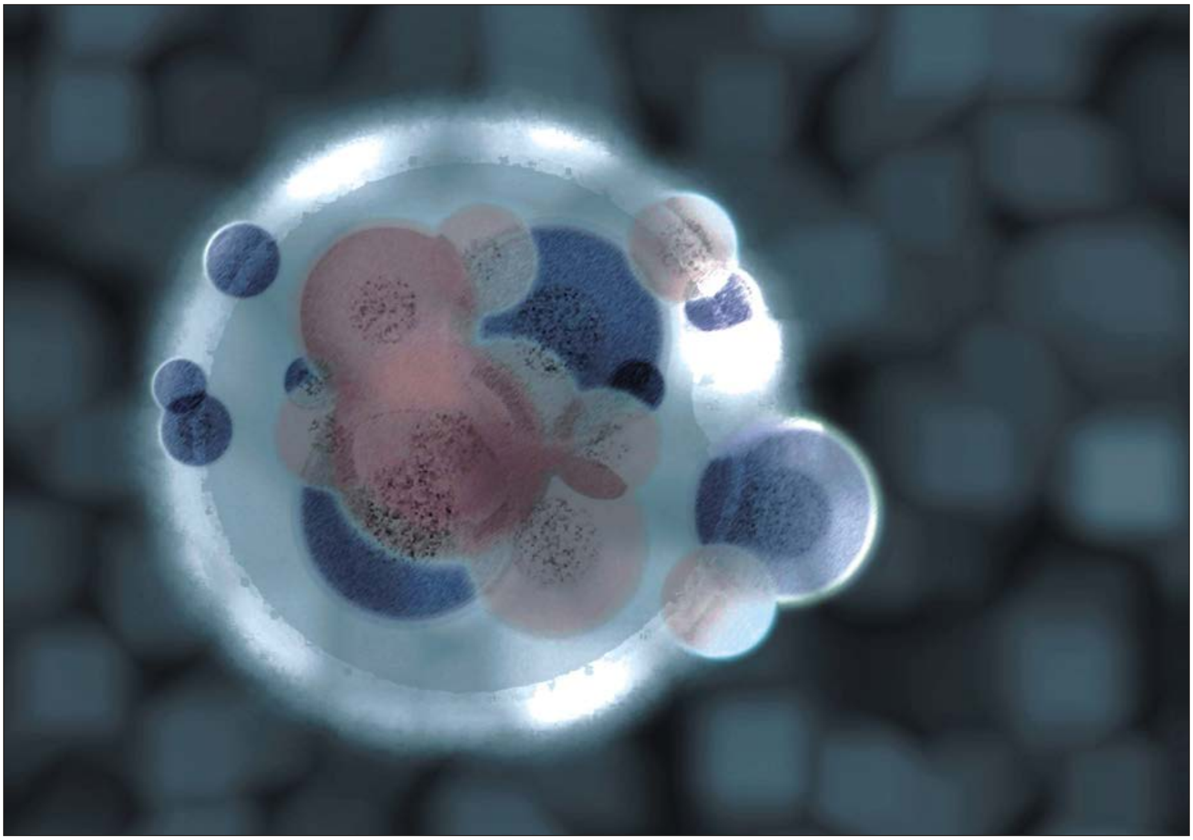

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The Effects of Exposure and Bale Storage on Water Potential and Field Performance in Anatolian Black Pine

