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## Determination of the Effect of Drought Stress on the Seed Germination in Some Plant Species

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### Abstract

Especially the use of drought-resistant plant species reduces maintenance and irrigation costs, and plants increase the retention and success to continue its life in arid landscape. In this study, some plant species used have been studied to determine their tolerance to drought stress in gardens and parks in Kastamonu. For this purpose, germination trials have been conducted -2, -4, -6, and -8 Bar water stress. Landscaping applications commonly used some species such as *Cupressus sempervirens* L., *Ailanthus altissima* (Mill.) Swingle, *Pyracantha coccinea* Roem, *Thuja orientalis*, *Pinus sylvestris* L., *Sophora japonica*, *Cedrus libani* A. Rich., *Acer pseudoplatanus* L., *Pinus brutia* Ten., and *Pinus nigra* Arnold. ssp. *pallasiana* (Lamb.) Holmboe. Their seeds were evaluated different levels of water stress in the germination percentage. PEG 6000 solution was used in the formulation of water stress. The seeds were exposed to constant temperature of 25°C for a period of 35 days at germination cabinet. As a result, this experiment calculated germination in different water stress levels what percentage has fallen, so the least affected by increased water stress was studied to determine the species. Also results showed increased water stress and reduce the percentage of germination in all species. The highest level of water stress -8 Bar, which was also obtained stress level proportional germination values *Pinus nigra* Arnold. ssp. *pallasiana* (Lamb.) Holmboe (64.8%) and *Pinus brutia* Ten. (46.5%).

**Keywords:** polyethylene glycol, germination percentage, PEG, drought stress, plants, seed

## 1. Introduction

Rapidly increasing population in the world, limitless industrialization process, poor urbanization activities, regional wars, pesticides which are used to increase crops, and unconscious use of fertilization and chemicals such as detergents have started to contaminate the environment, which results in damage for living beings as a result of extensive air, water, and soil pollutions. The use of fossil fuels has been on the increase since the industrial revolution. With the addition of rapid deforestation, these factors have yielded a serious situation nearly beyond prevention [1, 2]. Throughout history, the amount of CO<sub>2</sub> concentration in the air did not exceed 320 ppm. However, current concentration is above 385 ppm and it keeps on increasing [3]. This situation has led to a concern and long debates in relation to the effects of global warming [1].

It is inevitable that climate change manifests its effects all around the world due to global warming. The increase in temperature and changing precipitation are expected to increase water problems, which are already felt in certain regions. It is estimated that there will be changes in the frequency and severity of droughts and floods, which may lead to serious loss of lives and properties throughout Europe [4].

Drought is a phenomenon resulting from certain variables such as precipitation, temperature, humidity, evaporation, and transpiration. Basically, drought refers to water deficit resulting from below-average emergence of natural water assets, which are used by various systems, in some regions for a particular time period [5]. When drought is mentioned, precipitation and water deficit come to one's mind first. It can be defined as having higher levels of water loss due to evaporation than the water supplied by precipitation in a certain region [6].

Twenty-eight percentage of usable territories on the world are affected by drought [5]. Due to greenhouse gas accumulation in the atmosphere, a climate change will take place in the upcoming years, which is likely to leave us with arid and sub-arid territories. These, in turn, will add to the water problems in urban areas, and there will be an increase in the demand for water for both agricultural and drinking purposes. Hence, in addition to the expansion of arid and sub-arid territories, there will be an increase in summer drought period and severity accompanied by desertification, salinization, and erosion processes [7]. Undoubtedly, one of the most vulnerable territories to drought is green and outdoor spaces in cities.

The drought increasing day by day and the thirstiness as a result of this make their destructive effects felt in green fields as it is in all parts of our lives. Almost all of the green fields constituted with the approach of classical landscaping design, which requires great amounts of water especially in our metropolitan cities, were damaged greatly in a few months in which water usage was restricted [8–11].

While the purpose was healing the environment-ambience quality in the applications of landscaping architecture and repairing the damaged environment conditions in previous years, the wise usage of water for the worries depending on the climate change and herbal applications resistant to drought have come to the fore recently [12–16]. The plants used in landscaping fields are desired to be resistant to drought, and this becomes the most important criterion, which affects the choice of plants in some regions even [17–21]. It is of great impor-

tance for the wise usage of water that species and origins resistant to drought are identified first and these kinds of species and origins is used for the landscaping designs.

Different methods are used for identifying the resistances of species against drought. One of these methods is to conduct PEG applications on the seeds in different concentrations. PEG applications have been used in many species for identifying their resistance to drought, and it has given very successful results [22, 23].

