# Assessing Ecological Factors From an *Abies grandis* Provenance Test Area after *Phytophtora* Root Rot Attack

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**Abstract**

Due to expansion of world population and increasing variety of human needs, the demand for wood raw material is increasing rapidly. In this case, existing productive forest area as well as production of raw material in a unit area should be enhanced. For this goal, the productive forest area is being increased by planting native species. On the other hand, it is important to use appropriate species such as fast-growing exotic ones that could be adapted to the local conditions in the afforestation activities.

*Abies grandis* has been used for origin experiments in many countries because of the high potential productivity. Many exotic species except for *A. grandis* had been tested until 1988 in Turkey. In 1988 a total of 24 units, 16 originating from the USA, France and Canada and 8 from our native fir species (4 from *A. nordmanniana*, 2 from *A. bornmuelleriana* and 2 from *A. equi-trojani*), were used, the origins of seeds been provided. Seeds were sown in Meryemana Research nurseries (950 m asl) in the spring season of 1989. 3+0 age seedlings were transferred to Meryemana-Yeniköy research area.

All *A. grandis* seedlings died after 17 years due to *Phytophthora* root rot infection in the research area. In order to investigate the relation between dead and healthy fir species 24 soil profiles were dug up. Some soil properties such as particle size analysis and exchangeable bases were analyzed. Furthermore, the *Phytophthora* root rot disease causing the death of *A. grandis* seedlings was investigated ecologically.

**Key Words:** Fir species, origin experiments, soil properties, *Phytophthora* root rot

## Introduction

The increase of productive forest areas and the need to obtain more products from unit area caused not only the increase of afforestation activities involving native species but also research on the fastest-growing foreign species adapted to local conditions in the world. Due to its high yield potential *Abies grandis* (grand fir) was used for experiments on species adaptation and origin.

Many alien species had been tested until 1989. After this year, *A. grandis* has been started to experiment in our country. The studies have started with various origin sources of *A. grandis* and origins of native fir species (*A. nordmanniana*, *A. eqi-trojani*, and *A. bornmuelleriana*) in the Eastern Black Sea Region in 1989 (Gerçek et al., 2011).

In North America, grand fir's wide geographical distribution is from latitude 51° to 39° N and from longitude 125° to 114° W. It grows in the stream bottoms, valleys, and mountain slopes of northwestern United States and southern British Columbia (Silvics Manual, 2004).

The soft white wood of grand fir is a valued source of pulpwood. The wood is also commercially valuable as timber even though it is weaker and more prone to decay than many other species. The luxuriant foliage, symmetry, and deep green shiny color make grand fir one of the preferred species of Christmas trees grown in the Northwest. The attractive appearance of grand fir makes it valuable in recreation areas and urban plantings (Silvics Manual, 2004).

In this study; first of all, some soil properties of native species plantations (*A. nordmanniana*, *A. equi-trojani*, and *A. bornmuelleriana*) in Meryemana-Yeniköy and alien species (*A. grandis*) have performed. In addition, the dryness and deaths of *A. grandis* in the area have been considered ecologically.

**Description of Study Area**

Study area (Figure 1) lies between 40º42'04"-40º42'14" N latitude and 39º44'12"-39º44’20” E longitude and its elevation is 1,100 m. The average slope of study area is around 30-50% and its aspect is north (Gerçek et al., 2011).