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Abstract: Effects of exposure, watering and storage in bale after lifting on water relations and field performance in Anatolian Black Pine (*Pinus nigra* Arn subsp. *pallasina* (Lamb.) Holmboe) seedlings were examined in the study. Two-year-old bare root seedlings were lifted at end of March, 2005. Some of seedlings were planted after one, two and three days of storage in bale (cloth sacks filled with peat moss). Baled seedlings were watered with filter pail in lifting-planting process. A part of the seedlings were watered immediately after lifting and fully exposed for 30, 60 and 90 min indoors and then planted. Others were planted immediately after lifting without watering. Plant water potentials of all the seedlings were measured using the pressure chamber technique after lifting and before planting. The effects of desiccation and storage in bale on Plant Water Potential (PWP), survival, stem diameter and height growth were evaluated. PWP of the seedlings was increased with time desiccation and storage in bale. Desiccation and storage in bales treatments affected significantly on plant water potential stem diameter, height growth and bud length. However, there were no significant differences among the treatments for survival of first year, It was opposite for second year. Best survival and growth were obtained from seedlings fully exposed for 30 min indoors and watering after lifting. Besides, survival and growth of seedlings planted after one and two days of storage in bale were good as seedlings exposed for 30 min. Therefore, it could be recommended that Anatolian black pine seedling should be immediately sprayed water after lifting.

Key words: Storage, seedling physiology, survival, planting performance

INTRODUCTION

Anatolian black pine (*Pinus nigra* Arn subsp. *pallasina* (Lamb.) Holmboe) is one of the most commonly used coniferous tree species in forest plantations of Turkey. It is known that quality, morphology and physiology of seedlings and period between lifting and planting of seedlings play important roles in both the economical and biological success of the plantations. Once lifted from the well buffered soil environment, seedlings may be exposed to stress factors that affect seedling vitality while waiting to be planted. These factors may be drought, damaging temperatures, root desiccation and rough handling.

Desiccation stress between lifting and planting was one of the important factors influencing nursery stock survival and growth (McKay, 1996). Girard *et al.* (1997) determined that exposure to ambient conditions had detrimental effects on bare-root red oak seedlings in terms of survival and growth after planting. Balneaves (1987) determined in *Cupresus macrocarpa* and *Pinus radiata* that root exposure decreased seedling water potential. Similar results were also reported by Coutts (1981) in *Picea sitchensis*. Seedling roots, especially the fine roots can become desiccated rapidly when exposed to air (Brønnum, 2005). A way of protecting seedlings from desiccation is packaged in bags or bales. If seedlings must be packaged in bags, bales or crates, it can be protected from moisture loss by the maintenance of a high ambient humidity or packaged with a water-saturated material such as peat moos (Burdett and Simpson, 1984). Likewise, Lopushinsky (1990) reviewed the literature on water potential in bare root seedlings, concluding that water potentials should remain above -0.5 MPa during grading and packing.

In successful plantation, seedlings have to overcome a transplanting shock which is caused by plant water stress. Water stress is primary factor limiting growth, physiology and ecology performance (Donovan *et al.*, 2003; Bargali and Tewari, 2004). The stress is caused by insufficient water supply from soil to roots after planting which may result in poor survival and slower growth. For this reason, water potential of seedlings after lifting and before planting is very important to field performance.

The present study aims to examine the effects of exposure (root and shoot) and storage on plant water potential and field performance in Anatolian black pine seedlings and to discuss on plantation forestry.

MATERIALS AND METHODS

Experimental designs and measurements: The study was conducted at Egirdir forest nursery (lat 37°53' N, long 30°52' E, 920 m.a.s.l.) in Isparta, Turkey. The nursery had pedocal soils pH = 7.7 with loam texture. The nursery is having predominantly temperate climate (Fig. 1). Six hundred and twenty seedlings, in two-year-old bare root, chosen randomly, were lifted from the nursery on 23 of March, 2005. While 150 seedlings (C) were planted immediately after lifting without any treatment, water potential of five control seedlings were measured at the same time. Desiccation treatments were applied on other seedlings. The seedlings were dipped water for short period (<5 sec) before treatments. They were placed indoors on tables (11°C, 60% relative humidity) after dipping. The 465 seedlings (155 seedlings each treatment) were full exposed (root and shoots) to desiccation for 30 (E30), 60 (E60) and 90 (E90) minutes. Plant water potential was measured on five seedlings each treatment before planting. One hundred and fifty seedlings each treatment was planted to experimental areas at the nursery after the treatments as three replicates. Besides, 465 seedlings (155 seedlings each treatment) were lifted to examine effect of bale storage on water potential and field performance of seedlings on 24 of March, 2005. Lifted seedlings were packed in bales produced by cloth sacks filled with peat moss. Packed seedlings were stored for one (S1), two (S2) and three (S3) days indoors (10°C and 65% humidity). The seedlings were watered during storage periodically.

