Güney, D., Atar, F., Atar, E., Turna, İ. and Kulaç, Ş. (2015), *Seed Sci. & Technol.,* **43**, 1-9.
http://doi.org/10.15258/sst.2015.43.1.01

# The effect of pre-treatments and seed collection time on the germination characteristics of common hornbeam (*Carpinus betulus*) seeds in the Eastern Black Sea Region, Turkey

D. GÜNEY[1], F. ATAR[1], E. ATAR[1], İ. TURNA[1] AND Ş. KULAÇ[2]

[1] Department of Forest Engineering, Karadeniz Technical University, 61080 Trabzon, Turkey (E-mail: d_guney61@hotmail.com)
[2] Department of Forest Engineering, Düzce University, 81620, Düzce, Turkey

*(Accepted December 2014. Handling editor: A.A. Powell)*

## Abstract

The germination characteristics of common hornbeam (*Carpinus betulus*), which shows a natural distribution in Turkey, were analysed. Seeds were obtained from 12 populations at different altitudes in the river basins of Trabzon-Maçka, Trabzon-Çaykara, Rize-Çamlıhemşin and Giresun-Espiye. In common hornbeam seeds, there is a germination barrier caused by the seed coat and embryo. In order to eliminate the germination barrier and increase germination, 22 different pre-treatments, including control different concentrations of $GA_3$, citric and sulphuric acids, and different stratification periods were performed before seed germination was tested. Analysis of the effect of different seed collection times and pre-treatments on the germination percentage revealed differences according to population and altitude. The pre-treatments also showed differences on the basis of populations. The highest germination took place following $GA_3$ pre-treatments (30%) and in seeds collected in mid-September (54%).

## Introduction

The genus *Carpinus* comprises 35-60 species that have tree or shrub forms and are widely distributed over the mild regions of the northern hemisphere (Hora, 1981; Krüssman, 1984). *Carpinus betulus* L. is a shade-tolerant species exhibiting best growth in forests with deep rich and humid soils, but it may also be found in dry and shallow soils (Browicz, 1982). In Turkey, common hornbeam is found in the Black Sea Region, which is the area of the whole European- Siberian flora, but it also occurs locally in the Amanos Mountains. In general, it is found in mixed forests together with beech, chestnut, oak and redwood trees; pure stands of this species are found occasionally (Yaltırık, 1982; Anşin and Özkan, 2006). It grows in loamy, sandy, alkaline and acidic soils and is resistant to drought (Edward and Dennis, 1993). The tree form has the potential for being utilised as an ornamental plant due to its leaf colour and decorative fruits (Dirr, 1998). In the lathe industry, it is used as a sledge and plank in the construction of shuttles and vehicle bodies; it is also used in ship-building and for fuel (Anşin and Özkan, 2006).

The best time to harvest seeds may be considered to be when translocation of nutrients to the seed stops and the seed has attained maximum dry weight (Kozlowski, 2002). In order to germinate, a seed requires an adequate amount of endosperm and a fully developed embryo, proper temperature, a moist germination substrate, and appropriate light conditions (Gezer and Yücedağ, 2006). However, seed dormancy is a physiological condition in which the seeds cannot germinate even under the most suitable germination conditions or do not exhibit uniform germination. In general, seed germination is hampered by external factors (oxygen, temperature, humidity and light) and internal factors (e.g. seed coat, endosperm embryo) (Bewley and Black, 1982; Bradbeer, 1988; Copeland and McDonald, 2001; Koornneef, *et al*., 2002; Baskin and Baskin, 2004; Black *et al*., 2008).

Seed dormancy stemming from the seed coat (physical dormancy) is eliminated by methods such as artificial scratching, mechanical scarification, soaking, hot water treatment and acid treatment (Smith *et al*., 2002). Another pre-treatment is to leave seeds in water at room temperature for 24-48 hours (Genç, 2007). Physiological dormancy, in some plants, greatly depends on the balance between the chemical growth inhibitor, abscisic acid (ABA) and the growth-promoting gibberellic acid ($GA_3$) (Pua and Davey, 2010). Gibberellic acid both increases the growth potential of the embryo and eliminates the mechanical restriction caused by the seed coat through weakening the tissues around the radicle (Ogawa *et al*., 2003).

