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A Comparative Study of Plant Vitality Tests and Field Performance of Eleven Tree Species

By

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Summary

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The aim of this study was to assess the ability of plant vitality indicators to detect possible damage caused by ambient storage or desiccation and predict field performance after out-planting. Eleven commonly planted trees and bushes were selected for this experiment: *Acer pseudoplatanus* L., *Catalpa bignonioides* Walter, *Celtis australis* L., *Cercis siliquastrum* L., *Cupressus sempervirens* L., *Hibiscus syriacus* L., *Fraxinus ornus* L., *Koelreuteria paniculata* Laxm., *Pinus pinea* L., *Platanus orientalis* L., *Sophora japonica* L. (= *Styphnolobium japonicum* (L.) Schott). After lifting from the nursery bed, plants were either stored at ambient conditions or subjected to desiccation conditions for 3 hours. Plant vitality was assessed by measuring fine root electrolyte leakage, fine root moisture content, tap root moisture content, shoot moisture content and shoot water potential. Plant survival was measured at the beginning (spring) and end of the growing season (autumn). Ambient storage affected the quality parameters of some species, but no significant differences were found in survival compared to controls. REL and FRMC were most affected by ambient storage, followed by SWp, RMC and SMC. Seedlings of all species showed a high percentage of survival after planting and very low by the end of the growing season. Seedling quality indicators of *C. bignonioides* were affected by both desiccation and planting time. Desiccation and late planting increased REL values and reduced water content and potential. In April, survival of February lifted plants was higher than March lifted plants while no significant effect of desiccation was detected. No plants survived at the end of the growing season.

Introduction

Although a great amount of effort has been dedicated into the research field of seedling quality assessment prior to field planting, there is still a need for

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more reliable testing regarding the possibilities to predict field performance after outplanting especially for bare-root broad-leaved species. The conditions at the planting site such as soil and climate, affect the success of any forestation attempt. Adverse site conditions may be more significant than planting stock quality in plantation success, especially in hot climates. In Greece, seedlings are normally lifted immediately before planting but when there is a need for storage, for short periods of up to a month the root system of seedlings are covered with soil and left at ambient conditions until needed. Thus, desiccation is the most likely stress factor experienced by seedlings before planting. In this study, we assessed the use of various physiological methods (shoot, root and fine root moisture content, shoot water potential, root electrolyte leakage) as indicators of seedling quality. We also measured the field performance of tested plants and searched for possible relationships with pre-planting measurements.

Materials and Methods

Seedlings were grown under optimal conditions, then were selected for uniformity and carefully lifted from the forest nursery of Lagadas (23°01' E, 40°38' N, altitude 100 m). Seedlings were placed in black polyethylene bags, transported to the Forest Research Institute (FRI) of Thessaloniki (22°58' E, 40°35' N, altitude 10 m) and stored at +4 °C until required, usually within 2 days. Shoot and root height as well as diameter at the root collar were measured before planting.

In order to assess the effect of ambient storage on seedling quality, seedlings of *A. pseudoplatanus*, *C. australis*, *C. siliquastrum*, *F. ornus*, *C. sempervirens* and *P. pinea* were lifted from the nursery on 7th of January, transferred to the fields of FRI and their root systems were covered with soil for a month, while environmental conditions during that month were monitored. After a month, the plant quality indicators of ambient stored and freshly lifted seedlings were recorded before out-planting.

The effects of planting month and desiccation were investigated in this experiment. The following species were selected: *C. bignonioides*, *F. ornus*, *H. syriacus*, *K. paniculata, P. orientalis*, *S. japonica*. Plants were lifted on 16 of February and 15 of March. To simulate desiccating conditions before planting, seedlings were laid horizontally on wire mesh, inside a controlled environment room (15 °C, 50 % RH, air movement 0.3 m s^{-1}, PAR 150 µmol m^{-2} s^{-1}) and subjected to desiccation for 3 hours. After treatment, the plant quality indicators of treated and control seedlings were recorded and then planted. No irrigation or other culture measures were applied.