In this study, it was aimed at identifying the water stress tolerance for some plants, which are used in landscaping works. Trials have been conducted on nine species chosen for this purpose, and the water stress reactions of the species in different levels were determined.

## 2. Material and methods

In the study, a total of 10 species have been used which are *Cupressus sempervirens* L., *Ailanthus altissima* (Mill.) Swingle, *Pyracantha coccinea* Roem, *Thuja orientalis*, *Pinus sylvestris* L., *Sophora japonica*, *Cedrus libani* A. Rich., *Acer pseudoplatanus* L., *Pinus brutia* Ten., and *Pinus nigra* Arnold. ssp. *pallasiana* (Lamb.) Holmboe and which are frequently used in landscaping applications. The fruits and cones of above-mentioned species were gathered in October in the parks and gardens in Kastamonu, and seeds were attained after cleaning the cones and fruit fleshes. The seeds are except the ones of *Pinus nigra* and *Pinus brutia* which have been subject to stratification for a period of 8 weeks, and then, germination trials have been conducted in -2, -4, -6, and -8 Bar water stress, and in addition to these, control group has been used. The water potential of the germination substrates (0, -2, -4, -6 and -8 Bar) was determined using PEG-6000 solution and prepared as described by Michel and Kaufman [24, 25].

Germination tests were performed in 11-cm-diameter glass petri dishes on two layers of filter paper saturated with water solutions. Fifty pieces of seeds have been placed in each petri dish in a way that the seeds will not have a touch with each other, and the study has been conducted with 4 repetitions. In this way, a total of 9000 seeds consisting of 50 pieces of seeds, 4 repetitions, 5 applications, and 9 species have been used in the study.

The seeds have been subject to germination with the period of 35 days in  $25 \pm 1.0^\circ\text{C}$  constant-temperature in germination cabinet, and the filter papers have been renewed in each 3 days.

At the end of 35-day period, non-germinated seeds were cut and checked. Unfilled seeds were excluded from the evaluation, and germination percentage (GP) was calculated by proportioning the number of germinated seeds to healthy ones.

Germination percentage results were subjected to factorial variance analysis. The differences between species and the degrees of significance of such differences were revealed. In order to eliminate the misleading effects of the germination capability differences between the species included in the experiment in checking operations (0 Bar) on the analysis results, the values of these operations were proportioned to 100, and cumulative germination percentages (CGP) were calculated. Thus, the differences between the species were tried to be demonstrated more rationally. The data to be subjected to variance analysis were entered as they were proportioned to 100.

SPSS 17.0 statistics program was used to evaluate the data obtained through experiments. When statistically significant differences ( $P < 0.05$ ) were found through analyses of variance, Duncan's test was performed to form homogeneous groups. Duncan's test showed that the operations were in the same or different categories in terms of the measured characteristics [26]. Multivariate analysis of variance (ANOVA) employs two or more factors and attempts to reveal significant differences between the mean scores of many groups according to these factors. In other words, multivariate analysis of variance is used to test the difference between the mean scores of k-dependent groups [27]. In order to interpret study results with more ease, Excel program was used to create graphs.

### 3. Findings

**Table 1** shows the end-of-study values regarding the change in the germination percentages of species under water stress conditions.

Species	Water stress conditions				
	Control	-2 Bar	-4 Bar	-6 Bar	-8 Bar
<i>Pinus brutia</i>	45,2	40,0	36,3	24,5	21,0
<i>Pinus nigra</i>	81,9	71,0	65,5	62,3	53,1
<i>Cupressus sempervirens</i>	62,6	54,3	45,8	36,7	19,7
<i>Ailanthus altissima</i>	60,2	50,0	12,2	1,2	0,0
<i>Pyracantha coccinea</i>	51,2	32,5	26,6	10,2	5,6
<i>Thuja orientalis</i>	70,2	65,3	48,0	35,2	15,6
<i>Pinus sylvestris</i>	72,6	66,7	41,3	28,6	12,3
<i>Sophora japonica</i>	55,5	45,0	30,5	7,1	1,2
<i>Cedrus libani</i>	32,3	30,7	18,0	7,2	2,4
<i>Acer pseudoplatanus</i>	38,7	28,6	20,2	5,1	0,0

**Table 1.** The change of germination percentages under various water stress conditions.

Considering the values in **Table 1**, the highest germination was observed in *Pinus nigra* with a rate of 81.9% in the control group. It was followed by *Pinus sylvestris* with a rate of 72.6% and *Thuja orientalis* with a rate of 70.2%, respectively. *Cupressus sempervirens* and *Ailanthus altissima* yielded germination higher than 60% in the control group. *Cupressus sempervirens*' percentage was 62.6%, while the rate of *Ailanthus altissima* was 60.2%. Germination percentage of *Sophora japonica* was 55.5%, while the rate of *Pyracantha coccinea* was 51.2%. Germination percentages of *Pinus brutia*, *Acer pseudoplatanus*, and *Cedrus libani* remained under 50% in the control groups. *Pinus brutia* yielded a germination percentage of 45.2%, and *Acer pseudoplatanus*' rate was 38.7%. The lowest rate belonged to *Cedrus libani* with 32.3%.