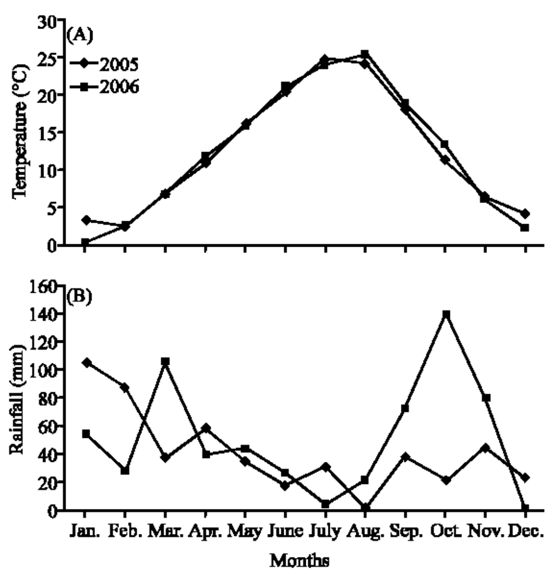

Fig. 1: Average temperature (A) and rainfall (B) of the nursery and experimental area for months and years

They were planted at 30×30 cm spacing at 30 cm deep planting holes to experimental areas of the nursery after each treatment as three replicates. Plant water potential was measured on five seedlings each treatment before planting. At the end of first and second growing seasons after planting, seedling height (distance between soil surface and terminal bud) and stem diameter (diameter on soil surface) were measured on 90 seedlings of each treatment. Furthermore, terminal buds were counted at the 30 seedlings of each replicate in each treatment at the end of second growing period. Percentage survival was determined at end of the two growing seasons (early October) in each treatment. Plant water potential was measured according to Scholander *et al.* (1965) using a Scholander pressure chamber (PMS Inst., 670 Oregon model.

Statistical analysis: Survival, seedling height, stem diameter and bud numbers were assessed at end of the first and second growing seasons. Relative increments (cm) of the height were estimated by Genc and Bilir (2000) as:

$$\text{Relative height increment} = \frac{(\text{Height}_1\text{-Height}_0)}{\text{Height}_1}$$

where, height_0 was seedling height at planting and height_1 was seedling height at the end of a growing season.

While proportional data were transformed by Arcsin $(P)^{1/2}$ and Log (X+1), numerical data were transformed by $\sqrt{x+0.5}$ for ANOVA to determine effect of treatments on plant water potential and field performance. The treatments were grouped by Duncan's multiple range tests by SPSS statistical package (Ozdamar, 1999) after ANOVA.

RESULTS

Effects on plant water potential of treatments: Average plant water potential (PWP) of all treatments was -1.3 MPa after lifting. Treatments had significant effects on PWP according to results of ANOVA. Its results showed that there were significant differences ($p<0.001$) among treatments before planting (Table 1). PWP increased up to - 0.39 MPa after 90 min of exposure (E90). In the same way, PWP of the seedlings stored in bale for one, two and three days were increased from -1.3 MPa to -0.31 MPa, -0.13 MPa and -0.19 MPa, respectively (S1, S2, S3) (Table 1).