This study examined the effect of pre-treatments prior to germination on the germination of *Carpinus betulus* and the effect of different seed-harvesting times. Seed collected from different sites in Turkey were used to examine the impact of populations (e.g. the altitude of the collection site) on germination and response to treatment.

## Materials and methods

*Selection of populations and trees*

Seeds of *Carpinus betulus* were obtained from populations growing at different altitudes in the river basins of Trabzon-Maçka, Trabzon-Çaykara, Rize-Çamlıhemşin and Giresun-Espiye, Turkey (figure 1).

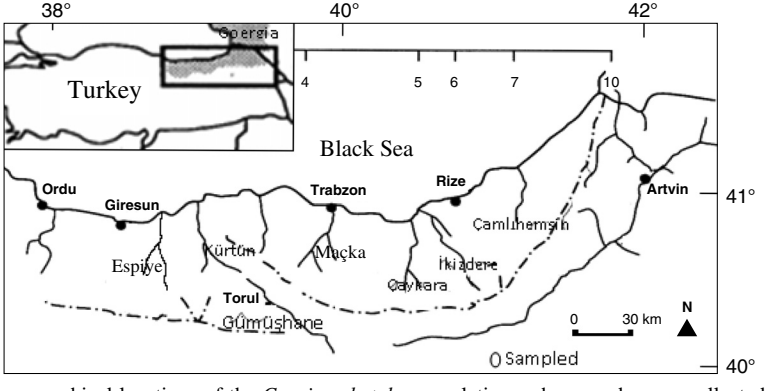


Figure 1. The geographical locations of the *Carpinus betulus* populations where seeds were collected.

Seeds were collected during the optimum seed maturation period in late September and early October. This process was carried out from a total of 12 populations from three different altitude zones up to 1200 m a.s.l. (table 1). Seed samples were harvested from a total of 134 trees; 28 in Maçka, 46 in Çaykara, 30 in Rize-Çamlıhemş in and 30 in Giresun-Espiye. The harvested seeds were labeled according to the population they were collected from by putting them separately into bags. Afterwards, they were separated from the pericarps by hand and empty and rotten seeds were removed. Filled seeds were identified through floatation in 96% alcohol. The seeds were organised for the treatments according to population and tree.

Table 1. Information on the location of the sites from which populations of *Carpinus betulus* were sampled.

| Population number | Population name* | Number of trees sampled | °E | °N | Altitude (m a.s.l.) |
|---|---|---|---|---|---|
| 1 | M1 | 13 | 559598-557006 | 4523304-4517700 | 452-645 |
| 2 | M2 | 11 | 553654-556689 | 4509432-4516356 | 770-864 |
| 3 | M3 | 6 | 554170-554703 | 4508674-4509904 | 900-1170 |
| 4 | Ç1 | 15 | 607637-606873 | 4527160-4521253 | 39-220 |
| 5 | Ç2 | 15 | 605099-605005 | 4510010-4507160 | 540-762 |
| 6 | Ç3 | 16 | 603327-601370 | 4505840-4505772 | 824-1155 |
| 7 | ÇH1 | 9 | 668909-664828 | 4568174-4538185 | 340-600 |
| 8 | ÇH2 | 12 | 664782-664877 | 4538050-4532100 | 634-867 |
| 9 | ÇH3 | 9 | 664012-662401 | 4532185-4527014 | 900-1120 |
| 10 | E1 | 12 | 481711-479347 | 4526243-4307857 | 70-695 |
| 11 | E2 | 12 | 479204-474968 | 4507895-4504708 | 705-1100 |
| 12 | E3 | 7 | 475158-474584 | 4504815-4504164 | 1105-1145 |

* M = Maçka; Ç = Çaykara; ÇH = Çamlıhemşin; E = Espiye.

*Germination tests*

In order to eliminate dormancy caused by the embryo, endosperm and seed coat, 22 treatments were tested. The study was carried out with 39,600 seed samples for pre-treatments (12 populations × 22 pre-treatments × 3 replications × 50 seeds) and 1800 seed samples for collection date (3 collection dates × 2 populations × 3 replication × 100 seeds).