*Pinus nigra*, having the highest germination rate in the control group with a rate of 81.9%, yielded a lower rate, 71%, under -2 Bar water stress level. The rate reduced to 65.5% under -4 Bar, 62.3% under -6 Bar, and 53.1% under -8 Bar. The values in the table show that the highest germination rates belonged to *Pinus nigra* at all experiment levels.

*Pinus sylvestris* had the highest germination rate following *Pinus nigra* in the control group with a rate of 72.6%. This rate reduced to 66.7% under -2 Bar, 41.3% under -4 Bar, 28.6% under -6 Bar, and 12.3% under -8 Bar. Though *Pinus sylvestris* seeds had the second highest germination rate in the control group, it rapidly reduced depending on water stress levels. It had the second highest value under -2 Bar water stress level; however, it ranked the 4th under -4 and -6 Bar water stress levels, while it became the fifth under -8 Bar water stress level. It is possible to say that *Pinus sylvestris* is more vulnerable than other seeds under examination against the increasing water stress conditions.

*Thuja orientalis* seeds had a percentage of 70.2% germination in the control group; however, this rate reduced in parallel with the increasing water stress and became 65.3% under -2 Bar, 48% under -4 Bar, 35.2% under -6 Bar, and 15.6% under -8 Bar.

*Cupressus sempervirens* also experienced a decrease in germination percentage due to increasing water stress. Its germination rate was 62.6% in the control group, but it reduced to 54.3% under -2 Bar, 45.8% under -4 Bar, 36.7% under -6 Bar, and 19.7% under -8 Bar, which was the highest water stress level. *Cupressus sempervirens* ranked 4th in terms of germination percentage in the control group, but it became the 3rd under -8 Bar.

*Ailanthus altissima* ranked 5th in the control group in terms of germination percentage. However, *Ailanthus altissima* experienced a rapid fall in germination percentage particularly after -4 Bar water stress level. The germination percentage which was 50% under -2 Bar reduced to 12.2% under -4 Bar and displayed 1.2% of germination percentage under -6 Bar. The seed did not germinate under -8 Bar. Accordingly, *Ailanthus altissima* had the lowest germination percentage under -4 and -6 Bar water stress levels.

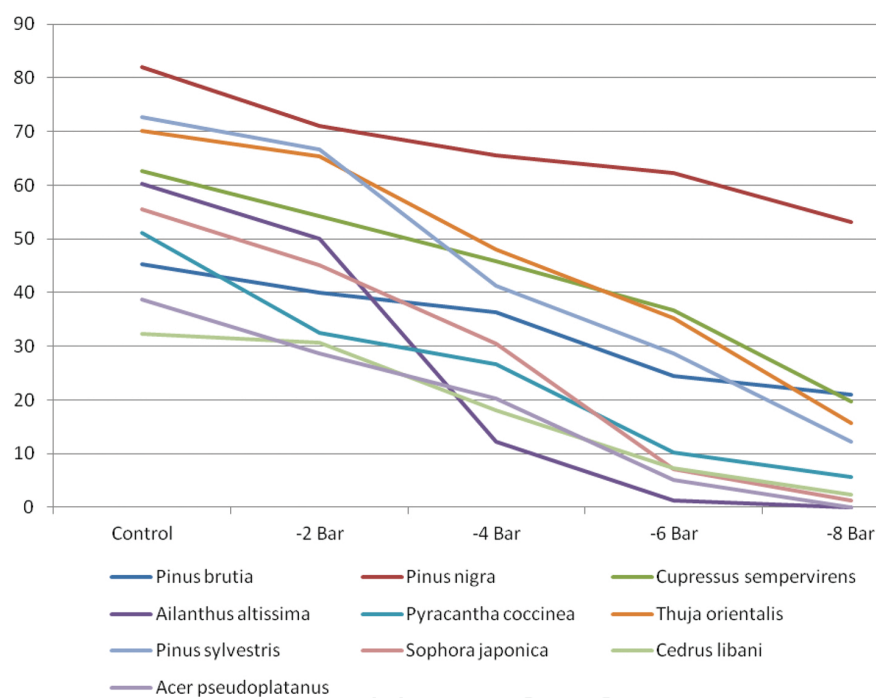
*Sophora japonica* showed a germination percentage of 55.5% in the control group. This rate reduced to 45% under -2 Bar, 30.5% under -4 Bar, 7.1% under -6 Bar, and 1.2% under -8 Bar water stress levels.

