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Full Length Research Paper

The effects of sowing time and depth on germination and seedling percentage of the Taurus Cedar (*Cedrus libani* A. Rich.)

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The aim of this study is to determine the appropriate sowing time and depth in spring for Taurus Cedar (*Cedrus libani* A. Rich) in Turkey. The effects of sowing time and depth were determined with regard to the germination rate of seedlings' quality. The seeds were collected from Kapidag-Isparta, in Turkey, in 2003 and 2004. The seeds were sown at 6 different dates and 5 different depths under natural conditions without any pre-treatment in 2004 and 2005. The statistical approach was randomized block design with 3 replications and 100 seeds were sown for each replication. The 1000 seed weights and germination percentages of the seeds were determined under laboratory conditions before sowing in the nursery. According to analysis of variance and Duncan's test, in locations with appropriate soil conditions, seeds should be sown at 5 mm depth as soon as possible until the second half of February. The germination of 65% can be obtained from seeds sown under these conditions. High quality, bare root and one-year-old seedlings can be grown from approximately 55% of the seeds. Moreover, spring sowing should not take place after March 15th and at depths of more than 20 mm.

Key words: *Cedrus libani*, germination, seedling percentage, sowing time, sowing depth.

INTRODUCTION

Cedrus species are represented by four different genera with a distribution covering North Africa, South Anatolia, Lebanon, Cyprus and the Himalayas. These genera are: *Cedrus libani* A. Rich. (Turkey, Lebanon and Syria), *Cedrus deodora* Loud. (Himalaya Mountains and Nepal), *Cedrus brevifolia* Hen. (Cyprus) and *Cedrus atlantica* Manettii. (Atlas Mountains) (Yaltirik, 1993; Ansin and Ozkan, 1997; Boydak, 2003).

Taurus Cedar (*C. libani* A. Rich.), which is mainly distributed in Antitaurus and Taurus Mountains, is an important tree specie which occurs naturally only in Turkey, apart from 400 natural members in Lebanon. It has a wide distribution area in the Mediterranean Region, from Fethiye in the west to Kahramanmaras in the east, incorporating varied ecological characteristics (Kantarci, 1982; Boydak and Calikoglu, 2008). There are isolated stands in Afyon and stands in the form of small islands locally in Erbaa and Niksar districts (Ansin and Ozkan, 1997). Natural forests of Taurus Cedar in Turkey cover an area of approximately 110000 ha (Boydak et al., 1990; Boydak, 2003). In addition, owing to the ongoing afforestation efforts, young and old pure forests of this species cover an area over 300000 ha (Boydak and Calikoglu, 2008). For instance, approximately 43 million (25.79%) of all 166719000 needle-leaved seedlings grown in Turkey's forest nurseries, to use for afforestation in 2007, were composed of Taurus Cedar seedlings, which were transferred to afforestation areas (Anonymous, 2008).

According to FAO report, Turkey is among the top ten most successful countries in the field of afforestation, and also the report reveals that Turkey is among several countries that are able to enhance her forest lands (Anonymous, 2005). Within this scope, Turkey successfully afforested and rehabilitated 400000 ha of land in 2006. The Ministry of Environment and Forestry started a

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national afforestation campaign with the aim of covering 30% of national territory with forests in 2008. During 2008, 60 million Taurus Cedar seedlings were grown and transferred to an area of approximately 35000 ha in the scope of seedling growth program (Anonymous, 2008).

The Central Anatolian Region, which has the poorest forest cover of all seven regions of Turkey, is considered as a part of the Mediterranean ecosystem (Cetik, 1985; Birant, 2006). This region is estimated to have a potential afforestation area of 1.7 million ha. Taurus Cedar constitutes 30% of the trees which have been used in the afforestation of this land (Anonymous, 2008). Hence, Taurus Cedar is one of the most-preferred species of the afforestation activities carried out in Mediterranean ecosystem and semi-arid zones (Carus and Çatal, 2010). Therefore, it is one of the species which are mostly grown in nurseries. Egirdir forest nursery is one of the pioneering nurseries mass-producing Taurus Cedar. Seedlings of this species are grown as aged 1-0 and bare root in Egirdir nursery and they are sent to afforestation areas, while they are grown as aged 2-0 (bare root or tubed) in other nurseries. One-year-old and bare root seedlings of Egirdir nursery are preferred by the foresters as well.