Effects of treatments on field performance: The highest survival was determined in E30 (96.7%) that subjected to full exposure for 30 min after watering following lifting in

Table 1: Plant water potential of seedlings after lifting and before planting

Treatments	PWP after lifting S1*, S2, S3, E30, E60, E90, C	PWP before planting** S1	S2	S3	E30	E60	E90	C
PWP (-MPa)	1.30	0.31bc	0.13a	0.19ab	0.72d	0.61d	0.39c	1.30e

*S1, S2 and S3 are storages one, two and three days in bale; E30, E60 and E90 are root and shoots exposed for 30, 60 and 90 min., respectively. C is immediately planted without any treatments. **Mean values followed by the same letter are not significantly different (p≤0.05)

Table 2: Results of ANOVA and Duncan's test for growth characters in the treatments

Years	Growth parameters	Treatments** S1*	S2	S3	E30	E60	E90	C	p-values
2005	Seedling diameter (mm)	4.56c	4.31ab	4.24a	4.98d	4.39abc	4.53bc	4.31ab	<0.001
	Seedling height (cm)	9.85c	9.97c	8.83b	9.97c	9.01b	8.75ab	8.100a	<0.001
	Annual height increment (cm)	1.40a	1.71bc	1.46ab	1.96c	1.65ab	1.73bc	1.47ab	<0.001
	Relative height increment (cm)	0.059a	0.068abc	0.066ab	0.077c	0.071bc	0.078c	0.071bc	<0.010
	Survival (%)	86.0a	92.0a	88.0a	96.7a	91.3a	84.7a	84.0a	<0.050
2006	Seedling diameter (mm)	8.84c	8.44bc	6.85a	9.74d	8.25bc	8.07b	7.84b	<0.001
	Seedling height (cm)	14.81bcd	14.26abc	13.01a	16.00d	15.07cd	13.55ab	13.89abc	<0.010
	Annual height increment (cm)	6.22cd	4.99ab	4.26a	6.99d	7.10d	5.82bc	6.23cd	<0.001
	Relative height increment (cm)	0.150b	0.121a	0.120a	0.151b	0.160b	0.151b	0.151b	<0.001
	Bud length (cm)	1.94ab	1.95ab	1.84ab	2.20c	2.03bc	1.76a	1.93ab	<0.001
	Survival (%)	82.7ab	86.0ab	78.7a	91.3b	77.3a	75.3a	74.0a	<0.050

*S1, S2 and S3 are storages one, two and three days in bale; E30, E60 and E90 are root and shoots exposed for 30, 60 and 90 min., respectively. C is immediately planted without any treatments. **Mean values followed by the same letter are not significantly different (p≤0.05)

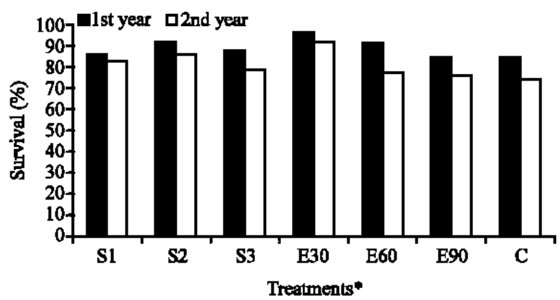

Fig. 2: Survival of each treatment in the growing seasons after planting. *S1, S2 and S3 are storages one, two and three days in bale; E30, E60 and E90 are root and shoots exposed for 30, 60 and 90 min., respectively. C is immediately planted without any treatments. **Mean values followed by the same letter are not significantly different (p≤0.05)

first year. Untreated (C) and exposed for 90 min (E90) after watering treatments were lower than other treatments for survival of first year, while there were no significant ($p>0.05$) differences among treatments for survival (Table 2, Fig. 2). Similar results were also found for average survivals of second year in treatments such as highest survival (91.3%) in E30 and the lowest in C (74%). However, there were significant differences ($p<0.05$), among treatments in second year in contrast to first year (Table 2).

Averages of stem diameter, height, height increment and bud length were presented for years in Table 2. Significant differences were found for the characters among the treatments based on ANOVA (Table 2). Stem diameter was the highest in E30 both first and second growing season. Seedling height in treatments S1, S2 and E30 were higher than other treatments in first year, while it was the lowest in C and E90. It showed higher performance in S1, E30 and E60 than the others in second year (Table 2).

Height increments were higher in S2, E30 and E90 than that of others in first growing season, while S1, E30, E60 and C had higher performance in second year. Besides, relative height increment showed different performances for treatment and years. For instance, while it ranged from 0.59 (S1) to 0.78 (E90) in first year, it varied between 0.12 (S3) and 0.16 (E60) in second year (Table 2). Length of terminal buds was the longest (2.20 cm) in treatment E30 for second years as seen from Table 2.