Another species experiencing a rapid fall in germination percentage due to increasing water stress level was *Pyracantha coccinea*. Its germination percentage in the control group was 51.2%. It first reduced to 32.5% and then to 26.6% due to increasing water stress and reached 10.2% under -6 Bar and 5.6% under -8 Bar.

Though its germination percentage was below 50% in the control group, *Pinus brutia* was one of the species experiencing one of the lowest fall in germination percentage due to increase in water stress. Germination percentage of *Pinus brutia* in the control group was 45.2%, while this rate reduced to 40% under -2 Bar, 36.3% under -4 Bar, and 24.5% under -6 Bar. Having one of the three lowest germination percentages in the control group, *Pinus brutia* had a germination rate of 21% under -8 Bar water stress level, which was the second highest value.

*Acer pseudoplatanus* was one the species with lower than 50% germination percentage in the control group. Its germination percentage rapidly fell due to increasing water stress. While its percentage in the control group was 38.7%, it reduced to 28.6% under -2 Bar, 20.2% under -4 Bar, and 5.1% under -6 Bar. *Acer pseudoplatanus* was one of the two species which did not germinate under -8 Bar water stress level.

*Cedrus libani* had the lowest germination percentage in the control group (32.3%). While its germination percentage was 30.7% under -2 Bar, this value reduced to 18% under -4 Bar, 7.2% under -6 Bar, and 2.4% under -8 Bar. According to these rates, *Cedrus libani* had the lowest germination percentage in the control group; however, its germination percentage under -8 Bar was the 4th lowest germination percentage. The **Figure 1** shows the change in the germination percentages observed in the species due to increasing water stress levels.



**Figure 1.** The changes in the germination percentages of the species due to increasing water stress levels.

The purpose of this study was to reveal the changes in the germination percentages of species depending on the water stress and to determine which species are least influenced by increasing water stress. However, not only the germination percentages of species but also to what extent they experience a fall in germination depending on the increasing water stress are of importance in order to make an evaluation in this matter. As a matter of fact, the germination percentage of a species may be low due to its biology or environmental conditions. For instance, Khera and Singh [28] studied various origins in their studies. They reported that *Dalbergia sissoo*'s germination percentage varies between 93 and 21% in different origins. Therefore, there is a need to reveal to what extent germination percentage reduces depending on increasing water stress, which is expected to provide a sounder evaluation of tolerance towards water stress among species and facilitate making comparison between them. Hence, the species in

the control group were accepted to have a germination percentage of 100%. The rates of reduction depending on the increasing water stress, in other words, cumulative percentages (CGP) are given in **Table 2**.

Species	Water stress conditions				
	Control	-2 Bar	-4 Bar	-6 Bar	-8 Bar
<i>Pinus brutia</i>	100	88,5	80,3	54,2	46,5
<i>Pinus nigra</i>	100	86,7	80	76,1	64,8
<i>Cupressus sempervirens</i>	100	86,7	73,2	58,6	31,5
<i>Ailanthus altissima</i>	100	83,1	20,3	2	0
<i>Pyracantha coccinea</i>	100	63,5	52	19,9	10,9
<i>Thuja orientalis</i>	100	93,0	68,4	50,1	22,2
<i>Pinus sylvestris</i>	100	91,9	56,9	39,4	16,9
<i>Sophora japonica</i>	100	81,1	55	12,8	2,2
<i>Cedrus libani</i>	100	95,0	55,7	22,3	7,4
<i>Acer pseudoplatanus</i>	100	73,9	52,2	13,2	0