In general, fall (September - November) sowing is preferred and seeds are sown at depths of 15 - 20 mm on average in the nursery. However, germination sometimes starts just after fall sowings and, seedlings can be frostbitten, leading to significant losses. Moreover, too many seeds are used in this method, as the required level of germination and seedling survival cannot be obtained by standard sowing methods. In addition to the use of excessive amount of seed, care and protection expenditures of newly-planted seedlings can be of a great importance in fall sowing. For these reasons, the present study aimed to determine appropriate spring sowing time and depth that would achieve the required quality and quantity of seedlings of this species under the conditions of Egirdir Forest nursery.

MATERIALS AND METHODS

Egirdir Forest Nursery experimental site is located at an altitude of 950 m; pH of the soil ranges from 6.79 to 7.83 and has alkaline features. Organic matter content is at an average of 1.67%, (Anonymous, 2004). In the nursery, irrigation water is obtained from Egirdir Lake. According to results of laboratory analysis, the quality of the water was appropriate for seedling irrigation (Anonymous, 2004). Within the nursery and its surroundings, annual average temperature is 12 - 13°C with a maximum temperature of 38°C, and annual average rainfall is 763 mm (Anonymous, 2006).

Seeds used in the present study were collected manually from Isparta Forest Enterprise Directorate, Senirkent Central State Forest Enterprises and Kapidag site on 10th to 15th September, 2003 and 2004. The average altitude and slope, main rock and aspect of Kapidag were respectively 1500 m, 40%, limestone and north. Across the region, 2003 showed a poor seed crop year, while 2004 displayed abundant seed crop year for Taurus Cedar. Equal numbers of cones were collected from 30 trees (aged between 70 and 80 years), that were at least 50 m away from each other.

Collected cones were kept under open field conditions until November 15 and irrigated twice a day for 20 min with a sprinkler. Seeds were extracted manually from cones between 15th to 20th November. After 1000 seed weight and full seed percentages were determined, they were kept in cold storage at 2 - 4°C until sowing. Average weights of 1000 seeds were determined according to International Seed Testing Association (ISTA) rules (ISTA, 1993). Filled seed percentage was identified with snipping of 8 x 100 seed lots.

Seeds collected in 2003 and 2004 were sown in 2004 and 2005, respectively, at 6 different dates and 5 different depths according to a randomized block design with 3 replications on the lines which were marked above seed beds of 120 cm width. Depending on severe winter conditions (rain, snow or frost) of the site of the nursery, soil can be appropriate for sowing at the beginning of February. Thus, the first sowing trial was set on February 1. The experimental design is as shown in Table 1. Place and row of the treatments in replications were determined by casting lots. A mixture of 50% leached brook alluvia and 50% humus of Anatolian Crimean Pine (*Pinus nigra* Arnold. subsp. *pallasiana* (Lamb.) Holmboe) was used as covering media. In addition, 3 x 100 seed lots from the two sample years were subjected to germination test in the laboratory, with the aim of comparing germination rates obtained in the nursery.

In trials, totally 300 seeds, 100 in each replication were sown with 2 cm spacing for each treatment. On seed beds, the distance between sowing rows was 15 cm. A 15 cm isolation zone was reserved between seed bed edges and treatments. During the period of the completion of the germination process, seed beds were manually irrigated regularly and equally on the days when there was no rain or frost. From the completion of emergence to the end of the vegetation period, seedlings were irrigated by sprinkler every other day in the early morning, at such amount to meet the field capacity. No fertilizer was used until the end of the trial. Weeds on the seed beds were removed manually.