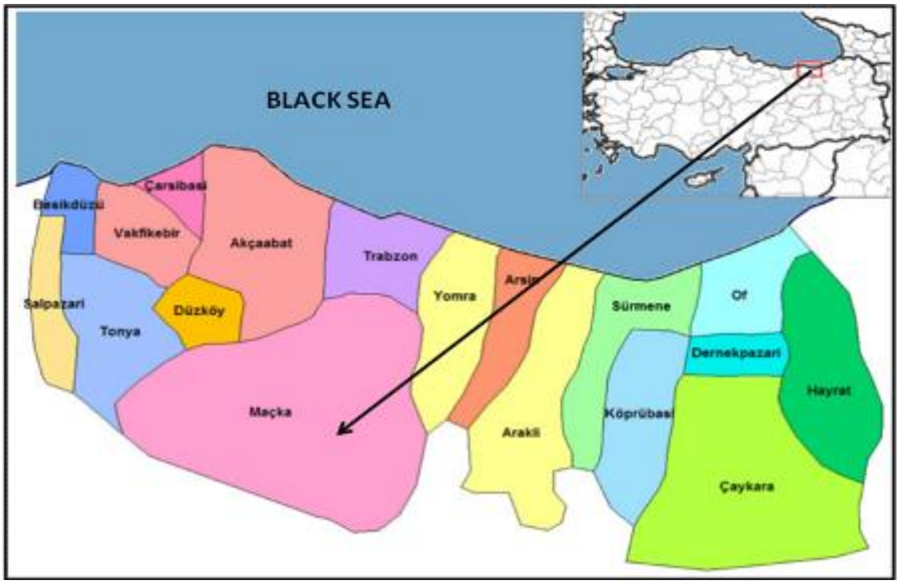


Figure 1. Geographical location of research area

**Material and Method**

**Material**

Research materials consist of climate data, geological maps (scale 1:25,000), other data such as aspect, elevation, slope, etc. collected from 24 sample plots (4 of *A. nordmanniana*, 4 of *A. bornmülleriana*, 4 of *A. equi-trojani* and 12 of *A. grandis*). 92 soil samples were taken from research area.

**Method**

This study was carried out in three stages including field, laboratory and ecological assessments.

***Determining Specific Position Factors***

Some data such as elevation, slope, aspect, relief, and the neighboring environment-specific information were collected for Specific Position Factors.

***Determination of Soil Properties***

Soil profiles were dug up and their layers were determined for each sample plot (Figure 2) (Irmak, 1970; Kantarcı, 2000). Soil samples were taken after measuring the thickness of each layer. In addition, in each soil profile the absolute, physiological, and excavation depths were determined (Çepel, 1984).

***Laboratory Analysis***

The soil samples obtained from the land, after being air-dried, were grounded inside the mortar, sifted through a 2-mm sieve, and prepared for analysis (Gülçür, 1974; Karaöz, 1989a). The soil analyses were conducted on the soils, with particle diameters smaller than 2 mm, by using the standard methods. The determination of particle size distribution (sand, silt, clay) of soils was carried out by using Bouyoucos hydrometer method; soil acidity (pH) was analyzed according to the glass electrode method in pure water; electrical conductivity (EC) was analyzed according to the glass electrode method in pure water; and the analyses of the soil organic matter (SOM) by using Walkley-Black wet burning (Gülçür, 1974; Arp, 1999; Karaöz, 1989b).

*A. equi-trojani*

*A. bornmuelleriana*

*A. nordmanniana*

*A. grandis*

Figure 2. Soil profiles

The amount of available water capacity (Karaöz, 1989a, Kantarcı, 2000). The determination of exchangeable bases ($Ca^{++}$, $Mg^{++}$, $K^{+}$ and $Na^{+}$) was performed by using 1 N Ammonium Acetate method (USDA, 1996).

***Ecological Assessments***

In this section, the research areas of dead *A.grandis* were evaluated according to some ecological factors.

**Results and Discussion**

Some properties (sand, silt, clay, pH, EC, organic matter, field capacity, wilting point, available water capacity, exchangeable bases) of fir plantation area soils are shown below (Figures 3-13).

Soils are in the same ecological conditions (e.g. climate, altitude, bedrock, aspect and slope) and similar tree species are likely to be found.