DISCUSSION

Plant water potential decreased to -1.3 MPa in the study, when the lifting. Actually it could be said that the water potential was low for seedling vitality when compared to Edgren (1984). Edgren (1984) reported that lower water potential than -1.2 MPa at lifting time decreased out planting performance of seedlings. Water potential could also be increased by periodically spraying water on the lifted seedlings to eliminate negative effect of low water potential until planting. Lopushinsky (1990) reported that water potentials should have not been lower than -0.5 MPa during all treatments (i.e., lifting, packing, selection, transporting) before planting. Likewise, in treatments S1, S2 and S3, PWP could be increased from -1.3 to -0.13 MPa by sprayed watering until planting. So, negative effects of low water potential were eliminated by that.

In the same way, full exposure and watering after lifting, increased PWP of seedling by time. Results from this study indicate that watering after lifting has increased PWP in the environments sheltered from wind, but seedling should be kept for a pretty short time kept on a ground for air drying after watering. Coutts (1981) found that root exposure of Sitka spruce seedlings caused a greater change in the moisture content of fine roots. So, desiccation can cause death of fine roots (Feret *et al*., 1985; McKay, 1996; McKay and White, 1996; McKay and Milner, 2000). However, damage air drying to fine roots and high of water stress may be prevented to on a large scale when watering immediately after lifting.

Survival is 80% or higher than that in successful plantations/reforestations (Genc, 2006). In the present study, average survival was higher than 84% in first year while it was lower than 80% in treatments S3, E60, E90 and C in second year. Moreover, survival in treatments C (74%) and E90 (75%) were lower than other treatments.

The study of May (1984) recommend that baled seedlings stored without refrigeration should be planted within 4 weeks after lifting. Present study, survival of the seedlings stored in bale for 3 days was lower than 80% in the end of second year, while their PWP was 0.19 MPa. May (1984) reported that after storage of about one week in bales, the survival rate of the seedlings may decline by time. So, the seedling stored in bale three or more than three days should not be planted even if their PWP had high.

Girard *et al*. (1996) found that exposure of *Pinus nigra* Arnold. sp. *laricio* var. *corsicana* seedlings decreased seedling water potential, new root elongation and increased mortality after planting. Coutts (1981) found that the primary cause of low performance in desiccated Sitka spruce was root injury. He showed that desiccated plants having the same water potential (-2 MPa) had lower field performance when roots had been exposed than plants with protected root systems (Brønnum, 2005). Present study, field performance were lowered by exposure after 30 min of exposure while increased PWP (from -1.3 to 0.39 MPa) of seedling by time.

The thickest seedlings were determined in treatment E30 (subjected to full exposure for 30 min after watered) after first and second growing season. Besides, beginning of survival, the diameter growth in treatment S3 was the lowest. The highest seedling height (average 9.97 cm) was measured in treatments S2 and E30 at the end of first growing period. At the same time, terminal buds were the longest in treatment E30. Height and diameter increments were considerably greater in second year than that of first. Height increment was greater in treatment E30 than the others in the end of first growth season. Genc (1996) had similar trial where four years old *Picea orientalis* (L) Link seedlings were exposed for 0, 15, 30 and 60 min with or without watering. Best water potential, survival and growth was obtained from transplants watered after lifting. Noble fir seedlings were subjected to full exposure by Brønnum (2005). Desiccation effects on plant parameters and performance were generally significant after 1.5 h of full or 10 h of partial exposure to treatment. Besides, Sarvaš (2003) reported that desiccation treatments were significantly effective on growth of Norway spruce seedlings.

CONCLUSION

Seedlings should be protected from desiccation stress by watering after lifting. It could also be said that baled seedlings may be stored at the nursery for a few days until planting because of higher performance from the point of view for most of studied morphological characters in S1, S2 and E30 treatments.

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