TREE AGE EFFECTS ON SEED GERMINATION IN *SORBUS TORMINALIS*

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Summary. Wild service tree (*Sorbus torminalis)* is a valuable native species in Iran. It is one of the best alternative species for plantation in Hyrcanian forest in Northern Iran. In order to determine tree age effects on seed germination in a mountainous nursery, seeds were collected from 40 individual trees on nearly 40000 hectares of Iranian residual forests (1700-2200 m altitude) and planted during 2 successive years in a nursery, located 1500 m above sea level. Percentage of germinated seeds was recorded for the two planting dates. Age effects (DBH) on seed germination rate were significant ($p<0.05$). The best germination rate was related to trees with DBH of 25 to 35 cm both in the first and second year. Besides, differences between total germination rate during the first and second years were significant ($p<0.01$). Seed germination measured in the first year increased by 9.22% compared with the second year. The

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decrease in seed germination rate recorded in older individuals was stronger than in the younger ones.

Key words: nursery, seed germination, *Sorbus torminalis*, tree age.

INTRODUCTION

Sorbus torminalis is a tall tree which is economically valuable (Lanier, 1993; Piagnani and Bassi, 2000; Demersure et al., 2000). It is also used as a medicinal plant (Tsitsa-Tzardi et al., 1992). The natural distribution of *Sorbus torminalis* is rather large, from the north of Maghreb to the south of Sweden and from the east of Great Britain to the north of Iran (Demersure et al., 2000). In the north part of Iran, its best habitate is in the fagetum, located on the foothills about 1500 to 1800 m above sea level at the north and the north-west aspects, on deep soils. At these sites, sometimes it can be seen with a height more than 32 m and its DBH can reach up to 100 cm (Espahbodi et al., 2002). It is also found on the steep foothills of the west and the south-west of the mountain ranges of the area where the soil is poor and usually stony, mixed with oaks and beeches (Zare et al., 2002).

Seed germination, seedling production and growth improvement of *Sorbus torminalis* have been studied by many researchers, such as Meyer (1980), Piagnani and Bassi (2000), Yagihashi, et al. (1998), Lyapova and Palashev (1988), Chalupa (1992), Takose and Efthimioa (2003). Many reforestation projects have been conducted to expand forests with the species in damaged areas or reproductive parts in fagetum and highland damaged forests in Iran. Despite this, experiences showed that producing seedlings in mountainous forest nurseries of the country is seriously limited. One of the main reasons is successive nursery bed freezing in which planted seeds would come out of the bed (Strouts et al., 1994; McDonald, 1984) and finally are consumed by seedeaters (Pepper, 1992). Espahbodi et al. (2002) improved seed germination rate by mulching the seedbed and increasing the planting depth. Another problem in *Sorbus* establishment is delaying the seed germination to one year after planting date. All of the seeds don't germinate during the first year and some of them remain in a dormant phase and germinate in the second year (Harris and Stein, 1974) which is harmful for seedling relocation.

It seems that delaying seed germination is related to seed physiology and tree age. Much of the studies on the effect of morphology of the mother plant on seed quality and quantity have been carried out on annual species and little attention has been paid to tree species (Malcolm et al., 2003). In general, larger seeds have an advantage over smaller ones in germination even in seedling survival and growth (Baskin and Baskin, 1998; Navarro and Guitian, 2003). This led to the suggestion of selecting larger seeds to improve seed germination rate and seedling vigour (Gamiely et al., 1990). For example, in peach rootstock (Malcolm et al., 2003) and *Eucalyptus regnans* (Close and Wilson, 2002) it has been reported that the best seed germination was related to the larger seeds. This, however, is not common for all plant species. For example, as found in *Glycine max*, the higher rate of germination was related to smaller seeds (Tiwari et al., 1982). In some species of *Sorbus*, Jensen (2003) suggested that seed and seedling vigour may be improved during late maturation and recommended late harvest.