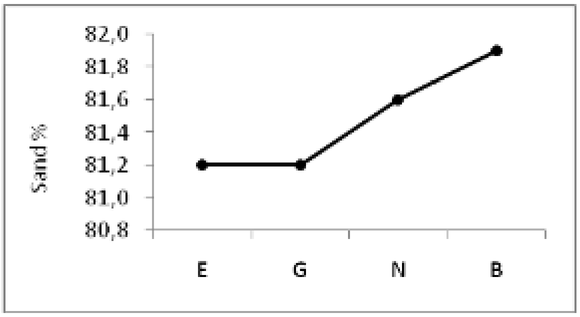


Figure 3. % Sand

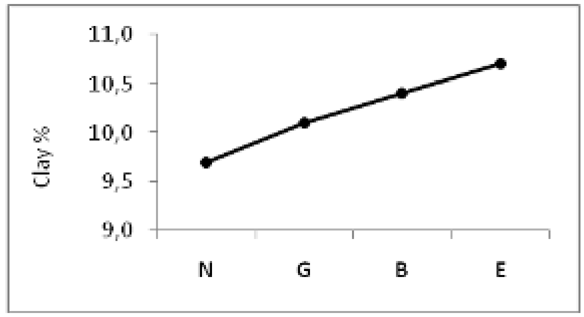


Figure 4. % Clay

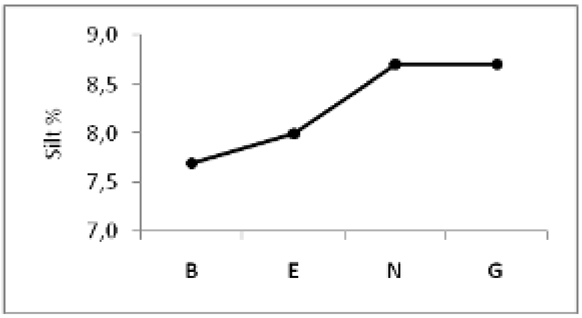


Figure 5. % Silt

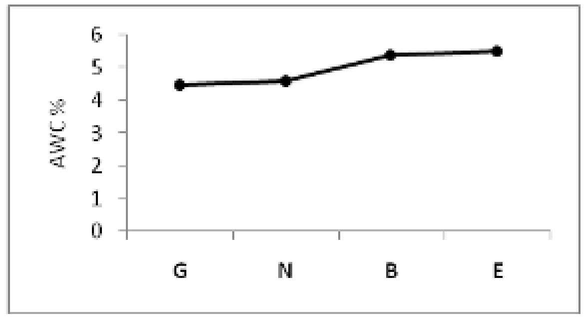


Figure 6. % AWC

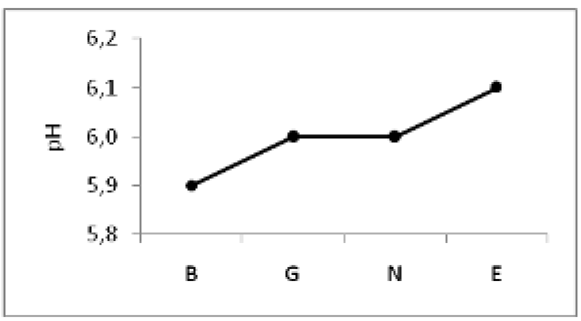


Figure 7. Soil reaction (pH)

