Germination Results on Dormant Seeds of fifteen Tree Species Autumn Sown in a Northern Greek Nursery

By I. A. TAKOS[1] and G. SP. EFTHIMIOU[2]

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Abstract

In early December 1999 field germination experiments of dormant seeds were carried out in the forest nursery of Langadas, Central Macedonia, Greece. Seeds of fifteen indigenous forest species were sown without any treatment in order to determine their germination (emergence). Laboratory germination and/or viability tests were carried out at the same time for the same species according to current international standards. Seeds of *Malus sylvestris* Mill. germinated 96%, *Fraxinus ornus* L. 88%, *Celtis australis* L. and *Cornus sanguinea* L. 79%, and *Euonymus europaeus* L. 67%. In contrast, seeds of *Laurus nobilis* L. germinated only 11%, *Sorbus torminalis* (L.) Crantz 1%, and *Prunus spinosa* L. 0%. Seeds with hard seed coat or with double dormancy (hard seed coat and embryo dormancy) had low percentages of germination or did not germinate at all. Seeds of *Paliurus aculeatus* Lamb. germinated 28%, *Cercis siliquastrum* L. 21%, *Cotinus coggygria* Scop. 19%, *Pistacia terebinthus* L. 17%, and *Carpinus betulus* L. 9%. Emergence of *Cornus sanguinea* L. and *Malus sylvestris* Mill. began in late March while for the rest of the species in the first half of April. Except for seeds of *Rhus coriaria* L. and *Phillyrea latifolia* L. which did not emerge at all, emergence for all species was completed in late April and early May.

Key words: Dormancy, forest nursery, forest seeds, germination, viability.

Introduction

In many nurseries, tree seeds may be sown in the autumn, spring or summer depending on their seed dormancy, the temperature required for germination, the management practice followed by the nurseries and the weather conditions that prevail in the nursery during the wintertime, that is, on whether the winter is mild or cold (HARTMANN *et al.,* 1997). The significance of sowing time has been discussed by numerous investigators (SCHUBERT and ADAMS, 1971; MCMILLAN-BROWSE, 1978; MCDONALD, 1986; DIRR and HEUSER, 1987; YOUNG and YOUNG, 1992; TAKOS and MEROU, 1995; TAKOS, 1999a,b).

Seeds of species that ripen in spring or early summer, and whose viability decreases rapidly (e.g., *Ulmus* spp., *Populus* spp.) are sown immediately (HARTMANN *et al.,* 1997). For other forest species, sowing can be performed in the autumn or spring. Outdoors autumn sowing is often preferred for large recalcitrant seeds, e. g., *Aesculus* spp., *Castanea* spp., *Corylus* spp., *Quercus* spp., the quality of which decreases after harvesting, especially if they are not properly stored over winter (DIRR and HEUSER, 1987; YOUNG and YOUNG, 1992; TAKOS and MEROU, 1995; HARTMANN *et al.,* 1997; TAKOS and MEROU, 2001; TAKOS *et al.,* 2002). Autumn sowing is also commonly used with seeds with embryo dormancy, e.g., *Malus* spp., *Pyrus* spp., *Prunus* spp., *Taxus* spp. (HARTMANN *et al.,* 1997), because it enables the low winter temperatures to break dormancy in these seeds. Autumn field sowing is also used with species that have double dormancy (a hard coat and embryo dormancy), such as *Berberis* spp., *Cornus* spp., *Cotinus* spp., *Crataegus* spp. (LAWYER, 1978), and is frequently performed with certain other species, e.g., *Fraxinus* spp., and *Carpinus betulus*, whose seeds are sown very early, while they are still green (DIRR and HEUSER, 1987). In this way, the storage of seeds is avoided and, therefore, the formation of a hard coat, which would make germination difficult, is prevented (THANOS *et al.,* 1992; DOUSSI and THANOS, 1994; THANOS and DOUSSI, 1995; HARTMANN *et al.,* 1997; MEROU *et al.,* 2002).

Nevertheless, autumn sowing has several disadvantages. Large seeds and seeds with wings are especially endangered by rodents. High autumnal temperature encourages germination leaving tender seedlings exposed to low winter temperatures that may damage them (HARTMANN *et al.,* 1997). Additionally, premature germination in the spring increases the possibility of damage caused by a late (spring) frost.