There is insufficient data on the relationship between the age of trees and seed production in *Sorbus torminalis*. However, some species, such as ash (*Fraxinus exelsior*) and birch (*Betula pendula*) produce more quantitative and qualitative seeds during the mid-age period. In addition, beech and oak seed production enhanced and improved at the time of elderly period (Fennessy, 2002). In many forest tree species, the main period of seed production is fixed in the middle of age. For example, in *Abies nordmandiana* (Vidakovich, 1991) and *A. pinsapo* (Gatalan and Parados, 1983) the best age for seed production is between 30-40. Moreover, trunk diameter and plant vigour are the two considerable aspects in seed production which are effective in some species of *Garcinia,* such as *G. lucida* (Guedje et al., 2003). By contrast, in some plant species, such as *Pinus pongence*, all trees at different age were able to produce normal and vigorous seeds (McIntyre, 1928). Harris and Stein (1974) reported that *Sorbus* trees mature at the age of 15. However, insufficient data exist on seedling, seed germination and plant age of *Sorbus torminalis*.

MATERIALS AND METHODS

Seed collection and plantation

The research site was located in a vast area at Savadkooh forests in Northern Iran (about 40000 ha.) with 1700-2200 m altitudes. During autumn, 40 trees of *Sorbus* in the DBH range between 15 to 80 cm were randomly selected. As soon as the first colour variation during early October was observed (Shoemaker and Hargrave, 1936), the brown and ripe fruits were collected from top the parts of the individual trees. One hundred fruits were randomly selected from each tree and their weight, diameters as well as number of seeds in each fruit were recorded. The experiment was repeated in two successive years (2000 and 2001) and continued for two years. Two hundred sound seeds of each tree were planted in plastic pots in Orimalek Fareem nursery, located at 1550 m above sea level in the north part of the country, early in October of 2000 and 2001. To prevent seed freezing and emerging the seeds resulting from soil freezing, the pots were covered by a layer of plant mulch (Strouts et al., 1994; McDonald, 1984; Pepper, 1992; Espahbodi et al., 2002).

Data analysis

Germinated seeds in early spring after planting (on time germination) and germinated seeds during the two years after planting (delayed germination) were recorded from early April to middle of January. The Kolmogorov-Smirnov normality test was used to test the normality and Levens' test was used to determine homogeneity of variances. Then due to normal distribution of data improved by Kolmogorov-Smirnov normality test and equability of variances showed by Levens' test, one-way analyses of variance (ANOVA) were used to compare several DBH (age) and its effect on seed germination (on time germination, delayed germination and total germination). Duncan's multiple range test was used to separate the means of dependent variables which were significantly affected by mother trees DBH (age). To compare seed germination rate for the two years (2000 and 2001), paired data were analyzed using Student's t-test. Pearson correlation coefficients were estimated for all combinations of the recorded parameters.

RESULTS

Fruit and seed characteristics

The average weight of the studied fruits (4000) was 1.24 g ranging between 0.89 g and 1.71 g. The maximum fruit large diameter was 18.64 mm and its minimum was 12.57 mm with a mean of 15.32 mm. The average small diameter of the fruits was 11.01 mm and each fruit contained 1.91 seeds. The average weight of one healthy seed was 0.04 g (Table 1).

Characters of fruits	Mininum	Maxinum	Mean
Weight (g)	0.89	1.71	1.24
Large diameter (mm)	12.75	18.64	15.32
Small diameter (mm)	9.46	12.62	11.01
Number sound seeds per fruit	0.72	2.97	1.91
Weight of sound seeds (g)	0.03	0.06	0.04

Table 1. Characteristics of the collected fruits and seeds.

Correlation between the characters

Results showed that there was no correlation between fruit weight and tree diameter with seed germination rate. Fruit weight correlated negatively with the tree diameter (R= -0.350 p=0.027). Although the number of sound seeds per fruit correlated positively with the total number of seeds per fruit (R= +0.587 p=0.001), there was a negative correlation between the weight of one sound seed and the total number of seeds per fruit (R= -0.394 p=0.012). In addition, the average weight of one sound seed correlated positively with fruit average weight (R=+0.528 p= 0.000), the large fruit diameter (R= + 0.486 p= 0.001) and the small fruit diameter (R=+0.322 p=0.042).

