LEBANON REFORESTATION INITIATIVE

NATIVE TREE NURSERIES CULTURING PRACTICES AND RESULTS

2014

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Outline

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I. EXECUTIVE SUMMARY

The survival rate of tree seedlings planted in the field depends largely on the quality of seedlings coming from tree nurseries. In addition, seedling quality is dictated by the culturing practices at each nursery. Developing the right nursery culturing practices is crucial to ensure sustainable production of robust seedlings with higher survival rates after planting in the field. The Lebanon Reforestation Initiative, a project funded by the United States Agency for International Development (USAID) and the United States Forest Service (USFS), has developed new cost-effective culturing practices that provide a basis for producing high quality native tree seedlings, building on both local experience and global knowledge. Science-based irrigation and fertilization practices, container selection founded on outplanting conditions, and crop scheduling are all part of a planned approach that has resulted in a marked improvement in seedling quality, sustainability in seedling production and exceptionally high rates of adoption by native tree nurseries in Lebanon.

II. INTRODUCTION

During the last few decades, Lebanon has witnessed a high rate of deforestation leaving the country with decreasing forest cover. In response, public and private reforestation initiatives were implemented at the national level to help counter the trend. Experience from those efforts showed that reforestation success depends on several factors at the nursery, field and community levels. At the nursery level, prior to 2012, the majority of seedlings used for forest restoration in Lebanon were produced in an assortment of large containers over several years. Culturing techniques were inconsistent with container size, species growth habits, and outplanting objectives. These practices often resulted in the production of suboptimal seedlings and subsequent restoration failure due to additional stresses from drought, vegetative competition, rocky soils, and ungulate damage.

The Lebanon Reforestation Initiative (LRI) was developed to strengthen the production of robust tree seedlings by native tree nurseries and increase the survivability of planted trees.

LRI began by assisting nine existing native tree nurseries throughout Lebanon with technical improvements for the sustainable production of quality native seedlings. Practices were developed to meet native nurseries needs and different capacity levels. The main challenge and objective in developing nursery culturing practices was to achieve the same high quality of seedlings in all nurseries and for different species requirements. A unified protocol was developed as a baseline and followed by all nine LRI-supported native tree nurseries.

III. CULTURING PRACTICES

A. Propagation environment

A well-designed propagation environment is critical to promote optimal seedling growth and achieve robust plants. Needed attributes include:

- Availability of water for irrigation
- Site accessibility and area
- Suitable irrigation system
- Nursery layout and greenhouse (depending on nursery objectives)

Prior to working with LRI, the nine Lebanese native tree nurseries had a basic infrastructure installed, consisting mainly of cement block seedling enclosures where polybags were held. Following individual nursery assessments, advanced propagation environments were designed for each nursery to increase seedling quality and maximize production at the same time:

- Leveling of nursery land. Terraces, if existing, were leveled, to increase nursery surface area that can be used to grow seedlings. Doing so also makes the daily and weekly monitoring activities easier because of better accessibility.

- Installing simple tunnel-shaped greenhouses with removable covers. The new greenhouses were designed to give nursery growers the capacity to control temperatures within the greenhouse, depending on the growth stages of seedlings. At sowing and germination time, the greenhouses should be covered, increasing the temperatures within the nursery and aiding seedlings to germinate and grow faster. As air temperatures increase (>30° C) , the greenhouses are periodically opened until they are all uncovered getting closer to hardening phase, where the seedlings should adapt to the outside environmental conditions before planting. Toward the end of winter, if weather conditions permit, the plastic cover is extended throughout the greenhouse.

Different species require different temperatures to germinate:

- Species that require cool temperatures will germinate if temperatures are below 25° C. Those species can be sown earlier than spring outside covered greenhouses (ex: *Quercus* sp.).

- Most species require temperatures above 10° C to germinate and can be kept in warm greenhouses in early spring.

Table 1 describes generally how greenhouse covering is managed according to growth phase and seedling requirements. As temperatures increase during the year, greenhouses are periodically opened, to decrease heat stress in the greenhouse and allowing seedlings to fully grow.

Table 1 – Greenhouse covering according to months and growth phase of seedlings

	Month											
Greenhouse cover	**Jan**	**Feb**	**March**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**

Greenhouse 100% covered
Greenhouse 50% covered
Greenhouse 100% uncovered

- Ground mulching to prevent weed emergence. Locally available material such as rock pebbles and mulching covers where used and sometimes a combination of both, covering greenhouse floors to keep weeds from proliferating.