The purpose of this study was to investigate the germination of the seeds of fifteen indigenous Greek flora forest species after autumn sowing and without pre-treatment, and of dormant seeds requiring pre-treatment for dormancy removal to permit spring sowing. None of the species studied here was previously investigated after sowing outdoors under the autumnal conditions of Northern Greece.

Materials and Methods

The forest species used are shown in *Table 1.*

Experiments in the field

All species were sown outdoors on 9 December 1999 in the forest nursery of Langada, Thessaloniki (23 01' E, 40 38' N). Seeds were sown in styrofoam containers in blocks, each with 100 cavities (cavity volume = 80 cm^3), in a 3:2 sand and turf mixture, and at a depth equal to three times the size of the

Table 1. – Species, gathering date and location, seed storage conditions until sowing.

Species	Gathering date and location (altitude)	Seed storage conditions until sowing
Carpinus betulus L.	1/10/99, Nymphea of Komotini (650 m.)	Air-tight vase (3°C)
Celtis australis L.	18/10/99, Komotini (300 m.)	Linen bag, basement (10/20°C)
Cercis siliquastrum L.	14/10/99, Ardanio - Esymi (500 m.)	Linen bag (3°C)
Cornus sanguinea L.	18/11/99, Tyria - Pedini (600 m.)	Air-tight vase (3°C)[1]
Cotinus coggygria Scop.	29/8/99, Baoussi of Ioannina (500 m.)	Air-tight vase (3°C)
Euonymus europaeus L.	18/11/99, Ioannina - Dodoni (500 m.)	Linen bag (3°C)[1]
Fraxinus ornus L.	2/12/99, Tyria -Igoumenitsa (450 m.)	Linen bag (3°C)
Laurus nobilis L.	25/10/99, Ardanio of Alexandroupoli (50 m.)	Linen bag (3°C)
Malus sylvestris Mill.	5/9/99, Baoussi of Ioannina (500 m.)	Linen bag (3°C)
Paliurus aculeatus Lamb.	16/10/99, Maronia of Komotini (50 m)	Linen bag, basement (10/20°C)[1]
Phillyrea latifolia L.	28/9/99, Maronia of Komotini (20 m.)	Linen bag (3°C)[1]
Pistacia terebinthus L.	1/10/99, Kozani valley (600 m.)	Air-tight vase (3°C)
Prunus spinosa L.	27/10/99, Polymylos of Kozani (900 m.)	Linen bag (3°C)[1]
Rhus coriaria L.	16/11/99, Tyria-Seniko (800 μ.)	Linen bag (3°C)[1]
Sorbus torminalis (L.) Crantz	19/10/99, Dragati of Komotini (800 m.)	Linen bag (3°C)

[1] Without the external coat

[1]) Department of Forestry, Institute of Technological Education of Kavala, 661 00 Drama, Greece. Tel.: +30-25210-60428. Fax:+30-25210-60401. E-mail: itakos@teikav.edu.gr

[2]) Consultant of „Egnatia Odos A.E." 6° Km Thessaloniki-Thermi, P.O. 30, 57001 Thermi, Greece. E-mail: gefthi@egnatia.gr or gsefthimiou@in.gr

seed (KRÜSSMANN, 1981). After sowing, the surface of the growmix was covered with 3 mm of sand. The containers were placed outdoors in the nursery and covered with a black plastic net and a layer of fir branches for protection from hail and heavy rainfall, as well as intense sunshine in the winter. This cover was maintained until spring. Watering began in mid-March and continued until the completion of germination, which was evaluated after seedling emergence in the spring. Measurements were taken once a week from the beginning of the germination until emergence was completed.

From the bioclimatic point of view, according to Emberger's bioclimatic diagram that was prepared for Greece by MAVROMATIS (1980), the region where the nursery is located belongs to the sub-humid bioclimatic level with cold winters and frequent frosts. Climatic conditions (temperature and rainfall) that prevailed during the experiments and the corresponding average values of measurements taken over several years are shown in *Table 2*. Data are from the Langadas Meteorological Station 1.5 km away from the Forest Nursery. The temperatures recorded from December 1999 until May 2000 were normal for the region, with the exception of January and February average temperatures, which were lower than normal.