Juvenile seedlings were observed and the emerging ones were counted and marked each day during the 20 day period starting from the date that seeds started to emerge on the surface and ended when the germination was completed. Germination rates (%) of seeds sown on different dates and at different depths, healthy seedling rates (%) achieved from sown seeds and healthy seedling rates achieved from germinated seeds (%) were calculated. Healthy seedling counts were made in November, when the vegetation period of the sowing year was over. The Turkish Standards Institute (TSE) defines healthy seedlings as the seedling with root-collar diameter of at least 2 mm and seedling height of 6 cm or more (Anonymous, 1988).

Data were analyzed using statistical package for the social sciences (SPSS) program (SPSS Inc., 2002). Before analysis, the data was checked for normality and data anomalies. Data anomalies occur because of mis-measuring, mis-reading or mis-recording and can cause data to diverge from normal distribution (Kalipsiz, 1994; Sokal and Rohlf, 1995). As proportional data did not show a normal distribution, they were analyzed after conversion by arc-sine transformation (Yurtsever, 1974; Kalipsiz, 1994). Analysis of variance (ANOVA) and Duncan's tests were used to determine separate and combined effects of sowing time and depth on germination percentages and healthy seedling rates which was set at $p < 0.05$ (Satterthwaite, 1946; Milliken and Johnson, 1984). ANOVA was performed based on the following model:

$$Y_{ijk} = \mu + + ST_i + SD_j + ST_iSD_j + e_{k(ij)}$$

Where, Y_{ijk} = The value of kth seed sown in ith time jth depth; μ = general mean; ST_I = the effect of ith sowing time; SD_j = the effect of jth sowing depth; ST_iSD_j = the effect of interaction between ith sowing time and jth sowing depth; $e_{k(ij)}$ = experimental error.

Table 1. Experimental design.

Seed harvesting	Seed sowing	Sowing time	Sowing depth (mm)
2003	2004	01st February 15th February 01st March 15th March 01st April 15th April	5 10 20 30 40
2004	2005	01st February 15th February 01st March 15th March 01st April 15th April	5 10 20 30 40

RESULTS AND DISCUSSION

1000 seed weight and full seed percentages of the seeds collected in 2003 were 79.13 g and 89%, respectively, compared with 84.20 g and 91% of those collected in 2004. The 1000 seed weight and full seed percentages in 2004 were higher than those in 2003 since 2004 was abundant seed crop year for this species in Kapidag and gene transaction among trees was at the highest level during 2004. Odabasi (1990) studied seed features of this species, and found that the average 1000 seed weight was 76.36 g and empty seed rate was 21.67%.

ANOVA of all tested factors indicated significant differences ($P < 0.001$) between sowing dates and sowing depths of seeds sown in 2004 and 2005. Interaction of sowing date and sowing depth was also found to be significant (Table 2). The F values given in the table indicate that the individual effects of sowing dates and sowing depths on the studied factors are more significant than their combined effects. For the seeds sown at different depths and on different dates in 2004, germination percentages varied between 4.0 and 61.67% (Table 3).

The highest rate of germination observed in 2004 was on 1st February at a sowing depth of 10 mm. At all sowing depths except for 40 mm, more than 50% of the seeds sown until 1st March germinated. However, irrespective of sowing date, seeds sown deeper than 20 mm showed a healthy seedling rate of less than 50% at the end of the vegetation period. This means only half of the seeds sown at dept deeper than 20 mm developed as high quality seedlings for plantation. When sowing dates in 2004 were taken into consideration, the healthy seedling rate of the seeds sown after 1 March was less than 50%, irrespective of variations in sowing depth. Approximately, 50% of the juvenile seedlings that formed from the seeds sown on 1st April or later at 30 and 40 mm depths did not survive due to dumping-off (Table 3).

Results from 2005 showed similarities to those recorded in 2004. However, seeds sown in 2005 achieved a slightly higher rate of germination than those sown in 2004. As in 2004, the highest germination rate in 2005 (67.33%) was also recorded to be on 1st February at a depth of 10 mm. On the other hand, the lowest germination rate (0.3%) was recorded on 15th April at a depth of 40 mm (Table 4). In 2005, the rate of healthy seedlings that were usable in afforestation decreased to less than 50% after 15th February and at a depth of more than 20 mm.