Figure 1– Simple tunnel structure

B. Container selection

A well-developed root system helps ensure establishment of the seedling post-planting, especially in harsh planting sites. Thus, the selection of a proper container type is important for the growth of well-developed root systems. In Lebanon, polybags have been the traditional container type used to grow native tree seedlings. In the last few years, with more awareness in the region about best reforestation practices, a few native tree nurseries were introduced to more modern types of containers. These new container types promoted the growth of non-swirling roots and had a higher production capacity compared to the polybags. In terms of practicality, polybags and Deepots are the only two sortable containers, ensuring a more uniform growth of seedlings pre-planting. However, because of their design in trays and light weight per pot, Deepots are less time and labor consuming while sorting them.

Table 2– Comparison between different types of growing containers used in Lebanon

Container type	Container volume	Practicality	Seedlings/ m2	Root swirling
Polybag	>600	Sortable	≈100	✔
Styroblock	130	Non sortable	430	-
Spanish 1	300	Non sortable	384	-
Spanish 2	400	Non sortable	292	-
HV120SS	120	Non sortable	528	-
HV150	150	Non sortable	316	-
H15	350	Non sortable	»198	-
D19	315	Sortable	174	-
D27	444	Sortable	174	-
D40	656	Sortable	174	-

During the project two different types of containers were selected, both for different purposes:

- Treepots: With a volume of 1.65 liters, Treepots are used to grow seedlings for more than one year or to transplant seedlings grown in smaller containers for another year. The best time to transplant seedlings is during outplanting season (usually during the fall season).
- Deepots: The selection of Deepots was made depending on several factors:
  - Site conditions and species characteristics: Three volumes D40 (656 ml), D27 (444 ml) and D29 (315 ml) (Figure 2) were used depending on site conditions, such as soil depth, and the growth characteristics of each species. *Quercus* sp. grow long roots downward and once established, shoots can grow to a height of more than 15 cm. Container volume should be considered for the production of *Quercus* seedling to achieve a proper root-to-shoot ratio. Thus, a volume of more than 400 ml, such as the D 40 (656 ml) (Figure 3), is recommended. On the other hand, *Abies cilicica* is a slow growing species and usually planted in moist condition sites. Containers with volumes between 120 and 350 ml, such as the D 19 (315 ml), are recommended to allow roots to have a well-developed structure suitable for planting. Table 3 shows the selection of preferred container volume according to species and species characteristics.
  - Practicality of use in the nursery: Deepots help nursery growers to better manage their growing season. Close to the traditional polybags in concept as a single seedling container, the ease in sorting the individual units helps in growing more uniform seedlings throughout the season by allowing for reorganizing and placement of containers for optimal growing results (Figure 4).
  - Root development: The structure of the Deepots allows for proper root development without swirling (Figure 5). The structure of the Deepots encourages roots to grow vertically, which Is essential for outplanting in arid environments like that of Lebanon. Moreover, the

design of the trays prevents nursery growers from using benches as support or laying the containers directly on the nursery floor, both of which impedes essential air pruning of roots.

Figure 2 – D19, D27, D40 containers

Figure 3 -Quercus sp. seedling root and shoot development in D40.

Figure 4 - Growing uniform seedlings in Deepots.

Table 3 – Recommended container selection per species.

Species	Stem height	Diameter	Container volume (ml)
Cedrus libani	15 cm minimum	2 mm minimum	250-450
Pinus pinea	15 – 30 cm	3 mm minimum	400 – 700
Quercus sp.	15 – 30 cm	4 mm minimum	400 – 700
Pinus brutia	15 – 30 cm	3 mm minimum	250-450
Abies cilicica	10 cm minimum	2 mm minimum	120 – 350
Ceratonia siliqua	10 – 15 cm	2.5-3 mm minimum	250 – 450
Laurus nobilis	15 – 20 cm	3 mm minimum	250 – 450
Acer sp.	15 – 20 cm	3 mm minimum	250 – 450
Arbutus andrachne	15 – 20 cm	3 mm minimum	250 – 450
Crataegus sp.	15 – 30 cm	3 mm minimum	250-450
Celtis australis	15 – 20 cm	4 mm minimum	250 – 450
Cercis siliquastrum	15 – 20 cm	4 mm minimum	250 – 450
Amygdalus	15 – 20 cm	3 mm minimum	250 – 450
Pyrus syriaca	15 – 20 cm	3 mm minimum	250 – 450
Pistachia palaestina	15 – 20 cm	4 mm minimum	250 – 450
Sorbus sp.	15 – 20 cm	4 mm minimum	250 – 450

Overall, roots of all species grew well in Deepot containers without swirling and with the development of strong root plugs. Root air pruning was also encouraged due to the Deepot designs.