A number of dormancy breaking treatments were applied:

- Gibberellic acid ($GA_3$; 100, 250 and 500 ppm) for 10 minutes.
- Citric acid (5,000, 10,000 and 15,000 ppm) for five days.
- Sulphuric acid (95-97%) for 30, 60 and 180 minutes.
- 500 ppm $GA_3$ plus cold stratification (in sand at +4°C) for 4, 8 and 12 weeks.
- 90°C water for 10, 30 and 60 seconds.
- Seed tip cut.

In addition, there were three 'control' treatments, namely seeds with the pericarp removed, seeds not separated by alcohol floatation and seeds with no treatment. Both the controls and pre-treated seeds were sown, using a randomised sampling design, in nursery seedbeds in October. Following the start of germination in April, germination percentages were determined.

To determine the effect of different seed harvesting times on germination, seeds harvested in the months of August, September and October were subjected to germination tests under open nursery conditions. All nursery operations were performed as uniformity as possible (i.e. irrigation, shading, weed control, maintenance, etc.).

*Statistical analysis*

Data were analysed using the SPSS 20.0 statistical program. The analyses conducted included ANOVA and Duncan's Test.

## Results

*Germination results of the pre-treatments*

The highest germination was with the pre-treatment of 250 ppm $GA_3$ for seven populations (M1, M3, Ç1, ÇH1, E1, E2 and E3) followed by 100 ppm $GA_3$ for two populations (Ç3 and ÇH2) (table 2). The 60-minute $H_2SO_4$ pre-treatment resulted in the highest germination in the Ç2 and ÇH3 populations, while for population M2, the highest germination was with 500 ppm $GA_3$ pre-treatment. No germination occurred following pre-treatment with hot water. Two-way ANOVA showed that there were highly significant ($P < 0.001$) main and interaction effects of population and pre-treatment on seed germination. Duncan's test was performed and enabled similar responses to be grouped together. The populations constituted 10 groups, while the pre-treatments formed 14 groups (table 2). The populations of Ç3, E1 and E2 formed one group, whereas each of the other populations formed a single separate group. Among the populations, ÇH2 had the highest germination, while Ç2 had the lowest germination. When each river basin was evaluated within itself, it was clear that germination in some basins increased with increasing altitude, while it decreased with increasing altitude in others. Due to this, it was ascertained that there was no effect of altitude on germination.

When the groups formed on the basis of the pre-treatments were examined, the treatments of seed tip cut and stratification four weeks + $GA_3$ 500 ppm were in one group, citric acid (10,000 ppm) and citric acid treatments (15,000 ppm) in another group; while the $H_2SO_4$ (30 minutes) and stratification for 12 weeks were in another group. Control and stratification 12 weeks + $GA_3$ 500 ppm were in the same group. $H_2SO_4$ (60 minutes) treatment was in the same group as 100 and 500 ppm $GA_3$ treatments.

The highest mean germination across all populations occurred following $GA_3$ (250 ppm) (% 15.5) treatment, followed by $GA_3$ (100 ppm) (% 11.9) and $GA_3$ (500 ppm) (% 11.8) treatments. Thus the $GA_3$ pre-treatments were the most effective in increasing the percentage of germination.

Table 2. Germination percentages of *Carpinus betulus* seeds from 12 populations (table 1) following different pre-treatments.

