The Effect of Altitude on Soil Properties and Leaf Traits in Wild *Vaccinium arctostaphylos* L. Populations in the Forest Understorey in Fırtına River Basin

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Abstract:

The study addressed the effect of altitude on soil properties and leaf traits in wild *Vaccinium arctostaphylos* L. populations in the forest understorey in Fırtına River Basin. For this purpose, 9 experimental sites were taken in three different levels of altitude (1000 -1200, 1300 -1500 and 1800-1900m, a.s.l.). In each experimental site, soil samples were taken from different depth steps (0-10, 10-30 and 30-50 cm). The soil were analysed for soil physico-chemical properties (such as, texture, bulk density, particle density, total porosity, field capacity, permanent wilting point, available water, pH, soil organic matter, total nitrogen, and C:N). We measured leaf width, leaf length, leaf area and LMA (leaf mass per unit area). According to elevation, the average silt ratio, total nitrogen and soil organic matter increased significantly while clay ratio, C/N and leaf width decreased. LMA, leaf length and leaf area, bulk density, pH, particle density and total porosity changed irregularly with raising elevation. The main reasons for these challenges might be the environmental variations that change with elevation. LMA may varied non-linearly with increased elevation, which could be due to changes at the macro and microscale when cloud banks are present at different elevations.

Key Terms: *Vaccinium arctostaphylos*, soil properties, leaf traits, altitude, forest understorey, Fırtına River

Introduction:

Altitude is one of the most important factors determining microsite conditions that impact plant distribution, morphology, physiology, and growth (Chapin et al. 1987; Despland and Houle. 1997; Parmesan. 2006; Li Pan et al. 2009 ). High altitude environment is characterized by high solar radiation, low temperature, rapid temperature changes, and low partial pressure of the air (Streb et al. 1998). Lowland environment is characterized by higher temperature, different atmospheric humidity, and higher potential evapotranspiration. The change in any of these parameters affects plant performance. Plant height, structure, and physiology have been observed to change with the changing environmental variables with elevation. In addition to varying with elevation, climate dramatically influences the pedogenic processes and soil properties by affecting types and rates of chemical, physical, and biological processes, and the type and composition of vegetation species (Hutchins et al. 1976).

In the forest understorey, seedlings and herbaceous or shrubby vegetation grow together and interact in different ways, e.g. for environmental resources, namely light, water and nutrients (Davis et al. 1999). Consequently most understory plant species is effected by the changing environmental conditions. Although several studies have examined properties of forest understories in many part of the world, research in Turkey concerning this subject is insufficient.

*Vaccinium arctostaphylos* L. is an ericaceous deciduous shrub that is commonly found in the understorey vegetation in Eastern Blacksea Forests (Kayack 1981; Davis 1978). It is widely distributed, growing from valley bottoms to high elevation sites in forests. Natural environmental conditions such as elevation and soil properties are known to be important in controlling the performance of *V. arctostaphylos* L. Unlike other members of the genus, which includes blueberries, this shrub is not easily cultivated. Moreover there is not sufficient information about the site
characteristic and ecology of the plant in Fırtına River Basin.

The aim of this study is to determine the effect of altitude on soil properties and leaf traits in wild Vaccinium arctostaphylos L. populations in the forest understory in Fırtına River Basin.

Materials and methods:

The study was carried out on the northern slope of Fırtına River Basin is located in Çamlıhemşin County, in the northeastern of Rize, Turkey (40° 58’ 07” N, 40° 58’ 38” E, 1000-1900 m a.s.l.) (Figure 1). Climate is sub-oceanic, with a mean annual temperature of 6 ºC and a mean total annual precipitation of 2745 mm at 1350 m (Yüksek 2013). The study area is usually covered with snow from December through May or June. Geologically, experimental sites are defined Çatak Geologic Formation (Güner 1983; Gedik et al. 1992; Okay and Şahintürk 1997).

The vegetation in the study area is dominated by a Picea orientalis L. or a mixed spruce (Picea orientalis L.) beech (Fagus orientalis Lipsky, ) forest. The canopy layer was dominated by Picea orientalis L. in experimental sites. The most common understory species were Vaccinium arctostaphylos L., Rhododendron ponticum L., Rhododendron luteum Sweet. Sorbus aucuparia L., ilex aquifolium L., Laurocerasus officinalis Roemer, Campanula sp, Epigaea sp., Carex sp., Hypericum sp (Yüksek 2013). Comprehensive survey of V. arctostaphylos distribution was carried out on the northern slope of the Fırtına River Basin. In order to determine possible differences in soil properties and plant characteristic, research area subdivided three altitude groups (such as 1000 and 1200 m, 1300 and 1500 m, and 1800 and 1900 m.) At each altitude groups, three experimental sites were selected. Three sample plots (36 m²) were established by stratified random sampling method and soil and vegetation sampling were carried on over each experimental site. All experimental plots were similar as regards light level (% 40-60 tree cover) and topographic factors. Three disturbed and three undisturbed soil samples were taken randomly at a soil depth of 0–10 cm, 10-30 cm and 30-50 cm in each plot. A total of 81 soil samples (3 altitude groups X 3 replicates X 3 soil pits X 3 soil depths) were collected in 2011.