Table 2. – Temperature and rainfall measured by the Meteorological Station in Langada (from December 1999 to May 2000).

Month	Dec	Jan	Feb	Mar	Apr	May
Average temperature °C	6,4	1,5	4,5	8,2	13,9	18,1
	(6,6)[1]	(5,0)	(6,3)	(9,9)	(14,1)	(19,2)
Absolute maximum temperature (°C)	20,0	18,0	15,0	18,0	25,0	30,0
	(22,0)	(22,0)	(23,5)	(26,0)	(31,5)	(36,0)
Absolute minimum temperature (°C)	-6,0	-6,0	-6,0	-5,0	-1,0	1,0
	(-12,0)	(-10,0)	(-11,5)	(-8,0)	(-1,5)	(3,0)
Rainfall (in mm)	32,0	25,0	47,0	73,0	59,0	49,0
	(44,0)	(23,0)	(31,0)	(33,0)	(43,0)	(41,0)

[1] In parentheses, mean values of the period 1978–1995 in the broader area (Source: National Agricultural Foundation – Forestry Research Institute, Thessaloniki.)

Laboratory tests

Germination test

Germination tests were performed on seeds of those species known to require pre-treatment (no longer than four months) and the germination of which is achieved in a short time. Several treatments for overcoming dormancy were tested because published prescriptions generally recommend several alternative methods (BONNER *et al.,* 1974; AOSA, 1985; ELLIS *et al.,* 1985; DIRR and HEUSER, 1987; BACHILLER, 1991; YOUNG and YOUNG, 1992; TAKOS and MEROU, 1995; ISTA, 1999). However, the germination percentages presented in the results refer to the treatment that produced the highest percentage for each species. The treatments as well as the species that gave the highest results are shown in *Table 3*. Seeds of all species treated with H_2SO_4 were immediately rinsed after removal under running water for a few minutes (ISTA, 1999). After pre-treatment, seeds of all species except *Laurus nobilis* were placed on Whatman No. 1 filter paper over sand saturated with distilled water, in 9 cm covered Petri dishes. L. *nobilis* seeds were placed in saturated sand only, in 20 cm Petri dishes (TAKOS, 2001). All dishes were placed in a germination chamber set at 25°C for 8 hours with light and at 20°C for 16 hours without light (AOSA, 1985; ISTA, 1999). Light, with an intensity of 1200 lux at the germination surface, was provided by cool-white fluorescent lamps on both side walls of the chamber. Using a criterion of a minimum of 2 mm of emerging radicle, germinants were counted once per week for 30 days (for 60 days in the case of *Laurus nobilis*).

Table 3. – Treatments that gave the highest germination in laboratory.

Species	Treatments
Celtis australis	Removal of the fleshy coat and soaking in concentrated H_2SO_4 for an hour (BACHILLER, 1991).
Cornus sanguinea	Removal of the fleshy coat, soaking in concentrated H_2SO_4 for an hour and stratified in sand for 120 days at 4°C (BACHILLER, 1991).
Cotinus coggygria	Soaking in concentrated H_2SO_4 for an hour and stratified in sand for 60 days at 4°C (DIRR and HEUSER, 1997).
Laurus nobilis	Removal of the fleshy coat and stratified in sand for 60 days at 4°C (TAKOS, 2001).
Pistacia terebinthus	Removal of the fleshy coat, soaking in concentrated H_2SO_4 for an hour and in water at room temperature for 24 hours (BACHILLER, 1991).
Rhus coriaria	Mechanical scarification and stratified in sand for 60 days at 4°C (DIRR and HEUSER, 1997).

Viability test with 2,3,5 – triphenyl tetrazolium chloride (TTC)

Following ISTA (1999) prescriptions, seeds not subjected to a germination test were prepared for staining as shown in *Table 4*. All seeds were soaked in distilled water for 18 hours at 20°C. When published prescriptions were not available, those for closely related species were used. Following cutting (transversely or longitudinally) they were immersed in a 1% solution of TTC, buffered to pH 7.0, and kept at 30°C in total darkness for the staining period (MOORE, 1985; ISTA, 1999).