The results of the sowings carried out in both years were found to be similar, except for the sowings on 1st April. This means that, except for extreme conditions, seeds which are sown in Egirdir forest nursery during the same period of each year and at the same depth will produce similar germination rates. Studies of appropriate sowing date and sowing depth in different tree species showed that there were no differences in germination rates between years (Arnold, 1972; Sorensen, 1978; Rowan, 1980).

In both years of the present study, germination rate between 55.0 and 67.33% were achieved from the seeds sown between 1st February and 1st March, at depths of 5, 10 and 20 mm (Figures 1 and 2). More than 70% of the juvenile seedlings that germinated at these dates and depths generally maintain healthy development until the end of the vegetation period. At the same time, the rates of healthy seedlings derived from the seeds of same sowing conditions, were higher than 50%, except for the sowings from 1st March. However, when the sowings were made at depths above 20 mm, the healthy seedling percentage at the end of the vegetation period was lower than 30% especially in 2004, regardless of sowing time

Table 2. Results of analysis of variance.

Sowing year	Source of variation	Traits (%)	Degrees of freedom	F value	Significance (P)
2004	ST_i	Germination	5	1574.83	< 0.001
		Seedling/Seed	5	1285.58	< 0.001
		Seedling/Germination	5	44.70	< 0.001
	SD_j	Germination	4	166.78	< 0.001
		Seedling/Seed	4	331.94	< 0.001
		Seedling/Germination	4	47.66	< 0.001
	ST_iSD_j	Germination	20	11.79	< 0.001
		Seedling/Seed	20	5.41	< 0.001
		Seedling/Germination	20	2.72	< 0.001
	$e_{k(ij)}$	Germination	60	-	-
		Seedling/Seed	60	-	-
		Seedling/Germination	60	-	-
2005	ST_i	Germination	5	3262.69	< 0.001
		Seedling/Seed	5	1453.58	< 0.001
		Seedling/Germination	5	44.35	< 0.001
	SD_j	Germination	4	184.02	< 0.001
		Seedling/Seed	4	156.82	< 0.001
		Seedling/Germination	4	49.41	< 0.001
	ST_iSD_j	Germination	20	16.45	< 0.001
		Seedling/Seed	20	2.78	< 0.001
		Seedling/Germination	20	6.34	< 0.001
	$e_{k(ij)}$	Germination	60	-	-
		Seedling/Seed	60	-	-
		Seedling/Germination	60	-	-

Table 3. Means of sowing in 2004.

Sowing Times (2004)		Sowing depths				
		5 mm	10 mm	20 mm	30 mm	40 mm
Germination (%)	01st February	61.33^{a}	61.67^{a}	61.33^{a}	59.67^{a}	55.67^{c}
	15th February	62.33^{a}	62.00^{a}	61.67^{a}	59.00^{ab}	52.00^{de}
	01st March	56.33^{bc}	61.00^{a}	60.00^{a}	54.33^{cd}	49.33^{e}
	15th March	53.00^{cd}	56.00^{bc}	54.00^{cd}	41.00^{g}	31.67^{i}
	01st April	30.33^{ij}	45.00^{f}	46.33^{f}	37.33^{h}	28.33^{j}
	15th April	10.67^{l}	17.00^{k}	16.33^{k}	07.00^{m}	04.00^{n}
Seedling/Seed (%)	01st February	54.33^{a}	55.67^{a}	51.33^{b}	46.33^{d}	37.33^{f}
	15th February	56.67^{a}	56.33^{a}	49.67^{bc}	45.00^{d}	33.67^{g}
	01st March	47.33^{cd}	51.00^{b}	41.67^{e}	34.67^{fg}	29.33^{h}
	15th March	44.67^{d}	46.67^{d}	40.33^{e}	30.00^{h}	17.33^{j}
	01st April	25.33^{i}	33.33^{g}	24.67^{i}	17.00^{j}	14.67^{j}
	15th April	07.33^{l}	10.67^{k}	08.00^{kl}	01.33^{m}	00.33^{m}
Seedling/ Germination (%)	01st February	88.59^{ab}	90.41^{a}	83.75^{abc}	77.82^{abcde}	67.23^{defgh}
	15th February	90.92^{a}	90.91^{a}	80.66^{abcd}	76.32^{abcde}	64.73^{efghi}
	01st March	84.06^{abc}	83.65^{abc}	69.64^{cdefg}	65.73^{efghi}	59.56^{fghij}
	15th March	84.31^{abc}	83.34^{abc}	74.69^{bcde}	73.20^{cdef}	55.28^{ghij}
	01st April	83.64^{abc}	74.07^{bcdef}	53.36^{hij}	45.42^{j}	52.00^{ij}
	15th April	69.87^{cdef}	63.30^{efghi}	48.89^{j}	21.80^{k}	11.11^{k}