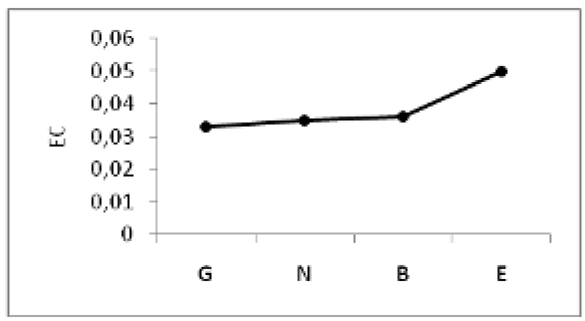


Figure 8. Soil EC

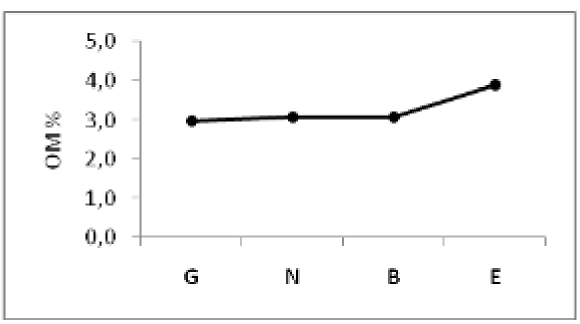


Figure 9. % OM

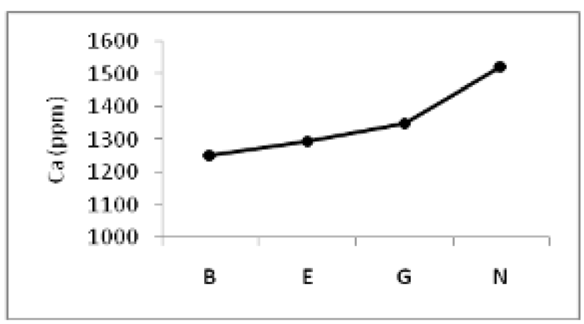


Figure 10. Exchangeable Ca++

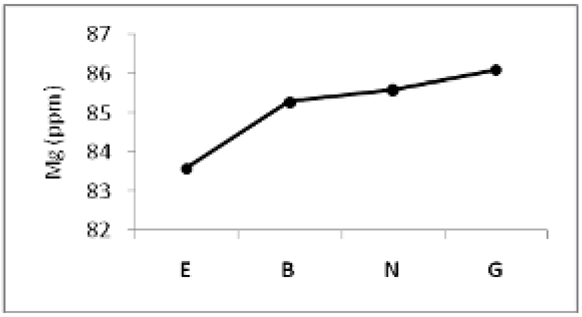

Figure 11. Exchangeable Mg++

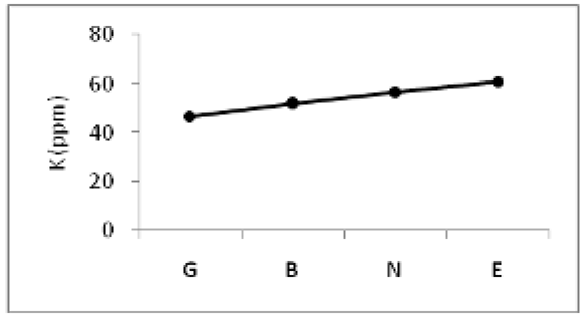

Figure 12. Exchangeable K+

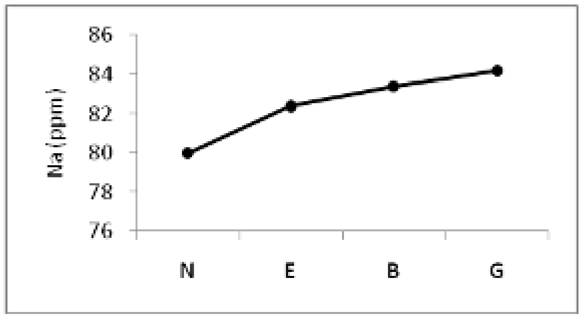

Figure 13. Exchangeable Na+

For this reason, it is not necessary to perform statistical analysis. The evaluation of the results of soil analysis has been made with graphical representation.

***Ecological Assessments***

There are no statistically differences between the soil properties of fir areas. For this reason, the dried *Abies grandis* seedlings were evaluated ecologically in 2008.

In study area, needles and branches of *A. grandis* are red brick color and spread around a pungent odor. Drying has been found in some trees covered partially or the whole tree. With closer observation: a very dense resin secretion which creates some node diameters ranging from 0.3 mm to 1 cm flowing through the tree branches on the trunk and branches has been detected. Intense odor is due to the secretion of resin. Observed in the fall of 2008, tree needles turned to brown color (Gerçek et al., 2011).