Table 4. – Procedure of tetrazolium tests (TTC).

Species	Preparation before staining	Staining period (hours) at 30°C	Prescription source
Carpinus betulus	Transversely cut 1/3 from distal end	48	ISTA, 1999
Cercis siliquastrum	Longitudinally cut through the coats	12	MOORE, 1985
Euonymus europaeus	Transversely cut 1/3 from distal end	48	ISTA, 1999
Fraxinus ornus	Longitudinally cut on both sides	18	MOORE, 1985; ISTA, 1999
Malus sylvestris	Remove seed coat	18	ISTA, 1999
Prunus spinosa[1]	Remove seed coat	18	ISTA, 1999
Sorbus torminalis	Transversely cut 1/3 from distal end	24	MOORE, 1985; ISTA, 1999
Paliurus aculeatus[2]	Remove seed coat	24	
Phillyrea latifolia[3]	Transversely cut 1/3 from distal end	24	

[1] Stony shells were cracked before soaking in TTC.
[2] As *Malus sylvestris* because there are not published relevant prescriptions.
[3] As *Sorbus torminalis* because there are not published relevant prescriptions.

Fifty seeds in four random replications were used both in the laboratory tests and in the nursery sowing trial. Comparisons were made between germination or viability means in the laboratory and nursery germination by means of the Duncan's t-test ($p<0.05$) using statistical software SPSS (NORUSIS, 1994).

Results

Nursery and laboratory germination

High nursery germination was observed in *Celtis australis* and *Cornus sanguinea* (*Table 5*). However, laboratory germination of the *Celtis australis* in the lab tests was very low, the difference being statistically significant. In contrast, for *Cornus sanguinea* there was no significant difference between laboratory and nursery germination. For *Cotinus coggygria, Laurus nobilis, Pistacia terebinthus* and *Rhus coriaria* laboratory germination was much higher than in the nursery, the differences being statistically significant (*Table 5*).

Table 5. – Comparison of nursery and laboratory germination (or viability) based on 4 replications each of 50 seeds.

Species	Laboratory Tests		Field sowing
	Germination (%) after pre-treatment	Viability (%) after TTC	Germination (%) in the spring without pre-treatment
Celtis australis	16 ± 4,6*[1]		79 ± 10,0*
Cornus sanguinea	65 ± 3,8 n.s.		79 ± 11,0 n.s.
Cotinus coggygria	73 ± 11,0*		19 ± 3,8*
Laurus nobilis	98 ± 2,3*		11 ± 2,0*
Pistacia terebinthus	60 ± 8,6*		17 ± 3,8*
Rhus coriaria	29 ± 6,8*		0 ± 0,0*
Carpinus betulus		73 ± 1,4*	9 ± 6,0*
Cercis siliquastrum		90 ± 1,6*	21 ± 6,8*
Euonymus europaeus		70 ± 6,9 n.s.	67 ± 8,2 n.s.
Fraxinus ornus		89 ± 7,5 n.s.	88 ± 0,0 n.s.
Malus sylvestris		98 ± 1,9 n.s.	96 ± 3,2 n.s.
Paliurus aculeatus		66 ± 3,2*	28 ± 8,0*
Phillyrea latifolia		75 ± 3,5*	0 ± 0,0*
Prunus spinosa		63 ± 2,9*	0 ± 0,0*
Sorbus torminalis		95 ± 2,1*	1 ± 2,0*

[1] Means within a species (rows) followed by * are statistically significant (DUNCAN's t-test, $p<0.05$). Means followed by n.s. are not significantly different. ± indicates standard deviation.

Nursery germination versus laboratory viability (TTC)

Viability percentages were similar to nursery germination means for *Euonymus europaeus, Fraxinus ornus,* and *Malus sylvestris,* the differences not being statistically significant. However, seeds of *Paliurus aculeatus* and *Cercis siliquastrum* germinated poorly in the nursery, while viability tests showed a significantly higher percentage of the seeds to be capable of germinating. Seeds of *Carpinus betulus, Sorbus torminalis, Phillyrea latifolia* and *Prunus spinosa* germinated very poorly or not at all in the nursery, while viability percentages were significantly higher.