Table 4. Means of sowing in 2005.

Sowing times (2005)		Sowing depths				
		5 mm	10 mm	20 mm	30 mm	40 mm
Germination (%)	01st February	66.67^{ab}	67.33^{a}	66.33^{ab}	65.00^{abc}	61.33^{de}
	15th February	64.00^{bcd}	63.00^{cd}	63.00^{cd}	59.67^{e}	53.67^{f}
	01st March	55.00^{f}	61.00^{de}	61.67^{de}	55.33^{f}	50.33^{g}
	15th March	31.00^{j}	45.00^{h}	45.67^{h}	37.33^{i}	30.00^{j}
	01st April	09.67^{l}	15.67^{k}	16.33^{k}	06.67^{m}	04.00^{mn}
	15th April	05.00^{m}	11.00^{l}	10.67^{l}	01.33^{no}	00.33^{o}
Seedling/ seed (%)	01st February	56.33^{a}	54.67^{ab}	53.00^{ab}	49.00^{c}	41.67^{f}
	15th February	55.67^{ab}	56.33^{a}	52.67^{b}	45.00^{de}	39.00^{f}
	01st March	46.67^{cd}	48.67^{c}	42.00^{ef}	31.67^{h}	26.33^{i}
	15th March	25.00^{i}	35.00^{g}	27.00^{i}	21.33^{j}	15.67^{k}
	01st April	07.00^{lm}	08.33^{l}	5.33^{lmn}	02.00^{no}	00.33^{o}
	15th April	04.67^{mn}	05.00^{lmn}	04.00^{mn}	00.33^{o}	00.00^{o}
Seedling/ germination (%)	01st February	84.58^{abc}	81.19^{abc}	79.96^{abc}	75.42^{bcd}	67.98^{cdef}
	15th February	87.00^{ab}	89.40^{ab}	83.62^{abc}	75.40^{bcd}	72.71^{bcde}
	01st March	84.83^{abc}	79.78^{abc}	68.14^{cdef}	57.27^{efg}	52.15^{fgh}
	15th March	80.81^{abc}	77.88^{abc}	59.59^{defg}	57.16^{efg}	52.40^{fgh}
	01st April	72.29^{cde}	53.48^{fgh}	32.48^{ij}	29.17^{jk}	6.66^{lm}
	15th April	93.33^{a}	46.01^{ghi}	38.77^{hij}	16.67^{kl}	0.00^{m}

and even if the seeds germinated and raised out of the earth. This situation causes serious problems, such as loss of seed, necessity of too much covering material, work force and healthy seedling/unit value. In other words, sowings carried out at a depth of more than 20 mm at Egirdir Forest Nursery are not economically viable.

The results of previous studies showed that sowing between 10 - 20 mm depth was sufficient for Taurus Cedar (Saatcioglu, 1976; Anonymous, 1986; Anonymous, 1994). However, according to the results of the present study, satisfactory germination and healthy seedlings can be acquired from the seeds sown at a depth of 5 mm and especially between 1st to 15th February. Furthermore, no matter when they were sown, 70% of the juvenile seedlings of the seeds that were sown at a depth of 5 mm continued their healthy development until the end of the vegetation period (Figures 1 and 2). At the same time, sowing at a depth of 5 mm significantly reduced the amount of covering material required. Therefore, it is possible to reduce seedling cost by sowing between 1st to 15th February at a depth of 5 mm. Nevertheless, it is important that seedbeds are smooth and homogeneous, as the smoothness of the seedbed is one of the most important issues in achieving a uniform sowing depth. If the seed bed is not prepared level and smoothly, sowing depth may vary from one line to another or even on the same line. This change causes a reduction in germination rate, retardation of growth and a heterogeneous physical structure of the surviving seedling (Thompson, 1984).