Despite deformation and symptoms were identified in the aboveground tree organs, the infection had been estimated for the underground organs. Following the microscopic root examination, transmission elements were wrapped around with mycelia but chlamydospores were not detected. All symptoms are compatible with *Phytophthora* root rot infection after comparing all the data with the literature (Gerçek et al., 2011).

All seeds used in the research area (a total of 24 units, of which 16 alien originating from the USA, France and Canada as well as our native fir species: 4 from *A. nordmanniana*, 2 from *A. bornmuelleriana* and 2 from *A. equi-trojani*), with known origins, have been provided in 1988. Information on species and origins of fir planting areas with opened soil profile is shown in Table 1. Despite the fact that elevation data on origins 20, 23, and 24 of *A. grandis* could not be obtained, they have been used in the experiment.

Table 1. Provenances of *A. grandis* and other *Abies* species (Gerçek et al., 2011)

| **Number** | **Origin Number** | **Origin of Seeds** | **Elevation (m)** |
|---|---|---|---|
| 1 | 1 | *A. grandis*, 2636/60 OL, Clearwater,Idaho, Sears Creaek,9900107, 05 | 760 |
| 2 | 3 | *A. grandis*, 2625/38, Zone 631, 9900107, 02 | 900-1,050 |
| 3 | 4 | *A. grandis*, 2628/40, Zone 422, 9900107, 6 | 300-450 |
| 4 | 5 | *A. grandis,* 2634/64 OL, Albany, Eugene, Oreg./USA, 9900107, 04 | 150 |
| 5 | 6 | *A. grandis*, 2633/62, Willamina/Forest Grove, 9900107, 07 | 150-300 |
| 6 | 8 | *A. grandis*, 2618/50, Zone 202, 9900107- Pos. 1 | 150 |
| 7 | 9 | *A. grandis*, 2626/42, Zone 652, 9900107, 03 | 450-600 |
| 8 | 10 | *A. grandis,* Creuse Correze, Sapin de Vancouver,45025, Vilmorin, F. | 600-700 |
| 9 | 14 | *A. nordmanniana*, Artvin- Meydancık | 1,950 |
| 10 | 15 | *A. nordmanniana*, Giresun- Şebinkarahisar | 1,900 |
| 11 | 16 | *A. equi-trojani*, Sarıkız-Bayramiç- Çanakkale | 1,200 |
| 12 | 17 | *A. equi-trojani*, Kaklım- Yenice- Çanakkale | 950 |
| 13 | 18 | *A. bornmuelleriana*, Karabük- Zonguldak | 1,500 |
| 14 | 19 | *A. bornmuelleriana*, Köke- Bolu | 1,300 |
| 15 | 21 | *A. nordmanniana*, Sariçdağı- Torul | 1,700 |
| 16 | 23 | *A. grandis,* Hokmadinie, France | - |
| 17 | 24 | *A. grandis,* Cokrese, France | - |

***Site Properties of Abies grandis***

*Climate*

The elevation of natural distribution areas can be up to 1,800 m above sea level (Silvics Manual, 2004). However, it shows the best development in areas close to the sea level. The elevation of *A.grandis* seeds used in the study area varies from 150 m to 1,050 m asl (Table 1). Moreover, Macka-Yenikoy firs planting area is 1,100 m elevation. Seeds of native fir species vary between 950 and 1,950 m elevation.

In northern Idaho, grand fir does well on level fields and on north and east slopes if rainfall exceeds 25 inches annually and weeds are controlled. Growers generally avoid south and west-facing slopes in this area (PNW, 1993**)**. While *Phytophthora* root rot does not usually cause severe damage in undisturbed vegetation in areas where annual rainfall is less than 600 mm, it can cause severe epidemics in areas with higher rainfall (deh.gov.au).

The hot summers and high rainfall of research area increases the air moisture. On the other hand, the research area is under the influence of the Black Sea, and the elevation is more than 1,100 m so it has often rain and fog. The moist air masses come from the north-west direction and the effect of the Black Sea coast leads to orographical rainfalls in Macka-Yenikoy area (Altun, 1995). Therefore, the meteorological data obtained from the nearest meteorological station of Meryemana were used for the research.