| Pre-treatments | M1** | M2 | M3 | Ç1 | Ç2 | Ç3 | ÇH1 | ÇH2 | ÇH3 | E1 | E2 | E3 | Mean | Duncan Group |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Without alcohol separation | 8.7 | 19.3 | 10.7 | 6.7 | 4.7 | 4.7 | 11.3 | 16.7 | 4.7 | 5.3 | 4.0 | 4.0 | 8.4 | **gh** |
| Control | 8.7 | 8.0 | 3.3 | 9.3 | 8.0 | 6.0 | 12.0 | 8.0 | 5.3 | 9.3 | 6.7 | 6.0 | 7.6 | **efgh** |
| Sowing with pericarp | 3.3 | 6.0 | 8.7 | 6.7 | 8.0 | 7.3 | 8.7 | 16.0 | 12.7 | 5.3 | 5.3 | 7.3 | 7.9 | **fgh** |
| Seed tip cut | 1.7 | 5.8 | 0.0 | 1.7 | 3.3 | 0.0 | 3.3 | 0.8 | 5.8 | 5.0 | 7.7 | 9.3 | 3.7 | **bc** |
| $GA_3$ (100 ppm) | 7.1 | 6.1 | 6.1 | 9.1 | 5.1 | 22.0 | 21.0 | 30.0 | 8.0 | 11.0 | 12.1 | 5.1 | 11.9 | **ı** |
| $GA_3$ (250 ppm) | 21.0 | 19.0 | 19.1 | 18.3 | 8.0 | 4.3 | 22.0 | 12.1 | 7.0 | 21.0 | 21.0 | 13.0 | 15.5 | **j** |
| $GA_3$ (500 ppm) | 14.0 | 20.0 | 12.1 | 10.1 | 0 | 5.1 | 7.0 | 16.0 | 14.0 | 17.0 | 16.0 | 10.0 | 11.8 | **ı** |
| Hot water (10 sec) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **a** |
| Hot water (30 sec) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **a** |
| Hot water (60 sec) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **a** |
| $H_2SO_4$ (30 min.) | 3.3 | 13.3 | 11.3 | 11.3 | 5.3 | 2.7 | 5.3 | 10.7 | 10.0 | 5.3 | 0.7 | 4.7 | 7.0 | **defg** |
| $H_2SO_4$ (60 min.) | 1.3 | 13.3 | 6.7 | 15.3 | 10.0 | 12.0 | 6.7 | 19.3 | 18.7 | 9.3 | 2.0 | 4.7 | 9.9 | **ı** |
| $H_2SO_4$ (180 min.) | 3.3 | 8.7 | 6.7 | 6.7 | 8.7 | 12.0 | 11.3 | 17.3 | 11.3 | 4.0 | 7.3 | 4.0 | 8.4 | **gh** |
| Citric acid (5,000 ppm) | 2.0 | 3.3 | 2.7 | 6.0 | 2.0 | 9.3 | 4.0 | 9.3 | 6.0 | 6.7 | 3.3 | 4.7 | 4.4 | **cde** |
| Citric acid (10,000 ppm) | 10.7 | 5.3 | 3.3 | 10.0 | 6.0 | 7.3 | 10.0 | 6.0 | 4.0 | 3.3 | 5.3 | 4.7 | 6.3 | **cdefg** |
| Citric Acid (1,5000 ppm) | 7.3 | 7.3 | 2.7 | 8.7 | 4.7 | 4.7 | 7.3 | 10.0 | 8.0 | 6.0 | 4.0 | 4.0 | 6.2 | **cdefg** |
| St* 4 weeks | 5.3 | 4.7 | 3.3 | 2.0 | 4.0 | 1.3 | 2.7 | 2.7 | 10.7 | 6.0 | 6.0 | 4.7 | 4.4 | **cd** |
| St 4 weeks+$GA_3$ 500 ppm | 2.0 | 5.3 | 2.7 | 6.0 | 2.0 | 0.7 | 8.0 | 6.0 | 0.7 | 4.0 | 7.3 | 6.0 | 4.2 | **bc** |
| St 8 weeks | 2.0 | 0.7 | 2.7 | 0.7 | 2.7 | 1.3 | 0.0 | 2.7 | 3.3 | 2.0 | 2.0 | 2.0 | 1.8 | **ab** |
| St 8 weeks+$GA_3$ 500 ppm | 4.0 | 6.7 | 8.0 | 3.33 | 1.3 | 5.3 | 10.7 | 11.3 | 5.3 | 3.3 | 3.3 | 2.7 | 5.4 | **cdef** |
| St 12 weeks | 1.3 | 5.3 | 15.3 | 8.0 | 6.7 | 10.0 | 17.3 | 10.7 | 2.7 | 3.3 | 2.7 | 1.3 | 7.1 | **defg** |
| St 12 weeks+$GA_3$ 500 ppm | 3.3 | 4.0 | 18.0 | 10.0 | 2.0 | 8.7 | 17.3 | 2.0 | 8.0 | 8.0 | 6.0 | 4.7 | 7.7 | **efgh** |
| Mean | 5.0 | 7.4 | 6.5 | 6.8 | 4.2 | 5.7 | 8.5 | 9.4 | 6.7 | 6.2 | 5.6 | 4.7 | | |
| Duncan Group | **abc** | **de** | **bcd** | **cde** | **a** | **abcd** | **ef** | **f** | **bcde** | **abcd** | **abcd** | **ab** | | |