**Table 2.** The change of the germination percentage compared with the control group.

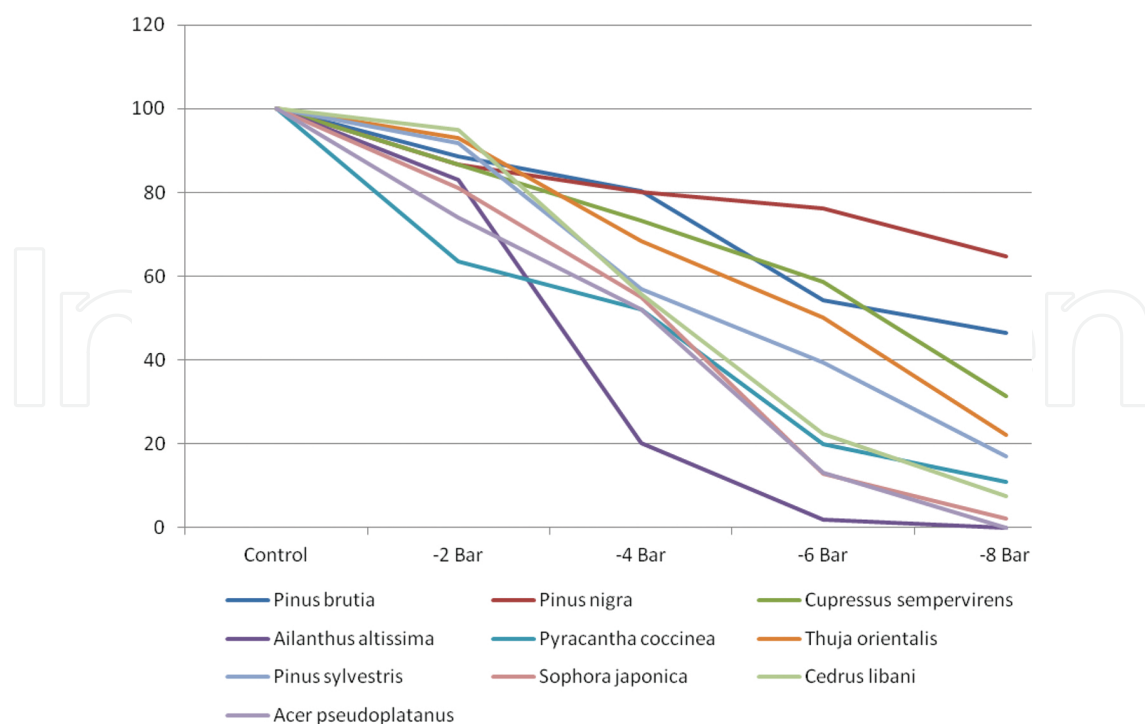
The values in the table show that the germination percentage reduced in all of the species due to increasing water stress. The minimum change took place in *Cedrus libani*, *Thuja orientalis*, and *Pinus sylvestris* under -2 Bar water stress level. Germination percentage under -2 Bar water stress level in *Cedrus libani* corresponded to 95% of the one in the control group, while germination percentage rate corresponded to 93 and 91.9% of the values in the control group for *Thuja orientalis* and *Pinus sylvestris*, respectively, under the same conditions. The changes in the germination percentage under -2 Bar water stress level compared with the control group are as follows: *Pinus brutia* 88.5%, *Cupressus sempervirens* and *Pinus nigra* 86.7%, *Ailanthus altissima* 83.1%, and *Sophora japonica* 81.1%. For these species, germination percentage under -2 Bar water stress level was higher than 80% of the control group. This rate was 73.9% for *Acer pseudoplatanus* and 63.5% for *Pyracantha coccinea*.

However, most of the species experienced great falls in their germination percentages starting from -4 Bar water stress level. The minimum change under -2 Bar water stress level was observed in *Cedrus libani*, *Thuja orientalis*, and *Pinus sylvestris*. Germination percentage of *Cedrus libani* fell to 55.7% of the control group under -4 Bar water stress level. These rates were 68.4 and 56.9% for *Thuja orientalis* and *Pinus sylvestris*, respectively. The species which were least affected by water stress at this level were *Pinus brutia*, *Pinus nigra*, and *Cupressus sempervirens*. The changes in the germination percentages of the species under -4 Bar water stress level compared with the control group percentages were 80.3% for *Pinus brutia*, 80% for *Pinus nigra*, and 73.2% for *Cupressus sempervirens*. The species which experienced the highest change under -4 Bar water stress compared with the control group are as follows: *Sophora japonica* with

55%, *Acer pseudoplatanus* with 52.2%, *Pyracantha coccinea* with 52%, and *Ailanthus altissima* with 20.3%.