Meryemana weather station was closed in the 1990s. For this reason, the climate of research area was determined according to the method of C.W. Thornthwaite using data between the years 1961-1990 of the Meryemana weather station (Thornthwaite and Hare, 1955; DMİGM).

Table 2., Water balance for research area according to the Thornthwaite method

| Climate index | MONTHS | | | | | | | | | | | | Vegetation Period | | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Vegetation Period | | | | | | | | | | |
| | I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII | In | Out | |
| Temperature $^{o}C$ | 1.5 | 2.8 | 4.1 | 8.7 | 11.7 | 14.1 | 15.8 | 15.9 | 13.7 | 10.3 | 6.8 | 3.5 | | | 9.1 |
| PET | 5.9 | 11.2 | 20.4 | 47.7 | 72.3 | 88.6 | 100.2 | 94.6 | 71.1 | 49.0 | 27.7 | 13.6 | 475.8 | 126.4 | 602.2 |
| Precipitation (mm) | 45.0 | 47.0 | 51.0 | 103.0 | 125.0 | 130.0 | 92.0 | 91.0 | 68.0 | 81.0 | 56.0 | 53.0 | 587.0 | 355.0 | 942.0 |
| Storage Diff. | - | - | - | - | - | - | -8.2 | -3.6 | -3.1 | 14.8 | - | - | | | |
| Storage (AWC) | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 24.3 | 20.7 | 17.7 | 32.5 | 32.5 | 32.5 | | | 32.5 |
| Actual ET | 5.9 | 11.2 | 20.4 | 47.7 | 72.3 | 88.6 | 100.2 | 94.6 | 71.1 | 49.0 | 27.7 | 13.6 | 475.8 | 126.4 | 602.2 |
| Water Deficiency | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0.0 |
| Surplus water | 39.1 | 35.8 | 30.6 | 55.3 | 52.7 | 41.4 | - | - | - | 17.1 | 28.3 | 39.4 | 111.2 | 228.6 | 339.8 |
| Runoff | 34.4 | 35.1 | 32.8 | 44.1 | 48.4 | 44.9 | 22.5 | - | - | 11.4 | 19.8 | 29.6 | | | 339.8 |

Storage (AWC) : Average AWC of soils : 32.5 mm

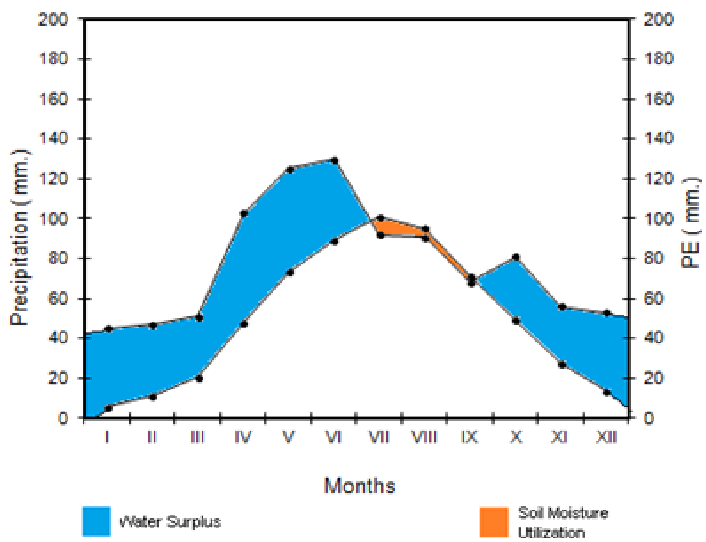


Figure 14. The water balance of the research area

According to the method of Thornthwaite, the climate of research area is moist, mezo-thermal (mild temperature), there is no shortage of water or it is low meaning oceanic (sea) climate type. In the research area, the total annual rainfall is 942 mm. 587 mm rainfall is falling down in the vegetation season. This is about 62% of the total annual rainfall. Most of the precipitation falls during the winter time in the natural range of fir. Generally, precipitation is about 15–25% of total annual precipitation in the vegetation period (Silvics Manual, 2004).