Soil texture was determined by the Bouyoucos hydrometer method (Gülçur, 1974). The dry bulk density (D₉) was determined by the core method (Blake ve Hartge 1986; Grossman ve Reinch 2002). The particle density (Dₚ) was determined by the pycnometer method (Flint ve Flint 2002). The total porosity (St) was calculated from the following equations: 

\[ St(\%) = (1 - D_9/D_p) \times 100 \]

Where St is total pore spaces, D₉ is bulk density and Dₚ is soil particle density (Flint and Flint 2002). Soil pH was determined from a mixture of 1:2.5 soil: water.
by volume using an Orion 420 A pH meter (Gülçur 1974; Karaöz 1989). The concentration of soil organic matter (OM) was determined by the Walkley-Black method (Gülçur 1974; Karaöz 1989; Kacar 1996). Total Nitrogen (TN) was determined by the Kjeldahl method (Öztürk et al. 1997) The C:N ratio was calculated from the following equations: [C:N = (Soil Organic Carbon: Total Nitrogen)]. Soil samples had been analyzed for soil field capacity, permanent wilting point and plant available water ratio as described by Gülçur (1974).

Statistical analysis of the data was carried out using SPSS for Windows version 15.0. We performed two-way factorial ANOVA to test for the difference in soil properties between altitudes and soil depth. Leaf variables were tested for differences between elevations using one-way ANOVA. Duncan tests were used to separate the averages of the dependent variables which were significantly affected by factors.

Results:

Soils are of sandy loam (SL) textures in all altitude groups and at all soil depths. The highest sand content was observed in the third altitude (1800-1900 m), while the highest clay content was observed in the first altitude (1000-1200 m). According to elevation, the mean clay contents decreased, while silt contents increased. Differences between first and third altitude was significantly important (Table 1).

The mean bulk density significantly decreased, while mean total porosity significantly increased in second altitude compared to first and third altitude steps. The mean pH significantly decreased in second altitude compared to first and third altitude steps (Table 1). The mean total nitrogen and OM content significantly increased in second and third altitudes compare to first altitude, while C:N ratio significantly decreased in second and third altitudes compare to first altitude (Table 1). The mean bulk density significantly increased, while mean total porosity decreased in according to sampling depth. Differences in core volume was significantly important in the third depth (30-50 cm) compared to the first (0-10 cm) and second depth (10-30 cm) (Table 1). The mean pH significantly increased, while total nitrogen and OM content significantly decreased according to sampling depth. The mean C:N ratio increased according to sampling depth and differences is significantly important between the first and third depth steps (Table 1).

Table 1. Classification of the means of the soil properties for different classes of altitude and soil depth using the Duncan method (Mean ± standard deviation)