Planting year	20 cm (15-25)	30 cm (26-35)	40 cm (36-45)	50 cm (46-55)	60 cm (56-65)	>60 cm
2000	37.06	52.89	38.75	38.17	42.2	39.17
2001	18.62	33.00	18.20	14.78	16.00	15.83
Mean	27.84	42.95	28.48	26.42	29.10	27.5

Table 2. Percentage of the on time germination rate and the mother plant DBH class.

On time germination

The highest rate of germinated seeds in the first spring referred to the class of 30 cm diameter (mid-age trees). The least germination rate referred to the class of 20 cm diameter (young trees) (Table 2). The average value for the on time germination of the first year planting (year 2000) was 41.60 percentage (Table 7). Germination rate for the planted seeds in 2001 for the class 30 cm was the same as in the first year, but the least germinated seeds were included in the diameter class of above 50 cm (Table 2). The total average of the on time germinated seeds planted in 2001 was 19.84% (Table 7). Statistical evaluation of the data obtained indicated that trunk diameter class differences significantly affected the on time seed germination rate in both 2000 and 2001 ($p<0.05$) (Table 5). However, Duncan's multiple range test showed that only the class including trunks with 30 cm in diameter can be separated from the other classes. These results showed that trees with a trunk diameter ranging between 25 and 35 cm produced normal seeds with

Planting year	20 cm (15-25)	30 cm (26-35)	40 cm (36-45)	50 cm (46-55)	60 cm (56-65)	>60 cm
2000	13.40	5.06	17.87	15.44	14.10	18.25
2001	27.62	17.31	29.38	33.67	24.60	25.17
Mean	20.51	11.19	23.62	24.56	19.85	21.71

Table 3. Percentage of the delayed germination rate and the mother plant DBH class.

Class diameter	20 (15-25)	30 (26-35)	40 (36-45)	50 (46-55)	60 (56-65)	>60
2000	50.46	57.96	56.62	53.61	57.30	57.41
2001	46.81	50.25	43.50	48.00	41.60	42.27
Mean	48.64	54.10	50.06	50.81	49.45	50.04
Difference	-3.65	-7.71	-13.12	-5.61	-15.70	-15.14

Table 4. Total germination rates in the two planting years depending on the class diameter.

higher germination rate than the other diameter classes in the first year after planting (Table 6).

Year	S.O.V.	DF	MS	F
2000	**On time germination rate**	5	272.25	2.60 *
	Delayed germination rate	5	165.62	3.41 *
	Total germination rate	5	64.55	0.76ns
2001	**On time germination rate**	5	361.75	2.66 *
	Delayed germination rate	5	241.71	1.21 ns
	Total germination rate	5	74.64	0.36 ns
Means	**On time germination rate**	5	277.05	2.81 *
	Delayed germination rate	5	17.32	1.86 ns
	Total germination rate	5	39.39	0.48 ns

*** = Significant at 5% probability level ns = non significant**

Table 5. Mean squares of the analysis of variance of the effects of mother plants DBH on germination rates.

Class diameter (cm)	On time germination rate in 2000	On time germination rate in 2001	Mean
20	37.06 b	18.62 b	27.84 b
30	52.89 a	33.00 a	42.95 a
40	38.75 b	18.20 b	28.47 b
50	38.17 b	14.78 b	26.47 b
60	42.20 ab	16.00 b	29.1 b
>60	39.17 b	15.83 b	27.5 b

Means with the same letter are not significantly different.

Table 6. Duncan's multiple range test for the on time germination rates measured in the two planting years.

Delayed germination rate

In the second spring after planting seeds from the class of tress having trunks with 30 cm in diameter showed less delayed seed germination rate both in 2000 and 2001. The class of trees having trunks with 20 cm in diameter showed the most delayed seed germination. This was in contrast to the seeds from trees with over 50 cm in diameter planted in 2001. Average germination in the second spring (delayed germination) of seeds from 2000

Mean germination	On time germination rate	Delayed germination rate	Total
2000	41.60	13.58	55.18
2001	19.84	26.35	46.16
Mean	30.72	19.96	50.67
Difference	-21.76	+12.77	-9.22

Table 7. Difference in seed germination rates measured in the two planting years.