Root electrolyte leakage (REL) was used to measure the physiological status of fine roots, before and after treatment, according to McKay & White 1997. Shoot water potential (SWp) was measured destructively on 50 mm shoot samples from every test plant, using a pressure chamber (Wescor, Inc., USA). Also, samples of seedlings were selected in random and used to measure shoot (SMC), root (RMC) and fine root (FRMC) moisture contents.

For each plant species and treatment there were three replications of 50 seedlings, outplanted in the Forest Research Institute's experimental field site. Percent seedling survival was measured at the beginning (April) and by the end (September) of the first growing season. Environmental conditions (air temperature, relative humidity, rainfall, soil temperature, soil moisture content) were monitored with an automated weather station located inside the experimental site.

Results

Ambient storage affected the quality parameters of some species, but no significant differences were found in survival compared to controls (Table 1). REL and FRMC were mainly affected by ambient storage, followed by SWp, RMC and SMC. The quality of *A. pseudoplatanus* seedlings was most severely affected by ambient storage, followed by *F. ornus*, *C. sempervirens*, *C. siliquastrum*, *C. australis* while no significant difference was observed for *P. pinea*. Seedlings of all species showed a high percentage of survival after planting and although a significant difference between treated and control plants was not observed a reduced survival of ambient stored seedlings was evident for most species. Field performance of all plant species by the end of the growing season was very low and no seedlings of *A. pseudoplatanus* survived.

Table 1. Pre-planting data of physiological parameters and plant survival for each species in experiment 1. Significant differences between means are indicated with an asterisk (p = 0.05).

Plant	Treatment	S1	S2	REL	SMC	RMC	FRMC	SWp
Acer	ALP	87	0	23	196	281	327	-1.4
	AS	77	0	45 *	170	238 *	152 *	-2.0 *
Celtis	ALP	98	12	14	257	210	255	-2.1
	AS	99	19	12	253	195	218 *	-2.4
Cercis	ALP	96	9	12	175	150	356	-1.6
	AS	90	11	18 *	159	131	339	-2.3 *
Cupressus	ALP	95	15	17	186	270	333	-1.3
	AS	89	10	29 *	168	245	241 *	-1.1
Fraxinus	ALP	84	17	24	227	280	352	-2.4
	AS	80	12	31	185 *	220 *	195 *	-2.2
Pinus	ALP	97	13	20	193	246	361	-1.4
	AS	93	15	22	201	220	350	-1.3

Abbreviations and units: Seedling survival (%) in spring (S1) and autumn (S2), REL = root electrolyte leakage (%), SMC = shoot moisture content (%), RMC = root moisture content (%), FRMC = fine root moisture content (%), SWp = shoot water potential (MPa). ALP = after lifting planting, AS = ambient storage.

Seedling quality indicators of *C. bignonioides* were affected by both desiccation and planting time (Table 2). Desiccation and late planting increased REL values and reduced water content and potential. In April, survival of February lifted plants was higher than March lifted plants while no significant effect of desiccation was detected. No plants survived at the end of the growing season. *F. ornus* seedlings were affected mainly by desiccation and only slightly by planting month. The effect of desiccation was more pronounced in the cases of survival, FRMC, SWp and REL values, while small differences were observed between planting months for SMC and RMC. Few seedlings survived the summer time and no significant differences were observed among treatments. Similarly, seedlings of *H. syriacus* were affected mainly by the desiccation treatment with the exception of survival of March lifted plants. Seedlings planted in March showed lower survival, FRMC and SWp. No plants survived until the autumn plant survival assessment. Exposing seedlings of *K. paniculata* to desiccating conditions aggravated significantly all measured parameters. Lifting in March was connected with a reduced value of survival, RMC and FRMC, while no significant difference was observed for other parameters. The autumn survival evaluation gave mean values of approximately 70 % and significant differences among treatments. Desiccation affected adversely most plant vitality parameters, especially the FRMC and REL of *P. orientalis* seedlings. Plants lifted in February were of better quality than in March, as indicated by all measured indicators and survival. Almost no seedlings survived until the autumn assessment. Seedlings of *S. japonica* subjected to desiccation were always of worse quality as proved by pre-planting tests and seedling survival. A significant difference between February and March planting existed only for REL and survival. Seedling survival by the end of the growing season showed a similar pattern to the beginning of the season but with lower values.