Not a big difference occurred in these results under -6 Bar water stress level. The species had similar ranks to the ranks under -4 Bar water stress level. Once again, the highest values in the comparison of germination percentages to the control group percentages were observed in *Pinus nigra* (76.1%), *Cupressus sempervirens* (58.6%), *Pinus brutia* (54.2%), and *Thuja orientalis* (50.1%). The rate was below 50% in all of the other species. Under -6 Bar water stress level, the rate was 39.4% for *Pinus sylvestris* and 22.3% for *Cedrus libani*, while other species went below 20%. *Pyracantha coccinea* had a rate of 19.9%; *Acer pseudoplatanus* had a rate of 13.2%; and *Sophora japonica* had a rate of 12.8%. The highest proportional fall under -6 Bar water stress level was observed in *Ailanthus altissima*, and germination percentage could only reach 2% compared with the control group.

Under -8 Bar water stress, which is the highest water stress level, *Ailanthus altissima* and *Acer pseudoplatanus* did not germinate. Under these conditions, the changes in germination percentages compared with the control group are as follows 2.2% for *Sophora japonica*, 7.4% for *Cedrus libani*, 10.9% for *Pyracantha coccinea*, 16.9% for *Pinus sylvestris*, 22.2% for *Thuja orientalis*, and 31.5% for *Cupressus sempervirens*. Under the highest water stress level, which is -8 Bar, the highest germination percentages were observed in *Pinus nigra* (64.8%) and *Pinus brutia* (46.5%). The graph showing the reduction rates in the germination percentages of species due to increasing water stress is given in **Figure 2**.



**Figure 2.** The reduction rates in the germination percentages of the species due to increasing water stress.

## 4. Discussion and conclusion

In today's modern life, it has been accepted that the presence of plants in cities is an indicator of their quality and inhabitability [29]. Plants reduce the air pollution and noise in their surrounding areas [30–35]. They also increase aesthetic value [36], have a good influence on psychology [37, 38], save energy [39, 40], prevent erosion [41], and decrease the speed of winds. Since they penetrate into soil with their roots, they prevent transportation of soil by precipitation and streams. They also protect wild life and hunting resources. Green and open areas surrounded by plants are important activity areas for both adults and children [42, 43]. In addition, indoor plants increase the productivity of people working in these places [44]. They relieve people psychologically and reduce stress and negative feelings [45–47].

Due to these functions of plants, a lot of issues such as plants' spread areas, [48–52], protection [53–59], production [60–64], tolerance against stress factors [65, 66], use in various areas [67–69], genetic variability [70–72], relationships with environment and other living beings [73–79], and raising awareness about them, as well as their legal aspects [80–82] have become main study areas. Therefore, a lot of studies have been conducted on these subjects.

In addition to these functions of plants, their contributions to the aesthetic aspect of the places they are in should be dwelt on under a separate title. Landscape practices for which various species and varieties are used have gained a distinct importance in the modern world. The desire to use diverse species has led to an intense use of plants outside their natural spread areas. The species which are not part of the natural flora of the region draw more attention when they are used for landscape practices and increase landscape quality. However, these practices also cause such plants to deal with ecological and climatic conditions which they are not used to. Therefore, maintenance and watering costs of such species are higher. However, global warming makes it necessary to have a reasonable and thrifty attitude in the use of water.

It is inevitable that climate change manifests its effects all around the world due to global warming. It is expected that the increase in temperature and changing precipitation will increase water problems. It is expected that there will be changes in the frequency and severity of droughts and floods throughout Europe, which may result in loss of lives and property [83]. Therefore, there is a need to determine species which are tolerant to water stress and use such species in both landscaping and forestation practices.

This study is an attempt to reveal the tolerances of certain plant species, which are commonly used for landscape practices, against drought stress. The results of the study indicate that increasing water stress reduced the germination percentage in all the species examined. Many previous studies have reported similar results for many other species so far. Sevik and Cetin [84] conducted a study to determine species' tolerances towards water stress and reported that the species which were most affected by water stress were *Sophora japonica*, *Ailanthus altissima*, and *Cupressus arizonica*, whereas the species which were most tolerant against water stress were *Pinus nigra*, *Cupressus sempervirens*, and *Pinus brutia*.

Falusi et al. [85] analyzed the influence of increasing water stress on the germination percentages of four origins of *Pinus halepensis* and revealed that there were great differences between

germination percentages of the origins. The origin, which was least affected by water stress, had a germination percentage of 94.10% in the control group, while this rate was 63.64% under -8 Bar water stress level. The origin, which was most affected by water stress, had a germination percentage of 90.1% in the control group, while this rate reduced to 11.8% under -8 Bar water stress level.