Consequently, the amount of rainfall during the growth period is higher in the study area than in the natural range. The average temperature of the study area is between 1.5 and 15.9 $^{o}C$. Furthermore, the average temperature ranges between 10.3 and 15.9 °C in the growing season.

Once the *Phytophthora* has spread through the root system of a plant, it releases zoospores (asexual spores) into the surrounding soil, if the conditions are warm and moist. The spores easily spread through storm water and drainage water. During drought or when temperatures are cooler, *Phytophthora cinnamomi* produces two different types of spores - chlamydospores and oospores — which can survive for long periods of time in soil or dead plant material. When conditions become more favorable for the spores, they will germinate and infect new plants (deh.gov.au). In the research area, the precipitation is 587 mm (62% of total annual rainfall) in the growing season. This low precipitation is thought to be effective of break out the disaster.

Figure 15. Dead *A. grandis* individuals

This disease should be monitored during the growing season when rainfall is extreme and in dry periods following heavy rainfall, as infected plants with compromised root systems will show signs of stress. Infected roots have a cinnamon color and lack white growing tips (Bowers et al., 2011). The average precipitation is higher before June than after June for the research area (Figure 16).

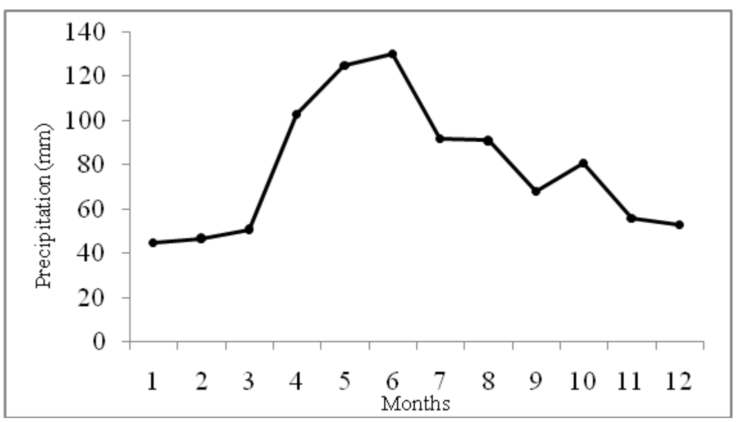


Figure 16. The Monthly average rainfall (1961-1990)

This disaster has first seen in 2008. After this year, the rainfall decreased around 150 mm and the climate became more arid than in the previous years in province Trabzon (Figure 17).


Figure 17. The Annual rainfall in Trabzon between 1970 and 2011 (DMİGM)

As can be seen from the chart, the annual rainfall was more than 800 mm before 2008 but it had decreased to 674 mm in 2008.

*Soils and Topography*

*Abies grandis* seems to grow equally well on soils derived from a variety of parent materials, including sandstone, weathered lava (rock), or granite and gneiss. These kinds of soils have some properties as less water holding capacity, good permeability and drainage. It grows most abundantly on deep, rich alluvial soils along streams and valley bottoms and on moist soils provided with seepage.