Table 2. Pre-planting data of physiological parameters and plant survival for each species in experiment 2. Means not sharing common letters are significantly different at p = 0.05.

Plant	Treatment	S1	S2	REL	SMC	RMC	FRMC	SWp
Catalpa	Feb ALP	76 a	0	18 a	179 a	252 a	357 a	-2.1 a
	Feb d3	69 a	0	36 b	137 b	194 b	145 b	-3.3 b
	Mar ALP	49 b	0	32 b	105 c	177 bc	246 c	-3.6 bc
	Mar d3	46 b	0	46 c	79 d	151 c	108 d	-4.1 c
Fraxinus	Feb ALP	79 a	10 a	19 a	273 a	310 a	360 a	-2.2 a
	Feb d3	65 b	10 a	37 b	247 b	270 b	97 b	-3.2 b
	Mar ALP	71 ab	11 a	16 a	255 b	265 b	354 a	-1.7 a
	Mar d3	61 b	7 a	45 b	227 c	230 c	114 b	-2.7 b
Hibiscus	Feb ALP	100 a	0	12 a	193 a	235 a	331 a	-1.0 a
	Feb d3	72 b	0	37 b	156 b	191 b	112 b	-1.8 b
	Mar ALP	85 b	0	19 a	189 a	236 a	283 c	-2.3 b
	Mar d3	83 b	0	30 c	127 c	186 b	91 b	-3.2 c
Koelreuteria	Feb ALP	100 a	71 a	16 a	209 a	236 a	336 a	-1.5 a
	Feb d3	91 b	71 a	33 b	145 b	155 b	84 b	-2.1 b
	Mar ALP	93 b	67 a	17 a	185 a	192 c	265 a	-1.7 a
	Mar d3	88 b	70 a	31 b	136 b	125 b	105 b	-2.4 b
Platanus	Feb ALP	47 a	0	27 a	260 a	305 a	401 a	-1.8 a
	Feb d3	39 b	1 a	38 b	208 b	189 b	120 b	-2.2 ab
	Mar ALP	37 b	0	42 b	223 b	201 b	282 a	-1.8 a
	Mar d3	37 b	1 a	58 c	167 c	155 c	106 b	-2.5 b
Sophora	Feb ALP	95 a	81 a	12 a	191 a	267 a	348 a	-1.6 a
	Feb d3	81 b	73 ab	26 b	146 b	206 b	87 b	-2.3 b
	Mar ALP	75 b	69 b	26 b	170 a	232 b	326 a	-1.5 a
	Mar d3	56 c	48 c	38 c	139 b	201 b	101 b	-2.1 b

Abbreviations and units: Seedling survival (%) in spring (S1) and autumn (S2), REL = root electrolyte leakage (%), SMC = shoot moisture content (%), RMC = root moisture content (%), FRMC = fine root moisture content (%), SWp = shoot water potential (MPa). Feb = February lifted, Mar = March lifted, ALP = after lifting planting, d3 = desiccation.

Discussion

Our results indicated that ambient storage of tree seedlings, for periods up to a month may not significantly affect the survival of seedlings. Ambient storage for short periods is widely applied in Greece and possible adverse effects on seedling quality might affect subsequent survival. To our knowledge, no other studies in this topic have been published.

Exposure of seedlings to desiccating conditions for 3 hours affected plant morphological and physiological parameters and survival to a varied degree depending on the plant species. Similarly, root desiccation was related to decreased survival of *Fraxinus angustifolia* (INSLEY & BUCKLEY 1985) and *Acer platanoides* and *Quercus pertraea* (INSLEY 1979). MCEVOY & MCKAY 1997 found marked differences among species in their sensitivity to fine root desiccation; oak and beech were less sensitive (REL=10-20 %), while maple and ash were more sensitive to desiccation (REL=40-70 %).