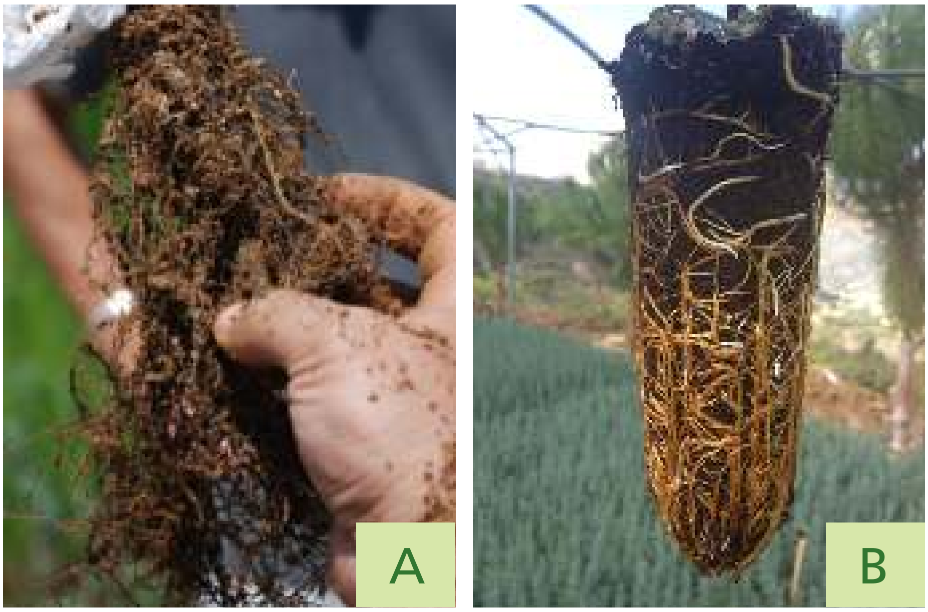


Figure 5– Comparison between root development in polybag (A) and D27 container (B).

C. Growing media preparation

Selecting the optimal growing medium is critically important in native tree seedling production as it is the support substance in which roots grow and take up water and needed nutrients. In the past, native soil from the field was used mainly because of its ready availability. However, using native soil often decreases the quality of seedlings by negatively affecting aeration, water supply and nutrient uptake. Native soils are also a main source of diseases such as bacteria and fungi and could stress the growing season, as seedlings will not reach targeted quality before planting.

Several factors should be considered for growing media preparation:

- Growing medium texture: Choosing a proper growing medium is important as it represents the basic structure for root growth, through which roots will extract water and nutrients. The growing medium should have good water holding capacity, provide adequate root aeration and ensure physical support to the seedling.
- Initial pH of growing media: pH is the measure of acidity or alkalinity, ranging from 0 to 14, with 7 being neutral. The pH affects how nutrients are absorbed by the seedlings through the roots. Most native species grow best between a pH of 5.5 and 6.5. Given that the general pH increases through the growing season, starting with an initial growing medium pH of 5-5.5 is recommended.
- Cost of growing medium: Growing media is a yearly cost and while production increases, cost increases too. Nursery growers should take this variable cost into account and try to achieve lower cost growing media. Peat moss is the mostly widely used artificial medium for its physical characteristics, but it tends to be relatively expensive. Mixing peat moss with other artificial and less expensive growing media such as coco-peat decreases total cost.

Reflecting the issues discussed above, the growing media used at the nine native tree nurseries in Lebanon consisted of the following:

- 50% coco-peat (3 kg block + 20 liters water » 80 liters coco-peat)
- 25% peat moss, pH 5.6
- 25% peat moss, pH 4

The pH of the growing media ranged from 5 to 5.5 at the beginning of the growing season.

Figure 6 – Preparation of growing media.

D. Sowing time and pre-sowing treatments

Determining the right sowing time is critical to achieve robust seedlings prior to planting, increase germination rates, and, if needed, start pre-sowing treatments on time. In the past, seed characteristics and requirements were not given sufficient consideration, resulting in overall lower germination rates. Knowing the preferable sowing time and treatment per species is a process that involves more awareness on seed handling prior to sowing.

Table 4 indicates recommended sowing times per species and treatments required before sowing that were followed by LRI-supported native tree nurseries.

Table 4 – Recommended sowing time per species and pre-sowing treatments.