Tilki and Dirik [86] performed experiments on various origins of *Pinus brutia*. They reported that Silifke-origin seeds had a germination percentage of 78.7% in the control group. This rate reduced to 44.8% under -0.4 MPa level. As for the Cehennemdere-origin seeds, they showed a germination percentage of 33.2% in the control group while this rate reduced to 4% under -0.4 MPa level. In this study, germination percentage of *Pinus brutia* was 45.2% in the control group while this rate was 40% under -2 Bar, 36.3% under -4 Bar, and 24.5% under -6 Bar water stress levels.

Boydak et al. [87] conducted a study with *Pinus brutia* seeds of 6 different origins. The germination percentage was observed to be 84.3% in the control group. This rate changed to be 88.7% under -2 Bar. It dramatically reduced after -4 Bar water stress level. Under -4 Bar water stress level, the percentage was 80.6%, whereas it was 55.5% under -6 Bar water stress level. The germination percentage was 25.2% under -5 Bar water stress level and was 29.8% under -8 Bar water stress level, according to what they report.

Ahmadloo et al. [88] conducted a study on *Cupressus sempervirens* and *Cupressus arizonica* and created -2, -4, -6 and -8 Bar water stress levels. They analyzed germination percentages. It was seen that *Cupressus arizonica* yielded 18.75% germination percentage in the control group. This rate reduced to 14.5% under -2 Bar water stress level. It was found to be 10.5% under -4 Bar, 9.25% under -6 Bar, and 7% under -8 Bar water stress levels. Germination percentage of *Cupressus sempervirens* in the control group was 27.75%. Under -2 Bar water stress level, this rate reduced to 18.5%, 18% under -4 Bar, 11.75% under -6 Bar, and 7.5% under -8 Bar water stress levels. These results generally support the results of this study. In this study, germination percentage of *Cupressus sempervirens* L. was 62.6% in the control group. This rate reduced to 54.3% under -2 Bar, 45.8% under -4 Bar, 36.7% under -6 Bar, and 19.7% under -8 Bar, which is the highest water stress level. Therefore, it was seen that germination percentage reduced to 31.5% of the control group under -8 Bar water stress level. Ahmadloo et al. [88] reported this number as 27%.

-5, -10, -15, and -20 Bar water stress levels were created in order to reveal the influence of water stress on the germination percentages of *Acacia catechu*, *Acacia nilotica*, *Albizia lebbek*, *Dalbergia sissoo*, and *Tectona grandis*, and the changes in the germination percentages were observed. At the end of the study, it was seen that the germination percentage which was 90% for *Acacia nilotica* in the control group became 90% under -20 Bar water stress level. Other species experienced a significant fall in germination percentages. *Acacia catechu* had a germination percentage of 94% in the control group, while this rate reduced to 60% under -20 Bar water stress level. *Albizia lebbek* had a germination rate of 59% in the control group, while this rate reduced to 35% under -20 Bar water stress level. The germination percentage for *Dalbergia sissoo* was 93% in the control group, while this rate reduced to 53% under -20 Bar water stress

level. The germination percentage of *Tectona grandis* was 22% in the control group, while this rate reduced to 6% under -15 Bar and 0% under -20 Bar water stress levels [28].

Boydak et al. [87] conducted a study with 6 different origins of *Pinus brutia* seeds. The average germination percentage of the seeds was 84.3% in the control group. The rate reduced to 25.2% under -8 Bar water stress level. That study also revealed that origins differed in their tolerances towards water stress. For instance, germination percentage in the 2nd origin was 91% in the control group, and this rate reduced to 40.5% under -8 Bar. In addition, the 5th origin had a germination percentage of 94.5% in the control group, and this rate reduced to 15% under -8 Bar water stress. Proportional values make the results clearer. The 2nd origin's proportional germination percentage was found to be 44.5% under -8 Bar water stress level, while this rate was found to be 15.8% for the 5th origin under the same conditions.

Kaufmann and Eckard [89] stated that water stress at a level of -8 Bar may reduce the germination percentages of *Pinus contorta* and *Picea engelmannii* seeds at a rate of 50%. Djavanshir and Reid [90] evaluated germination percentages in *Pinus ponderosa* and *Pinus elderica*. They concluded that increasing water stress affected the germination percentage; and germination percentage reduced nearly to zero in *Pinus ponderosa* under -8 Bar and in *Pinus elderica* under -12 Bar water stress levels.