Results of our study showed that root electrolyte leakage formed high relationships with spring survival for most study species. This is in consistence with MCKAY 1992 who found that electrolyte leakage from fine roots of Sitka spruce, Douglas fir and Japanese larch was highly correlated to both survival and height growth after 2 growing seasons. BIGRAS 1997 reported that electrolyte leakages of fine roots were less well correlated with seedling survival than electrolyte leakage from the whole root system or coarse roots and suggested that electrolyte leakage of the whole root may be useful for monitoring large samples of seedlings in the nursery.

The desiccation treatment affected the shoot water potential of all studied species. COUTTS 1981 found that leaf water potential of –2 MPa was attained after only 0.7 h of Sitka spruce seedlings exposed to desiccating conditions. TABBUSH 1987 reported that exposure of seedlings to ambient conditions caused a drop in shoot water potential to –3 MPa in Sitka spruce and –2.7 MPa in Douglas fir. MCKAY & WHITE 1997 found that after 3 hours of desiccation, needle water potential values for Sitka spruce and Douglas fir were –3.62 MPa and –3.32 MPa respectively. RITCHIE 1984 in his review on assessing seedling quality, reported that in USA thirteen nurseries routinely measured water status with a pressure chamber and do not lift when stress exceeds -1.0 or -1.5 MPa and do not permit stress to exceed 0.5 MPa when grading and packing.

Our results suggest that moisture content may help to assess damage caused by desiccation. GIRARD & al. 1997b found that two-years-old, bare-root Corsican pine exposure to ambient conditions for 8 hours caused a significant reduction in needle relative water content from 0.94 to 0.86. GIRARD & al. 1997a found that exposure of one-year-old bare-root red oak seedlings to desiccating conditions for 2 to 12 days caused a reduction to water content of stem, taproots and terminal buds.

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References

BIGRAS F. J. 1997. Root cold tolerance of black spruce seedlings: Viability tests in relation to survival and regrowth. - Tree Physiology 17: 311-318.

COUTTS M. P. 1981. Effects of root or shoot exposure before planting on the water relations, growth and survival of Sitka spruce. - Canadian Journal of Forest Research 11: 703-709.

GIRARD S., CLEMENT A., BOULET-GERCOURT B. & GUEHL J. M. 1997a. Effects of exposure to air on planting stress in red oak seedlings. - Annales des Sciences Forestieres 54: 395-401.

— , — , COCHARD H., BOULET-GERCOURT B. & GUEHL J. M. 1997b. Effects of desiccation on post-planting stress in bareroot Corsican pine seedlings. - Tree Physiology 17: 429-435.

INSLEY H. 1979. Damage to broadleaved seedlings by desiccation. Arboriculture research Note 8, Department of Environment. - Arboriculture Advisory and Information Service UK 4p.

— & BUCKLEY G. P. 1985. The influence of desiccation and root pruning at the survival and growth of broadleaved seedlings. - Journal of Horticultural Sciences 60: 377-387.

MCEVOY C. & MCKAY H. 1997. Root frost hardiness of amenity broadleaved seedlings. - Arboricultural Journal 21: 231-244.

MCKAY H. M. 1992. Electolyte leakage from fine roots of conifers seedlings: A rapid index of plant vitality following cold storage. - Canadian Journal of Forest Research 22: 1371-1377.

— & WHITE I. M. S. 1997. Fine root electrolyte leakage and moisture content: Indices of Sitka spruce and Douglas-fir seedling performance after desiccation. - New Forests 13: 139-162.

RITCHIE G. A. 1984. Assessing seedling quality. - In: DURYEA M. L. & LANDIS T. D. (Eds.), Forest nursery manual: Production of bareroot seedlings, pp. 243-259. - Martinus Nijhoff/ Dr. W. Junk Publishers, The Hague/Boston/Lancaster.

TABBUSH P. M. 1987. Effect of desiccation on water status and forest performance of bare-rooted Sitka spruce and Douglas fir transplants. - Forestry 60: 31-43.