*St = Stratification at +4°C; ** M = Maçka; Ç = Çaykara; ÇH = Çamlıhemşin; E = Espiye.

The results were evaluated depending on the interaction of both the populations and the pre-treatments as shown in table 2 for three pre-treatments only for the sake of clarity. The highest outcome was seen in the population of Çamlıhemşin-2 and 100 ppm $GA_3$ pre-treatment. When analysed merely on the basis of population and treatment, the Çamlıhemşin-2 population again seems to bear the highest value, whereas the 250 ppm $GA_3$ treatment yielded the highest germination value on the basis of treatment.

*Germination results depending on seed collection dates*

Seeds from different harvest dates and sown outdoors began to germinate after six months, in spring. Both of the populations had the highest germination (54%) from the seeds collected during the second harvest (September), with very low germinations after the August and October harvests (figure 2). Thus collection time had a significant impact on seed quality.

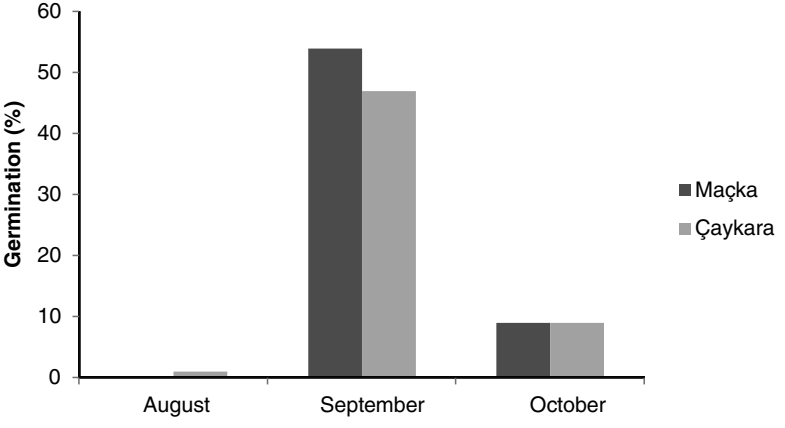


Figure 2. Germination of two populations of *Carpinus betulus* following harvest at three different times.

## Discussion

In our study, pre-treatments affected germination and differences were evident between populations. Germination was highest for seeds treated with $GA_3$ (table 2). In other studies, germination in seeds treated with $GA_3$ was also high; thus, germination can be increased by applying $GA_3$ to the seeds. In continued observations it was determined that common hornbeam had a dormancy period of one year.

Pre-treatment may yield the highest result in one population, but achieve a different outcome in another population. In other words, origin has an impact on germination as well as pre-treatments. Therefore, although our study was conducted using seeds germinated under the same environmental conditions often applying the same pre-treatments, it can be inferred that the differences in germination were also due to the populations, which means that genetic factors also had an impact on this outcome.

The length of hot and cold stratification periods that are necessary to eliminate dormancy may vary according to the species of *Carpinus*. Application of gibberellin, may remove several types of seed dormancy such as physiological dormancy (West *et al.*, 1970; Hartmann *et al.*, 2002; McMahon *et al.*, 2007; Pijut, 2008). $GA_3$ treatment and stratification increased germination and $GA_3$ treatment shortened the stratification period in studies conducted in *Carpinus* spp. including *C. betulus*, *C. orientalis* Mill, *C. loxiflora* (Siebold & Zucc.) Blume, *C. tschonoskii* Maxim. and *C. cordata* Bl. (Suzska, 1968; Bretzloff and Pellett, 1979; Suzuki, 2000; Czapracki and Holubowicz, 2010; Pipinis *et al.*, 2012 ). In our study the highest germination also occurred with the $GA_3$ pre-treatments.