When the germination effects caused by the people carrying out sowing are ignored, seed sowing date changes depending on various factors. Some of these relate to the development of seedlings and others solely to operational reasons (Thompson, 1984). Sorensen (1978) reported that Douglas fir (*Pseudotsuga meziesii* Mirb.) seedlings, which were sown earlier than normal, produced buds earlier and developed longer offshoots. In Douglas fir seeds sown between April 23rd and May 12th, even a sowing variation of one day caused 1-0 aged seedlings to develop an additional 0.5 mm height. This difference in budding and height development continues in the second year. Therefore, it is possible to acquire physically better developed saplings through early sowing. However, some factors, such as severe cold and wet soil, also reduce the rate of germination (Sutherland and Anderson, 1980). These situations should be taken into consideration in the sowing period.

In the laboratory germination tests carried out in the scope of the present study, an average germination rate of 60% was achieved from the seeds of 2003 and 68% from those of 2004. Therefore, germination rates that were recorded from the nursery were comparable with laboratories results. According to some researchers on growing of this specie in nursery, it was found that 81.6% of seeds sown at the beginning of the winter season developed quality seedlings, while in late spring sowings, only 2% of the seeds germinated and some of them subsequently died. Thus, it was suggested that seeds of Taurus Cedar should be sown in the late autumn or early winter in Turkey (Saatcioglu, 1971; Anonymous, 1994). However, in practice, foresters prepare the sowing calendar according to ecological conditions of the nursery.