<table>
<thead>
<tr>
<th>Variable</th>
<th>1000-1200</th>
<th>1300-1500</th>
<th>1800-1900</th>
<th>0-10</th>
<th>10-30</th>
<th>30-50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand (%)</td>
<td>72.68 ± (4.14)</td>
<td>71.49 ± (5.82)</td>
<td>74.28 ± (3.67)</td>
<td>72.40 ± (5.03)</td>
<td>72.83 ± (5.11)</td>
<td>73.22 ± (4.08)</td>
</tr>
<tr>
<td>Clay (%)</td>
<td>14.93 ± (4.10)a</td>
<td>14.86 ± (4.29)a</td>
<td>10.44 ± (1.71)b</td>
<td>12.62 ± (2.51)</td>
<td>13.48 ± (4.57)</td>
<td>14.13 ± (4.84)</td>
</tr>
<tr>
<td>Silt (%)</td>
<td>12.39 ± (3.73)b</td>
<td>13.65 ± (4.97)ab</td>
<td>15.28 ± (3.62)a</td>
<td>14.98 ± (4.56)</td>
<td>13.69 ± (4.00)</td>
<td>12.65 ± (4.08)</td>
</tr>
<tr>
<td>FC (%)</td>
<td>37.40 ± (4.69)</td>
<td>35.33 ± (6.05)</td>
<td>38.17 ± (4.75)</td>
<td>36.30 ± (5.12)</td>
<td>38.34 ± (4.89)</td>
<td>36.27 ± (5.69)</td>
</tr>
<tr>
<td>PWP (%)</td>
<td>20.64 ± (5.29)</td>
<td>20.16 ± (5.43)</td>
<td>21.48 ± (3.64)</td>
<td>20.93 ± (5.31)</td>
<td>21.63 ± (4.71)</td>
<td>19.72 ± (4.40)</td>
</tr>
<tr>
<td>PAW(%)</td>
<td>16.76 ± (3.03)</td>
<td>15.17 ± (3.59)</td>
<td>16.69 ± (2.78)</td>
<td>15.37 ± (3.42)</td>
<td>16.71 ± (3.02)</td>
<td>16.55 ± (3.08)</td>
</tr>
<tr>
<td>Db (gcm⁻³)</td>
<td>0.94 ± (0.10)a</td>
<td>0.74 ± (0.09)b</td>
<td>0.95 ± (0.09)a</td>
<td>0.81 ± (0.11)c</td>
<td>0.87 ± (0.13)b</td>
<td>0.95 ± (0.14)a</td>
</tr>
<tr>
<td>Dp (gcm⁻³)</td>
<td>2.30 ± (0.13)</td>
<td>2.23 ± (0.16)</td>
<td>2.33 ± (0.21)</td>
<td>2.25 ± (0.12)</td>
<td>2.29 ± (0.11)</td>
<td>2.32 ± (0.13)</td>
</tr>
<tr>
<td>St (%)</td>
<td>59.13 ± (4.62)b</td>
<td>66.81 ± (4.38)a</td>
<td>59.22 ± (3.62)b</td>
<td>64.00 ± (4.93)a</td>
<td>62.01 ± (5.50)a</td>
<td>59.05 ± (5.11)b</td>
</tr>
<tr>
<td>pH</td>
<td>4.81 ± (0.34)a</td>
<td>4.60 ± (0.23)b</td>
<td>4.76 ± (0.26)a</td>
<td>4.53 ± (0.23)c</td>
<td>4.73 ± (0.28)b</td>
<td>4.91 ± (0.24)a</td>
</tr>
<tr>
<td>TN (%)</td>
<td>0.21 ± (0.11)b</td>
<td>0.41 ± (0.18)a</td>
<td>0.46 ± (0.13)a</td>
<td>0.45 ± (0.17)a</td>
<td>0.35 ± (0.18)b</td>
<td>0.26 ± (0.13)c</td>
</tr>
<tr>
<td>OM (%)</td>
<td>5.96 ± (1.94)a</td>
<td>7.87 ± (1.64)b</td>
<td>8.09 ± (1.40)b</td>
<td>8.51 ± (1.24)a</td>
<td>7.57 ± (1.80)b</td>
<td>5.84 ± (1.65)c</td>
</tr>
<tr>
<td>C:N</td>
<td>18.85 ± (6.92)a</td>
<td>13.89 ± (7.29)b</td>
<td>10.91 ± (2.67)b</td>
<td>12.37 ± (4.12)b</td>
<td>15.44 ± (7.06)b</td>
<td>15.81 ± (8.23)a</td>
</tr>
</tbody>
</table>

FC: field capacity (%), PWP: permanent wilting point (%), PAW: plant available water (%), Db: particle density (gcm⁻³), Dp: bulk density (gcm⁻³), St: total porosity (%), OM (%): Organic matter content, TN (%): total nitrogen. Different letters indicate significant differences between altitudes and soil depths (P < 0.05).
The highest leaf width was measured in the first altitude step (1000-1200 m), and the lowest leaf width was determined in the third altitude step (1800-1900 m). The mean leaf width significantly decreased according to elevation. The highest leaf length was measured in second altitude, while the lowest leaf length was found in the first altitude. According to elevation, mean leaf length first significantly increased, then decreased statistically (Table 2).

The highest leaf area was measured in second altitude, while the lowest leaf area was found in the third altitude. According to elevation, mean leaf area first significantly increased, then decreased statistically (Table 2). The highest LMA was estimated in the third altitude, while the lowest LMA was calculated in the second altitude. Compare to the third altitude, the mean LMA was statistically lower in the first and the second altitude (Table 2).