Merou *et al.* (2012) pointed out that in *C. orientalis* the mechanical process of breaking dormancy can have a fatal effect on the seed, and that reduced germination could also result from chemical treatments damaging the embryo. Hence, in our study, the low germination percentage following "seed tip cut'' and $H_2SO_4$ treatments coincides with the results of the studies above.

In a study conducted in China on *C. cordata* var. *chinensis* and *C. fargesiana*, the seeds of both species had a dormancy period of one year or more. Seeds germinated during the second and the third years (Guo, 2000). In our study, seeds continued to germinate in the second growing season. As the embryos do not fully develop in hornbeam seeds, seeds sown in nursery beds one year continue to germinate the following year (Yahyaoğlu and Ölmez, 2005). Following pre-treatments, sowing was carried out under nursery conditions. The fact that germination remained low was for this reason. In a study conducted by Takos and Efthimiou (2003), germination of *C. betulus* seeds was determined to be 9%, possibly due to late collection of seeds. It was pointed out that there is dormancy caused by both the seed coat and the embryo in *C. betulus* seeds and thus, it was suggested that it was necessary to collect the seeds early when they were still green and within the month of September, and also to sow them immediately (Dirr and Heuser, 1987; Takos and Merou, 1995). In our study, the fact that the highest germination in the seeds collected at three different times was obtained from the seeds collected when still green in mid-September, and that it declined for seed collected in the first week of October.

## Acknowledgements

This study was supported by TUBITAK (Project No: 112 O 033).

## References

Anşin, R. and Özkan, C.Ö. (2006). *Spermatophytha, Woody Plant*. Karadeniz Technical University, Faculty of Forestry, Publication No: 167, Faculty Publication No: 19, Trabzon.

Baskin, C.C. and Baskin J.M. (2004). A classification system for seed dormancy. *Seed Science Research*, **14**, 1-16.

Bewley, J.D. and Black, M. (1982). *Physiology and Biochemistry of Seeds. 2. Viability, Dormancy and Environmental Control*, Springer-Verlag, Berlin, Heidelberg, New York.

Black, M., Bewley, J.D. and Halmer, P. (2008). *The Encyclopedia of Seeds: Science, Technology and Uses*, CAB International, Wallingford.

Bradbeer, J.M. (1988). *Seed Dormancy and Germination*, Blackie and Son Ltd., Glasgow.

Breztloff, L.V. and Pellett, N.E. (1979). Effect of stratification and gibberellic acid on the germination of *Carpinus caroliniana* Walt. *Hortscience*, **14**, 621-622.

Browicz, G. (1982). *Chronology of Trees and Shrubs in South-west Asia and Adjacent Regions*, vol. 1, Polish Scientific Publishers, Warszawa-Poland.

Copeland, L.O. and McDonald, M.B. (2001). *Principles of Seed Science and Technology*. 4th edition, Kluwer Academic Publishers, Boston.

Czapracki, M. and Holubowicz, R. (2010). Some factors influencing the germination of the Common Hornbeam *Carpinus betulus* L. seeds. *Bulletion UASVM Horticulture*, **67**, 1.

Demirci, A. (2006). *The Basic Principles of Silviculture*, Karadeniz Technical University, Faculty of Forestry, Lecture Notes Series No: 83, Trabzon.

Dirr, M.A. (1998). *Manual of Woody Landscape Plants; Their Identification, Ornamental Characteristics, Culture, Propagation and Uses*, 5th edition, Stipes Publishing L.L.C., Champaign, Illinois, U.S.A.

Dirr, M. and Heuser, C.W. Jr. (1987). *The Reference Manual of Woody Plant Propagation: From Seed to Tissue Culture*, Varsity Press Inc., Athens, Georgia.

Edward, F.G. and Dennis, G.W. (1993). *The Environmental Horticulture*, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida.

Genç, M. (2007). *Forestry Information Lecture Notes*, Süleyman Demirel University, Faculty of Forestry, Isparta.

Gezer. A. and Yücedağ, C. (2006). *Forest Tree Seed and Seedling Production Techniques with Seed*. Süleyman Demirel University, Faculty of Forestry Publication No. 56, 149s., Isparta.