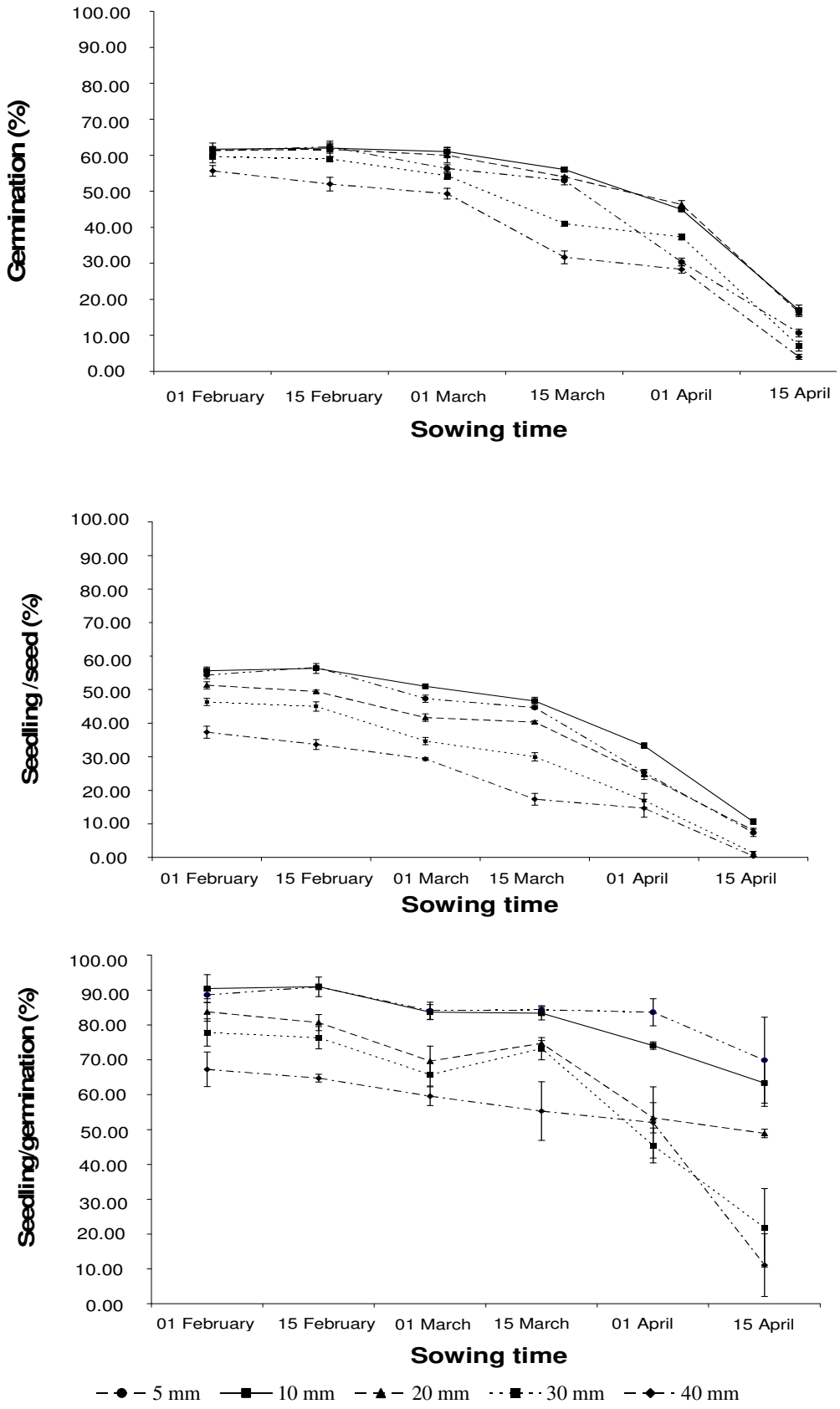

Figure 1. Interactions between sowing time and sowing depth in 2004.