The inception and duration of nursery germination for all 15 species is presented diagrammatically in *Figure 1*, and shows that no species germinated prematurely. *Cornus sanguinea* and *Malus sylvestris* began germinating in the last week of March (a little early), while *Cotinus coggygria, Cercis siliquastrum, Fraxinus ornus* and *Paliurus aculeatus* began germinating in the first week of April. *Celtis australis, Carpinus betulus, Sorbus torminalis* and *Euonymus europaeus* began germinating in the second week of April, while *Laurus nobilis* and *Pistacia terebinthus* began germinating the third week of the same month.

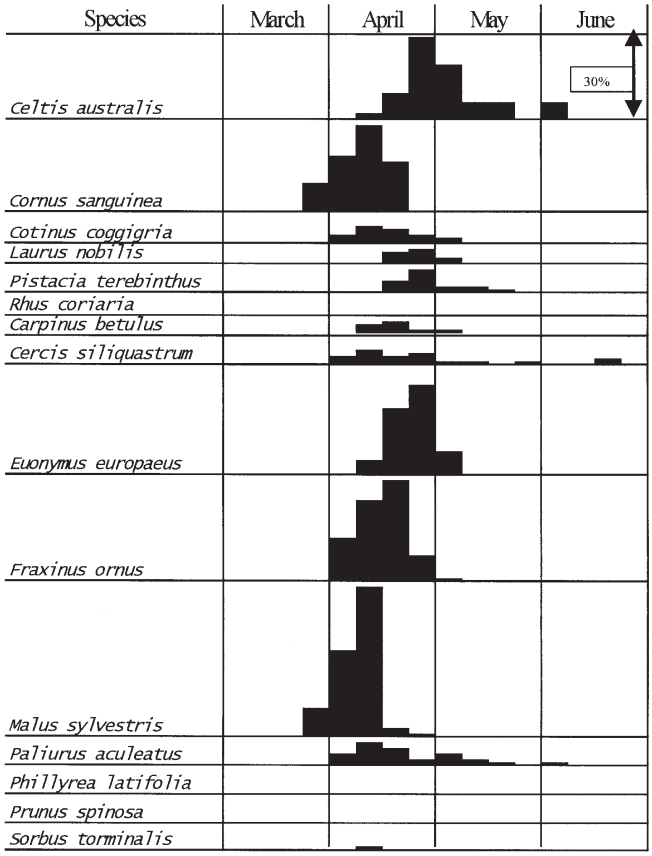

Figure 1. – Initiation and duration of nursery emergence after autumn sowing[1].

[1] The height of the columns show the % percentage of weekly emergence.

Discussion

Celtis australis, Cornus sanguinea, Euonymus europaeus, Malus sylvestris

The results showed that autumn sowing of these four species was adequate to meet the cold requirements for breaking dormancy. This finding is supported by numerous other reports (AOSA, 1985; ELLIS *et al.,* 1985; DIRR and HEUSER, 1987; YOUNG and YOUNG, 1992; HARTMANN *et al.,* 1997; ISTA, 1999). The external fleshy seed coat of *Celtis australis* was not removed in these trials, but this can aid germination (DIRR and HEUSER, 1997). The success of autumn sowing for *Cornus sanguinea* is also confirmed by YOUNG and YOUNG (1992), according to whom, autumn sowing gives better results than spring sowing when the seeds are fresh. Removal of the fleshy outer coat of *Euonymus europaeus,* as performed in this trial, and sowing quickly thereafter to prevent the seeds drying out (RUDOLPH, 1974), gave good germination; in this trial, seeds were collected in late November and sown before mid-December after fleshy coat removal (*Table 1*).