SOV	DF	T	Probability
On time germination rate	39	10.37 **	0.000
Delayed germination rate	39	-6.73 **	0.000
Total germination rate	39	3.53 **	0.001

**** = Significant at 1% probability level**

Table. 8. T-test results on the time, delayed and total germination rates in 2000 and 2001.

and 2001 was 13.58% and 26.35%, respectively (Table 7). The average delayed seed germination in both years (2000 and 2001) was 19.96%, and the least delayed seed germination was observed for the trunks between 25 to 35 cm in diameter. These diameter classes referred to the mid-age tree category.

Total seed germination

Total seed germination in 2000 was 55.18% (Table 7). In this case, in spite of the fact that there was not any significant difference between trunk diameter classes, seeds from trees having trunks with 30 cm in diameter showed higher rate of germination than the other classes (57.96%) (Table 4). Regarding the seeds planted in 2001, total germination was 46.16% (Table 7) and the class including trees having trunks with 30 cm in diameter showed higher rate of seed germination (50.25%) than the other classes (Table 4).

Difference between the seed germination rate of the two planting years

The on time germination rate of the seeds planted in 2001 was 19.84% which was lower than in 2000. However, the rate of delayed germination of the seeds planted in 2001 exceeded by 12.77% the delayed germination rate registered in 2000. Total seed germination rate of the seeds planted in 2001 was lower compared with seeds planted in 2000 (Table 7). In general, seed germination registered in both planting years (2000 and 2001) showed a significant difference ($P<0.01$) (Table 8). The reduction in the seed germination rate of the seeds from old trees was stronger compared with young trees.

DISCUSSION

In the present study, we showed that there was not a significant correlation between *Sorbus* seed size, seed weight and germination percentage. Our results are in contrast to those reported by Baskin and Baskin (1998) and Navaro and Guitian (2003) showing a general positive effect of seed size on seed germination. Therefore, the recommendation of Gamiely et al. (1990) to use larger seeds to increase germination rate is not applicable to *Sorbus* seeds. On the other hand, our results are supported by the data of Close and Wilson (2002) on *Eucalyptus delgatensis* in which the seed germination rate was not affected by seed size.

The highest seed germination rate, both the on time and delayed seed germination in *Sorbus* plants for the two years of study referred to the 30 cm diameter class (mid-age *Sorbus* trees). These results were in accordance with the data reported by Fennessy (2002) on *Betula pendula* and *Fraxinus exelsior* and also the information based on some species of *Abies* e.g. *A. nordmandiana, A. balsamea* and *A. pinsapo* (Vidakovich, 1991; Gatalan and Parados, 1983). In *Pinus echinata* Mill, there was a significant correlation between mid-age trees (33-cm class) and seed characteristics, such as cone dry weight, 1000 seed weight, total seed production and seed germination when compared with the other classes like 28, 38 and 43 cm in diameter (Grayson et al., 2002). Similar results were obtained in this research for mid-age *Sorbus* trees (30-cm class) which produced more quantitative and qualitative seeds.

The lowest rate of delayed germination was registered for the 30-cm diameter class of trees. *Sorbus* seeds need a 3 to 9-month period of cool wet stratification treatment to break seed dormancy (Piagnani and Bassi, 2000). Thus, *Sorbus* seeds without treatment cannot germinate fully in the first year and untreated seeds retain in dormancy for a longer period and seed germination delay to the next year (Harris and Stein, 1974).

Thus, variations between trunk diameter classes and seed physiology of *Sorbus* differed between different trunk diameter classes of trees. On the other hand, it can be realized that the mid-age *Sorbus* seeds need a shorter dormancy period. This can result in a higher rate of seed germination and more vigorous seedlings.

As was mentioned above, part of the seeds collected in 2000 were planted and the rest were stored to be planted in 2001. Total number of germinating seeds showed a 9.22% reduction in one-year-old seeds planted in the next year (Table 7). Old *Sorbus* tree seeds germinated at a lower rate and with a delay in germinating time, even if the seeds remained on the tree for a season. Seeds of *Sorbus* can be stored for 8 years in a metal can (USDA FS 1948), but their germination rate was strongly reduced in 25% RH or at 25 ^{o}C and at higher temperatures.

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