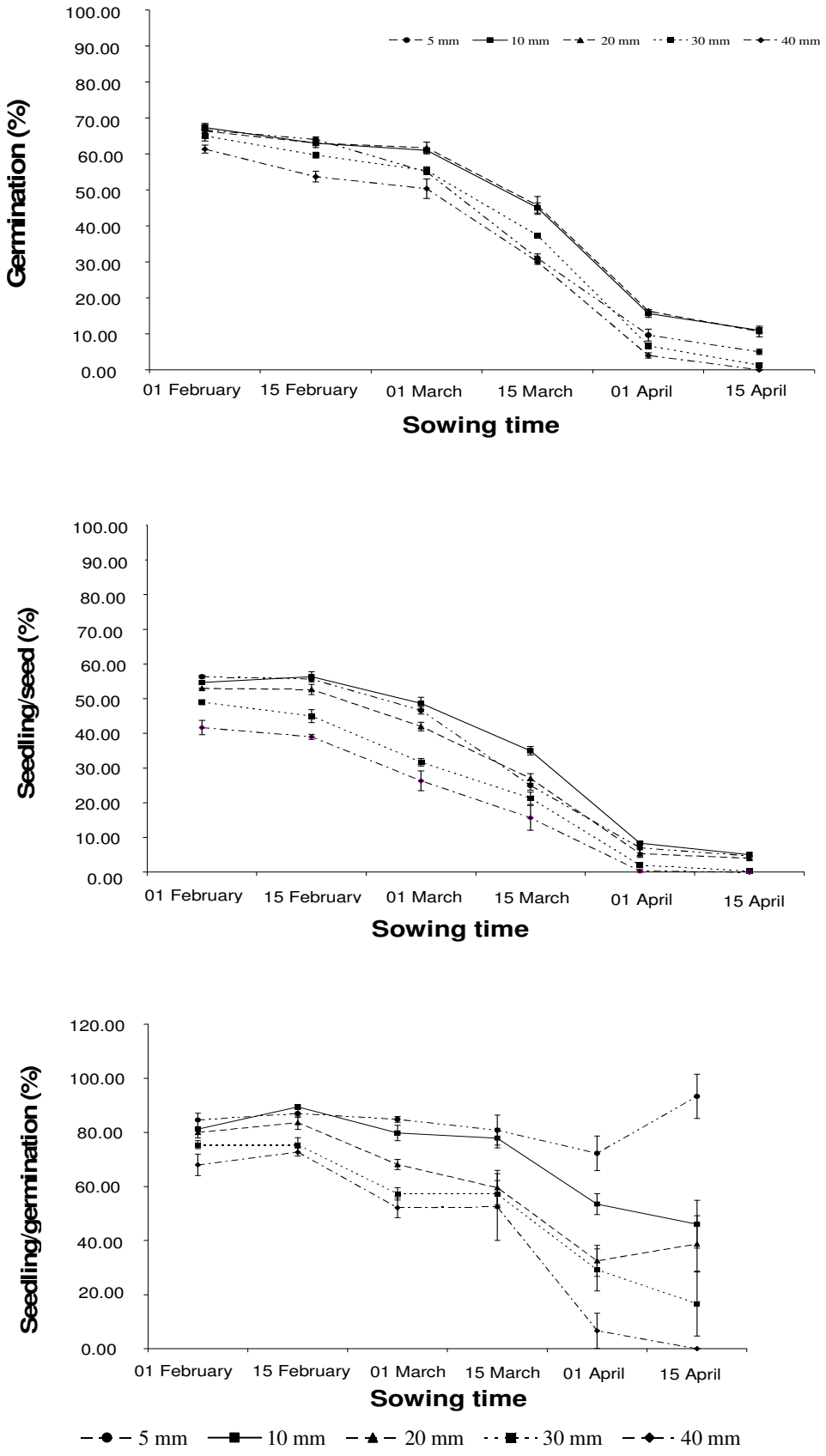

Figure 2. Interaction between sowing time and sowing depth in 2005.

For example, it is impossible to sow Taurus Cedar in Egirdir Forest Nursery between November - February, due to severe winter conditions (frozen ground, rain, mud or snow). Therefore, sowings should occur either in autumn or early spring. Autumn sowings in the nursery have been shown to be risky, since Egirdir forest nursery is located in the transition zone of the Mediterranean and continental climates. Thus, in some years, warm weather conditions soon after autumn sowings may prompt premature germination. These juvenile seedlings which germinate early are likely to be damaged or killed by severe frost in late October and early November.

Moreover, autumn sowings in the nursery produce low quality seedlings and costs are recorded to be higher due to high maintenance and protection costs during the severe winter. Therefore, it is more profitable and practical to sow Taurus Cedar in Egirdir Nursery at a depth of 5 mm and in the earliest period of spring when soil temperature reaches + 5°C at 10 cm depth. Yet, the results of the present study also show that early spring sowings are satisfactory for sowing success.

Conclusion

For seeds that were sown in 2004 and 2005 at a depth of 5 mm, the germination rate after 15th February sowing was lower than 60%. This is due to the fact that the 10°C and higher temperature recorded in March leads to a loss of moisture on the soil surface in a short time. The ideal germination temperature for this species is between + 5 and +10°C. Germination rates for the same seeds that were sown after 1st March at depths of 10 and 20 mm were less than 60%. Therefore, sowings at a depth of 5 mm or less should be carried out as early as possible till the second half of February if the soil conditions are appropriate.

Except for 1st February 2005, sowings at depths of 30 and 40 mm did not produce a germination rate of more than 60%. In both years, at the sowing depths with a germination rate of 50% or more, the rate of quality seedling sowed after the second half of March decreased to the level of 25-35%. This means approximately 70% of the seeds that were sown after 15th March was lost. Furthermore, no matter at which depth they were sown or at which rate they germinated, 25% of juvenile seedlings that germinated from sowings made after March died. Therefore, Taurus Cedar seeds should not be sown in the nursery after 15th March.

Seeds that were sown under the nursery conditions in early February (February 1st to 15th) at a depth of 5 mm achieved germination rates close to those observed in laboratory tests and similar to values given in the literature. This shows that there is enough germination in spring sowings too. Therefore, because of technical and economic difficulties, autumn sowings should be abandoned and spring sowings should be practiced for this species in Egirdir forest nursery.

It is possible to acquire successful results in spring sowings until 15th March at depths of 10 and 20 mm. However, these depths are not recommended other than for economic or technical reasons. It is recommended that sowing should take place between 1st to 15th February, or earlier, when the soil conditions are suitable, at a depth of 5 mm.

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