Fraxinus ornus

Autumn sowing of this species also met the cold requirements for removal of dormancy, is supported by other reports (YOUNG and YOUNG, 1992). European nurseries typically autumn sow seeds of this species immediately after collection while the appendages are still green, and obtain high germination (YOUNG and YOUNG, 1992). In this trial seeds were gathered at the beginning of December when the wings were dark brown, but they still germinated 88%. Compound stratification, that is a warm treatment (30 days) followed by cold stratification (90 days) has been recommended (BONNER, 1974). In this trial, nursery temperatures were high, especially in December (*Table 2*), which may have had a similar effect.

Laurus nobilis, Prunus spinosa, Sorbus torminalis, Carpinus betulus

These species are known to exhibit embryo dormancy, and numerous reports have indicated that seeds respond well to cold, wet nursery conditions over winter (AOSA, 1985; ELLIS *et al.,* 1985; DIRR and HEUSER, 1987; YOUNG and YOUNG, 1992; TAKOS and MEROU, 1995; HARTMANN *et al.,* 1997; ISTA, 1999). Elsewhere it has been demonstrated that low temperatures in northern nurseries can harm the seeds (*Laurus nobilis*), so autumn sowing should be avoided (TAKOS, 2001).

Prunus spinosa seeds failed to germinate in this trial probably because they were harvested late (end of October). In similar circumstances elsewhere, *P. spinosa* seeds tended to germinate the following year (GRISEZ, 1974; TAKOS and MEROU, 1995).

Very few *Sorbus torminalis* seeds germinated, which was surprising because they were shallowly sown and kept moist overwinter (*Table 2*), conditions that produced good germination elsewhere (YOUNG and YOUNG, 1992). As with *P. spinosa* seeds, collection was late (mid-October) and the *S. torminalis* seeds had dried considerably by the December sowing.

Low germination of *Carpinus betulus* seeds was anticipated due to their late harvest (October 1). Elsewhere it has been reported that seeds of this species must be harvested early, in September, while still green, and sown immediately (DIRR and HEUSER, 1987; TAKOS and MEROU, 1995).

Pistacia terebinthus

Like those of other *Pistacia* species, dormancy in *P. terebinthus* seeds may be due to hard seed coats (ELLIS *et al.,* 1985; TSAKALDIMI and GANATSAS, 2001). This may be removed with H_2SO_4 treatment for 10 minutes, or by breaking the endocarp (ELLIS *et al.,* 1985). Autumn sowing is common (DIRR and HEUSER, 1987), but in the trial reported here germination failure after autumn sowing was likely because the seeds had been stored for two months. This allowed the seed coats to harden in a large portion of the lot, and the coats did not soften sufficiently over winter to permit germination in the spring. Elsewhere it has been recommended that *Pistacia* seeds be sown immediately after harvest to avoid this coat hardening (YOUNG and YOUNG, 1992).

Cotinus coggygria, Cercis siliquastrum

Seeds of these species have double dormancy (a hard coat and embryo dormancy), and while low winter temperatures probably overcame embryo dormancy, the seed coats remained hard. Other reports have mentioned that autumnal sowing of *C. coggygria* succeeds if the seeds are harvested while green (late August, early September), and sown immediately (HEIT, 1967; DIRR and HEUSER, 1987; RUDOLPH, 1974). In this trial, the seeds were gathered early (late August), but were stored more than 3 months during which time their seed coats hardened. Similarly, a large portion of the seeds of *Cercis siliquastrum* hardened during storage and did not soften over winter.

Rhus coriaria

Rhus coriaria seeds also have double dormancy as besides the fact that they are hardcoated, they also show an additioanal embryonic dormancy (DOUSSI and THANOS, 1994). The *Rhus coriaria* seeds used in this trial were not scarified as has been recommended (YOUNG and YOUNG, 1992), and therefore autumn sowing was not sufficient to soften the hard seed coats.

Paliurus aculeatus

Due to the hard seedcoats, germination of this species was reported to be high (92%) after seeds have been soaked in concentrated H_2SO_4 for 4 hours, but lower (70%) following cold stratification for 4 months (TAKOS *et al.,* 2001). In this trial, *P. aculeatus* seeds were not stratified prior to sowing, so not only was the over-winter period in the nursery less than 4 months, it was interrupted by warm intervals (*Table 2*). Thus, germination was poor.