### Table 2. Classification of the means of leaf traits for different groups of altitude using the Duncan method (Mean ± standard deviation)

<table>
<thead>
<tr>
<th>Altitude (m)</th>
<th>Leaf Width (cm)</th>
<th>Leaf length (cm)</th>
<th>Leaf Area (cm²)</th>
<th>LMA (gr/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000-1200</td>
<td>5.21 ± (0.39)a</td>
<td>7.76 ± (0.81)c</td>
<td>17.96 ± (3.09)b</td>
<td>45.76 ± (5.89)b</td>
</tr>
<tr>
<td>1300-1500</td>
<td>5.31 ± (0.42)b</td>
<td>8.69 ± (1.46)a</td>
<td>19.35 ± (4.81)a</td>
<td>43.91 ± (5.35)c</td>
</tr>
<tr>
<td>1800-1950</td>
<td>5.41 ± (0.36)c</td>
<td>8.31 ± (0.98)b</td>
<td>16.19 ± (3.16)c</td>
<td>48.96 ± (5.81)a</td>
</tr>
<tr>
<td>F</td>
<td>154.40</td>
<td>57.45</td>
<td>55.51</td>
<td>54.14</td>
</tr>
<tr>
<td>P</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Different letters indicate significant differences between altitudes (P < 0.05).

Discussion and Conclusions:

There is an association between elevation and climatic parameters such as precipitation and temperature. In this research, elevation significantly affected some leaf traits and soil properties. But leaf traits did not change linearly with increased elevation. The effect of elevation may be complex and probably indirect.

We suggested that plants may be changes some leaf traits to survive under different environments. Especially smaller leaves in the highest altitude can also play a role in freezing resistance at high elevation by decreasing the wettability of the leaf surface. Beside that this fact is undoubtedly associated with genetics and environmental pressure (Kofidis 2007). Some published results showed a decrease in leaf area with increasing altitude because this fact principally attributed to the low air temperature (Cordell et al. 1998; Kofidis et al. 2007; Kao and Chang 2001; Yüksek 2013). Consequently, LMA of plants grown at low temperature is higher. Velázquez-Rosas et al. (2010) reported that leaf traits did not always change linearly with increased elevation, which could be due to changes at the macroscale when cloud banks are present at different elevations. Additionally, each species cope with light and other environmental factors, according to their plasticity and sensitivity to environmental factors that determine the point at which the distribution of each species declines.

The Total N and OM content increased along the altitudinal gradient. Low temperature together with high precipitation may decrease soil organic matter decomposition. It is likely that differences in soil nitrogen storage were also caused by differences in decomposition and nitrogen turnover rates. The pH, Db, Dp, St did not decrease or increase consistently with increasing altitude. The higher altitude have more herbaceous biomass than lower altitudes. The wild animals who grazing on herbaceous biomass on higher altitude could lead to compaction and decrease soil pore volume and pore network. It was reported that grazing intensity causes soil compaction and decreases soil pore volume (Greaten and Sands 1980; Froehlich and McNabb 1983; Short et al. 1986; Gökbakal 1998; Brady and Weil 1999; Yüksek 2009; Yüksek et al. 2010).

The C/N did decrease consistently with increasing altitude. A possible explanation to the differences in the soil chemistry may be composition of the litter. The understorey vegetation at the lower elevation is dominated...
by ericaceous shrubs (such as, *V. arctostaphylos* L. and *Rhododendron* sp.). The most common understory species were *V. arctostaphylos* and herbaceous plants at the higher elevation so different plant composition may influence soil pH. pH and C:N may be affected not only by vegetation type but also climate.

St, OM and Total N decreased along the soil depth. Plant and animal wastes constitute the most important organic matter and total nitrogen sources in soil. If nitrogen not taken up by plants, it will move easily with water through soil, potentially resulting in nitrates reaching (by runoff or erosion) groundwater. According to soil depth steps below ground biomass decreases and transportation of organic matter of this area through erosion might have negative effects on the low amount of organic matter but higher bulk density. On the other hand wild animal grazing in higher altitudes might have effects on the higher amount of soil bulk density.

pH and C/N increased along the soil depth. It might be concluded that leaching of alkaline cations (such as Ca, Na, K, Mg) from upper layer to down layer might have affected increasing of soil pH according to soil depth. On the other hands, the decreasing of soil organic matter content may lead to increasing soil pH according to soil depth. It was reported that soil pH increases according to soil depth (Özyuvacı 1976; Short et al. 1986; Finzi et al. 1998; Yüksek 2001; Yaşar Korkanç 2003).

These results may be provided evidence that variations in these leaf traits of *V. arctostaphylos* reflected genetic adaptations to native habitats. Beside that our data are helpful for understanding plant life strategies of *V. arctostaphylos* L.. Further studies involving plants grown under different environmental conditions combined with studies of population genetics are necessary to better understand how natural selection is acting upon these populations.

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