Guo, K. (2000). Germination, seedling, survival and growth of the two Carpinus species from a Chinese beech forest. *Acta Phytoecologia Sinica*, **24**, 385-390.

Hartmann, H.T., Kester, D.E., Davies, F.T. and Geneve, R.L. (2002). *Plant Propagation. Principles and Practices*, 7th edition, Prentice-Hall International.

Hora, B. (1981). *The Oxford Encyclopedia of Trees of the World*, Oxford Unviersity Press. Oxford, U.K.

Işık, K. (1988). The importance of site race in forest tree species and genetic pollution problems. *Journal of Forest Engineering*, **25**, 25-30.

Koornneef, M., Bentsink, L. and Hilhorst, H. (2002). Seed dormancy and germination. *Current Opinion in Plant Biology*, **5**, 33-36.

Kozlowski, T.T. (2002). Adaptive responses of woody plants to environmental stress. *The Botanical Review*, **68**, 270-334.

Krüssmann, G. (1984). *Manual of Cultivated Broad-Leaved Trees and Shrubs*, volume 1, A-D, Timber Press Inc., Portland, Oregon.

McMahon, M., Kofranek, A.M. and Rubatzky, V.E. (2007). *Hartmann's Plant Science, Growth Development and Utilization of Cultivated Plants*, 4th edition, Columbus, Ohio.

Merou, T., Takos, I., Varsamis, G. and Xofis, P. (2012). Effect of stratification and scarification treatments on the germination of oriental hornbeam (*Carpinus orientalis*) seeds. *Seed Science and Technology*, **40**, 265-270. http://doi.org/10.15258/sst.2012.40.2.12

Ogawa, M., Hanada, A., Yamauchi, Y., Kuwahara, A., Kamiya, Y. and Yamaguchi, S. (2003). Gibberellin biosynthesis and response during arabidopsis seed germination. *The Plant Cell*, **15**, 1591-1604.

Pijut, P.M. (2008). *Carpinus*. In *Woody Plant Seed Manual*, *Agriculture Handbook 727*, (eds. F.T. Bonner and R.P. Karrfalt), pp. 328-332, USDA Forest Service, Washington, DC.

Pipinis, E., Milios, E., Kiamos, N., Mavrokordopoulou, O. and Simiris, P. (2012). Effect of stratification and pre-treatment with gibberellic acid on seed germination of two *Carpinus* species. *Seed Science and Technology*, **40**, 21-31. http://doi.org/10.15258/sst.2012.40.1.03

Pua, E.C. and Davey, M.R. (2010). *Plant Developmental Biology-Biotechnological Perspectives*, University of Nottingham, UK.

Smith, M.T., Wang, B.S.P. and Msanga, H.P. (2002). Dormancy and germination. In *Tropical Tree Seed Manual*, *Agriculture Handbook 721*, (ed. J.A. Vozzo), pp. 149-176, USDA Forest Service, Washington, DC.

Suszka, B. (1968). Condition for the breaking of dormancy and germination of hornbeam (*Carpinus betulus* L.) seed. *Rocznik*, **13**, 147-172.

Suzuki, W. (2000). Germination traits and adaptive regeneration strategies of the three *Carpinus* species. *Journal of Forest Research*, **5**, 181-185.

Takos, I.A. and Efthımıou, G.S.P. (2003). Germination results on dormant seeds of fifteen tree species autumn sown in a Northern Greek nursery. *Silvae Genetica,* **52**, 2.

Takos, I. and Merou, T.H. (1995). *Technology of Woody Plants Seeds*, Art of Text, Thessaloniki.

West, W.C., Frattarelli, F.J. and Russin, K.J. (1970). Effect of stratification and gibberellin on seed germination in *Ginkgo biloba*. *Bulletin of the Torrey Botanical Club*, **97**, 380-388.

Yahyaoğlu, Z. and Ölmez, Z. (2005). Seed Technology and Nursery Technique, Kafkas University, Artvin Forestry Faculty, Publication No. 1, Artvin.

Yaltırık, F. (1982). *Flora of Turkey and Aest Eagen Island*, University Press, Edinburgh.