The parent material of the research area is granite. The soil:sand ratio was determined between 69.9% and 87.6% (mean sand ratio 81.2%) in plantation areas of *A. grandis*. Soil texture is sandy loam and loamy sand. But, when soil samples were taken from the study area, it was observed that the soil is very tight. However, the soil structure was expected not to be compact, with a good air capacity. When soil profiles were dug up in July, this situation can be explained very easily. The soil is too dry that has led to a hard and compact soil. On the other hand, the soils have quite a lot of stone that provides aggregation and increases the air capacity of soils. However, it decreases organic matter ratio of soils (mean OM 3%). In fact, except for the topsoil (Ah), the average amount of organic matter was found to be 1.7% for subsoil horizons (AB, Bt, and BC) for various types of native fir and *Abies grandis*. Such adverse conditions help the development of *Phytophthora* root rot disease. A question may come to mind as why this disease did not develop in the first years of planting? New plants were infected by *Phytophtora* hosted in their own body. This causes the drying and deaths of new plantations (Smiley et al., 1999). *Phytophtora* root rot disease was not observed in the nursery. In addition, it should be noted that roots cannot reach deeper horizons in the early years. There are no problems due to air capacity and nutrition. When the plant roots go through deeper, tighter, and compacted subsoil, this combined with the deficient nutrition elements can easily increase the stress of plants. The disaster can be spread in later years.

Major human activities that may spread *Phytophthora* root rot include road building, timber harvesting, mine exploration, nursery trade and bushwalking (deh.gov.au). In the research area, a 8-10-m wide forest road was built between 2007 and 2009. The maximum drying of *A. grandis* was seen in the same year. The forest road could have increased the disaster (Figure 18).

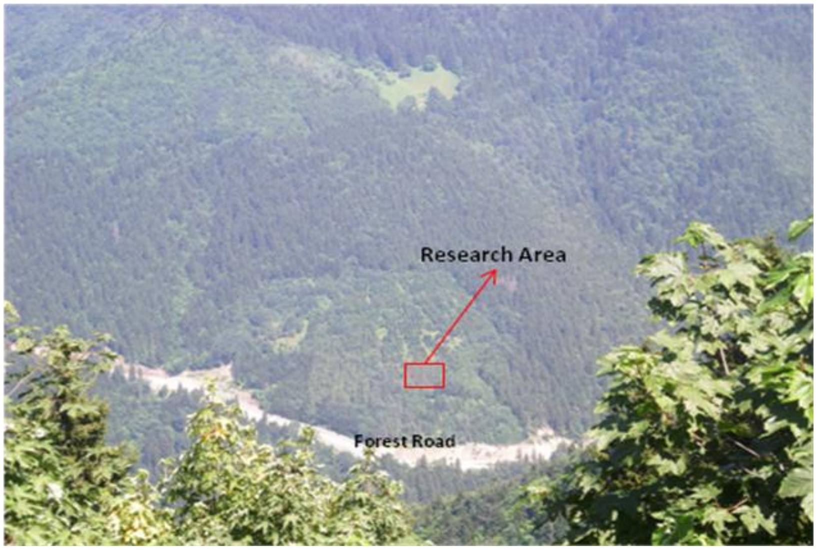

Figure 18. New forest road built in the research area

*P. cinnamomi* fungus grows through the root system (and sometimes the stem) of a plant, destroying it and preventing the plant from absorbing water and nutrients. Infected plants usually die from lack of water and nutrients, although some can survive the disease. Trees are generally dry and die because of the lack of water and nutrients. A similar situation exists in the research area. During the field study, firstly the lower branches of the trees get dry due to fungal infection, then the upper branches were drying.

## Conclusion

In a similar study carried out in the USA, the *Phytophthora* root rot killed many *A. grandis*. The study notices that there is no satisfactory solution for fighting against disease. The only successful way was the use of species originating from Turkey (Chastagner, 2010). *Phytophthora* can affect not only fir but also some other species. It had caused great losses for fir in the USA (Benson, 2000; Chastagner, 2000).

In this study, some soil properties of different fir plantations were determined and the results were more or less the same. In addition, the *Phytophthora* root rot disease on the grand fir, which is not native, was examined in terms of ecological features. Thus, it is hypothesized that the blooming of *Phytophthora* root rot may be connected with site index and seed features from different origins.

Provenance trials are long-term and risky studies. We need experiments at tree species level. Thus, the used tree species should fulfill the site requirements and need to be healthy and resistant against local factors such as fungi, insects, etc. This will save time, manpower and money.

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