Semerçi et al. [5] studied the influence of water stress on various *Pinus nigra* origins. They created -2, -4, and -6 Bar water stress levels. They analyzed the seeds' germination percentages based on the origins. They concluded that germination percentage varied between the origins, and increasing water stress led to a significant reduction in germination percentages. The study included seeds originating in Ballıköy in Tavsanlı. The germination percentage of the seeds in the control group was 98%. This rate reduced to 76% under -2 Bar, 52% under -4 Bar, and 16% under -6 Bar water stress levels. However, the seeds originating in Göksun B. Çamurlu had a germination percentage of 62% in the control group, while this rate was 58% for Andırın Akifiye-origin seeds. The germination was at a rate of 1% under -2 Bar water stress level for these seeds, while no germination took place under -6 Bar water stress level.

The same study also reported that proportional germination percentages largely vary between the origins. For instance, proportional germination percentage in seeds originating in Tavsanlı Ballıköy was 77% under -2 Bar, 53% under -4 Bar, and 17% under -6 Bar water stress levels. Similarly, proportional germination percentage in seeds originating in Mengen Daren was 75% under -2 Bar, 63% under -4 Bar, and 16% under -6 Bar water stress levels. However, the same study revealed that the proportional germination percentage of seeds originating in Göksun B. Çamurlu and Andırın Akifiye was only 2% under -2 Bar water stress level. Topacoglu et al. [91] reported that *Pinus nigra* originating in Ankara Uluhan yielded 95.08% cumulative germination percentage under -8.0 Bar water stress level, while the seed originating in Isparta Tota yielded a cumulative germination percentage of 85.41%.

Buyurukçu [27] compared the tolerance of Anatolian *Pinus nigra* (*Pinus nigra* Arnold. subsp. *pallasiana* (Lamb.) Holmboe) clones from clonal seed garden in Hanönü Günlüburun against the drought. In order to compare the clones against drought during the phase of germination, the seeds were subjected to -2, -4, -6, and -8 Bar water stress levels using PEG 6000 solution.

All in all, it was seen at the end of ANOVA and Duncan's test results that clones had different responses of tolerance against water stress. Germination percentage, which was 48% on average in the control group, reduced to 16% under -2 Bar, 15% under -4 Bar, 2% under -6 Bar, and 0.4% under -8 Bar. However, what is remarkable in this study is the great differences between clones. For instance, the 17th clone had a germination percentage of 29% in the control group, while this rate reduced to 2% under -2 Bar water stress level. The seed did not germinate under the higher water stress levels. Similarly, the 9th clone had a germination percentage of 78% which reduced to 0% under -2 Bar water stress level. However, the 14th clone had a germination percentage of 49%, which reduced to 8% under -6 Bar water stress conditions and 5% under -8 water stress conditions. Taking into account the fact that these clones belong to the same stand of origin and are grown under the same conditions, it is possible to say that genetic structure may be prominent in determining the tolerance towards water stress.

## 5. Recommendations

The plants used for parks and recreational areas consist of a wide variety. Previous studies report that water stress works in which PEG solution is used yield successful results. It is possible to have an idea about the water stress tolerance of alternative species to be used in an area where landscape work will be practiced through a 1-month preliminary work performed in this area. Thus, it will be possible to use species which are tolerant to water stress. However, if researchers conduct such studies and provide the practitioners with ready-to-use information, this will bring a great ease for them. Therefore, such studies should be varied and increased in number.

Due to global warming, drought and scarcity of water make their devastating effects felt in all aspects of our lives including green areas. Therefore, the water should be used reasonably, which makes drought-tolerant plants and their practices crucial. The plants to be used in landscape areas are required to be drought-tolerant. It sometimes functions as a crucial criterion determining plant choice in some areas. In order to use water reasonably, the species and origins which are tolerant to drought should be determined. Using the seeds and saplings of such species and origins in landscape arrangements is of great importance. In this sense, species should be subjected to drought stress under equal conditions and compared. Accordingly, selecting the species which are most tolerant to drought for landscape practices is important.

The fact that species have rather variable tolerance against water stress has been revealed in previous studies. Even the regions and territories where water scarcity has not influenced the growth of tree species much yet may experience problems due to drought stress in near future. Hence, it is even important to compare the drought stress tolerances of populations in the same climatic regions. Therefore, the situation of local origins is not guarantees, which makes the identification of relatively tolerant species important as part of decision-making on future forestation strategies.

Therefore, it is very important to perform experiments on the origins of the species that have been proved to be drought-tolerant in order to determine their most drought-tolerant origins

through studies focusing on extreme fields and to produce seeds from them. Hence, these seeds can be used for landscape practices, which may yield great benefits in future. The use of such species, particularly in areas where maintenance will be performed after mining activities, areas prone to erosion, areas involving forestation on side slopes and traffic islands, urban forests in arid areas, and so on, will both reduce watering, maintenance, fertilization, etc. costs and extend the lifespan of saplings.

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