	36.9	317.2*
	Relative Humidity (%)	61.8	62.2	58.6	59.5	61.7	60,76
ERZURUM(1900 m)	Minimum Temperature (°C)	-2.2	1.4	6.4	16.4	-1.2	4.16
	Maximum Temperature(°C)	22.2	26.4	31.4	34.1	28.9	28.60
	Avarage Temperature (°C)	10.6	13.9	20.2	20.4	14.0	15,82
	Precipitation (mm)	92.1	12.0	20.3	23.3	15.4	163,1*
	Relative Humidity (%)	62.2	56.7	55.1	50.9	59.1	56.8

* (Total)

Table 2: Some vegetative growth parameters according to different locations and cultivars

Cult~vars / Parameter	ERZURUM (1900 m)							TORTUM (1200 m)						
	SD	GS	SSGD	SCD	GD	Sig. level	Avrg.	SD	GS	SSGD	SCD	GD	Sig. level	Avrg.
Shoot length (cm)	22.0	23.5	29.5	29.5	21.5	NS	25.2B	32.3b	40.3a	39.15a	32.01b	37.1ab	0	36.15A**
Shoot thickness (mm)	5.84ab	5.33bc	6.17a	5.86ab	4.89c	0	5.61	6.04	5.80	6.30	6.15	5.30	NS	5.92
Shoot number (unit)	35.5b	33.5b	46.0a	26.0c	28.5c	**	33.9	41.0b	37.5bc	48.5a	32.0d	35.5cd	**	38.9
Leaf area (cm^2)	17.35c	31.1a	26.3b	19.02c	25.3b	**	23.81	26.92c	34.2a	33.1ab	26.2c	30.3b	**	30.14
Stomata number (units per mm^{-2})	162.5c	243.8a	153.3c	206.3b	187.5bc	**	191.3B	287.5bc	450.0a	256.3c	406.3a	343.8b	**	348.8A**

NS., Non Signifiant ; * $P < 0.05$; ** $P < 0.01$

Table 3: The correlations among some climatical data and vegetative growth parameters

	Average temperature (°C)	Total precipitation (mm)	Relative humidity (%)	Shoot length (cm)	Shoot thickness (mm)	Shoot number (units)	Leaf area (cm^2)
Shoot length(cm)	0.192	0.295	0.295				
Shoot thickness (mm)	0.280	0.191	0.191	0.319			
Shoot number (units)	0.633*	0.654*	0.656*	0.334	0.539		
Leaf area (cm^2)	0.689*	0.688*	0.768*	0.321	-0.313	0.336	
Stoma number (units mm^{-2})	0.131	0.152	0.152	0.127	-0.340	-0.624*	0.224

* ($P < 0.05$)

plant vegetative growth and indirectly fruit development and quality. Stomata open-closure on leaves changes based on ecological factors and is associated with the plant growth and development[4,26].

The climate changes occurring due to the altitude differences can show significant effects on plant growth. This situation also affects on the capability of plant adaptation in all the regions. The changes on stomata, vegetative growth parameters and the relations among those have an importance during adaptation processes of plants since those have some important functions in photosynthesis and transpiration processes. Therefore, the studies on these relationships could be important for determining the adaptability range of plants in different climatic locations.

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