Phillyrea latifolia

Despite showing high viability in the TTC tests, seeds of this species failed to germinate. There are no published reports of seed performance so this failure cannot be explained. *P. latifolia* belongs to the *Oleaceae* family, the seeds of which are known to contain oils in the endosperm and seed coat that inhibit germination (LAGARDA *et al.,* 1983a, b; CRISOSTA and SUTTER, 1985; VOYIATZIS and PORLINGIS, 1987); however, the possibility of embryo dormancy cannot be excluded. The internal woody seed coat is not only hard, but may also contain oils or other inhibitors.

Conclusions

Of the 15 species investigated, seeds with embryo dormancy, which included *Celtis australis, Cornus sanguinea, Euonymus europaeus, Fraxinus ornus, Malus sylvestris, Prunus spinosa, Laurus nobilis* and *Sorbus torminalis,* germinated successfully following the few moths of cold stratification after being autumn sown in the nursery. For *Carpinus betulus, Cercis siliquastrum, Cotinus coggygria, Paliurus aculeatus, Phillyrea latifolia, Pistacia terebinthus,* and *Rhus coriaria,* the low winter temperatures were insufficient to break dormancy due to hard seed coats, or double dormancy (hard coat and embryo dormancy), despite plenty of moisture. None of the species displayed premature germination, although seeds of *Cornus sanguinea* and *Malus sylvestris* began germination at the end of March. All other species that germinated did so within the first two weeks of April, and germination was complete in late April or early May.

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Reciprocal and Maternal Effects on Growth and Form Traits in Radiata Pine in New Zealand

By S. KUMAR[1*] and H. X. WU[2]

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Abstract

The information from two experiments was used to study reciprocal and maternal effects on several growth and form traits in *Pinus radiata.* In *Experiment 1*, 10 families and their reciprocals obtained from a 5 x 5 diallel experiment were planted across three sites. In *Experiment 2*, 17 parents were used in a partial diallel design and all available crosses were planted at a single site. All three sites for *Experiment 1* were assessed at 9 years of age. The site for *Experiment 2* was assessed at the age of 6-years. Four growth and form traits, namely diameter at breast height (DBH), straightness (STR), branching (BR) and malformation (MAL) were measured in both experiments while needle retention (NRA) was assessed only in *Experiment 1.*

General combining ability (GCA) effects, in *Experiment 1*, were found to be significant for all traits. The overall reciprocal effects were, in general, found insignificant at all three sites. Further partitioning of the reciprocal effect revealed that maternal effect was non-significant for all traits at all three sites and non-maternal (or residual reciprocal) effect was significant only for BR at Site 1 and for NRA at Site 2. The interaction of reciprocal by site effect was found non-significant for all traits. Analysis of *Experiment 2* revealed significant overall reciprocal effects for all traits. Further partitioning of reciprocal effects revealed that maternal effect was significant for all traits except STR, but non-maternal effects were significant for STR and BR only. This study showed that existence of maternal and non-maternal effects could vary considerably for different sets of parents. Estimated correlation between parental GCA estimates obtained with-and-without taking into account reciprocal effects were 0.99 for all growth and form traits considered in this study.

Key words: Reciprocal effect, maternal effect, radiata pine, general and specific combining abilities.

Introduction

In monoecious tree species, like *Pinus radiata*, it is possible to use the same tree both as a male and a female parent in controlled crossing. Assuming normal diploid chromosomal inheritance, each parent contributes genes equally to the offspring. Thus, the progeny of $m_i \times f_j$ (i^{th} tree as male and j^{th} tree as female) are expected to be, on the average, genetically similar to those of $m_j \times f_i$ (i^{th} tree as female and j^{th} tree as male). The difference in the performance of a full-sib family when a parent is functioning as the mother or the father is termed as reciprocal effect. Reciprocal crosses may not perform the same owing to early phenotypic differences between them in the size and vitality of the embryos, associated with respective peculiarities

[1] NZ Forest Research Institute, Private Bag 3020, Rotorua, New Zealand.

[2] CSIRO Division of Forestry and Forest Products, PO Box E4008, Kingston, ACT 2604, Australia.

[*] Corresponding author, Email: Satish.Kumar@forestresearch.co.nz