Species	Sowing time	Storage	Treatment pre-sowing
Abies cilicica	February	Cold-dry 4 C	2 months cold stratification
Sorbus flabellifolia	February-March	Cold-dry 4 C	3 to 4 months cold stratification
Sorbus torminalis	February-March	Cold-dry 4 C	3 to 4 months cold stratification
Styrax officinalis	February-March	Cold-dry 4 C	Cold stratification > 3 months
Acer tauriculum	March	Cold-dry 4 C	3 months cold stratification
Acer syriacum	March	Cold-dry 4 C	3 months cold stratification
Arbutus andrachne	March	Cold-dry 4 C	2 months cold stratification
Cedrus libani	March	Cold-dry 4 C	No treatment needed
Celtis australis	March	Cold-dry 4 C	3 months cold stratification
Cercis siliquastrum.	March	Cold-dry 4 C	3 months cold stratification
Laurus nobilis	March	Cold-dry4 C	1-2 months cold stratification
Malus trilobata	March	Cold-dry 4 C	
Ostrya carpinifolia	March	Cold-dry 4 C	
Ceratonia siliqua	March-April	Cold-dry 4 C	2 weeks in water
Pistacia palaestina	March-April	Cold-dry 4 C	Cold stratification 15 days
Pyrus syriaca	April	Cold-dry 4 C	
Alnus orientalis	April	Cold-dry 4 C	No treatment needed
Cupressus sempervirens	April	Cold-dry 4 C	1 month stratification

Fraxinus angustifolia	June	Cold-dry 4 C	No treatment needed
Fraxinus ornus	June	Cold-dry 4 C	
Pinus pinea	June	Cold-dry 4 C	
Pinus brutia	May	Cold-dry 4 C	No treatment needed
Pinus halepensis	May	Cold-dry 4 C	No treatment needed
Quercus brantii	December-January	No storage	No treatment needed
Quercus cerris	December-January	No storage	No treatment needed
Quercus calliprinos	December-January	No storage	No treatment needed
Quercus infectoria	December-January	No storage	No treatment needed

Sowing at the right time is crucial to achieve robust seedlings. In Figure 7 the differences in stem height and diameter with *Ceratonia siliqua* is noticeable, with higher values in 2013, within the recommended range. The main reason behind the difference is that in 2012 the sowing was done later than the recommended sowing time in March-April, resulting in sub-optimal stem height and diameter.

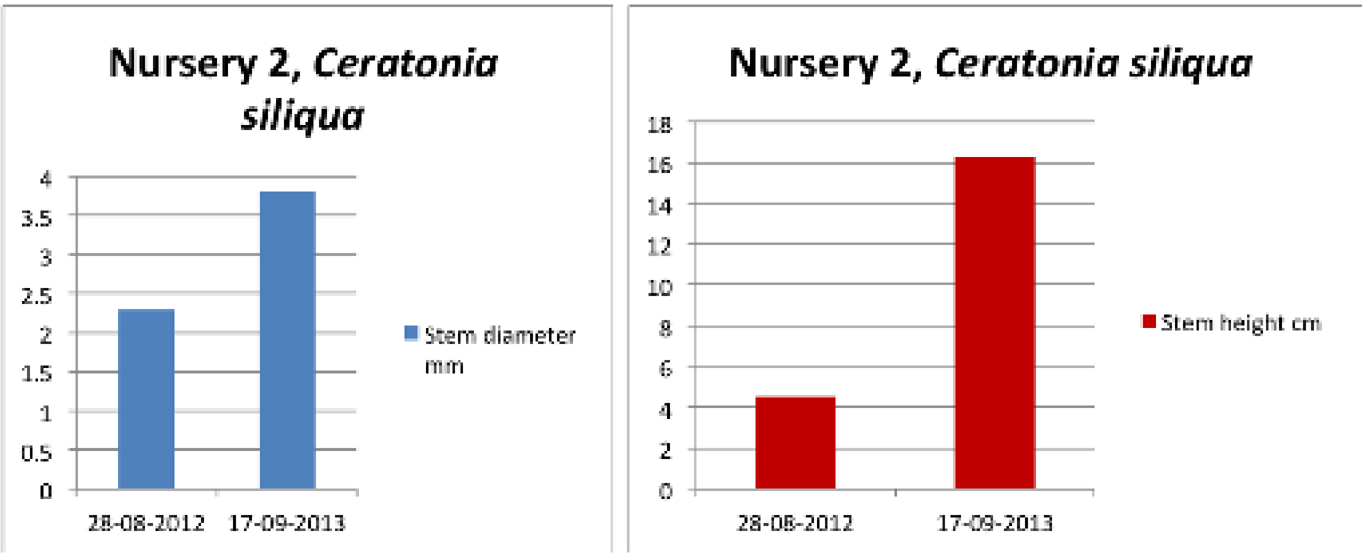


Figure 7 – Compariaon of Ceratonia siliqua seedling growth between August 2012 and September 2013.

In the case of *Pinus* sp., seeds in 2013 were sown at a later time (end May-June) than in 2012 (April). This allowed managing height of the seedlings pre-planting and keeping root-to-shoot ratios at the recommended levels. Figure 8 shows *Pinus pinea* stem height differences between October 2012 and October 2013. The later sowing in 2013 resulted in shorter stems, but stem diameter and height were still within recommended values. Smaller shoot mass requires less water post-planting, which is especially important in dry planting conditions.

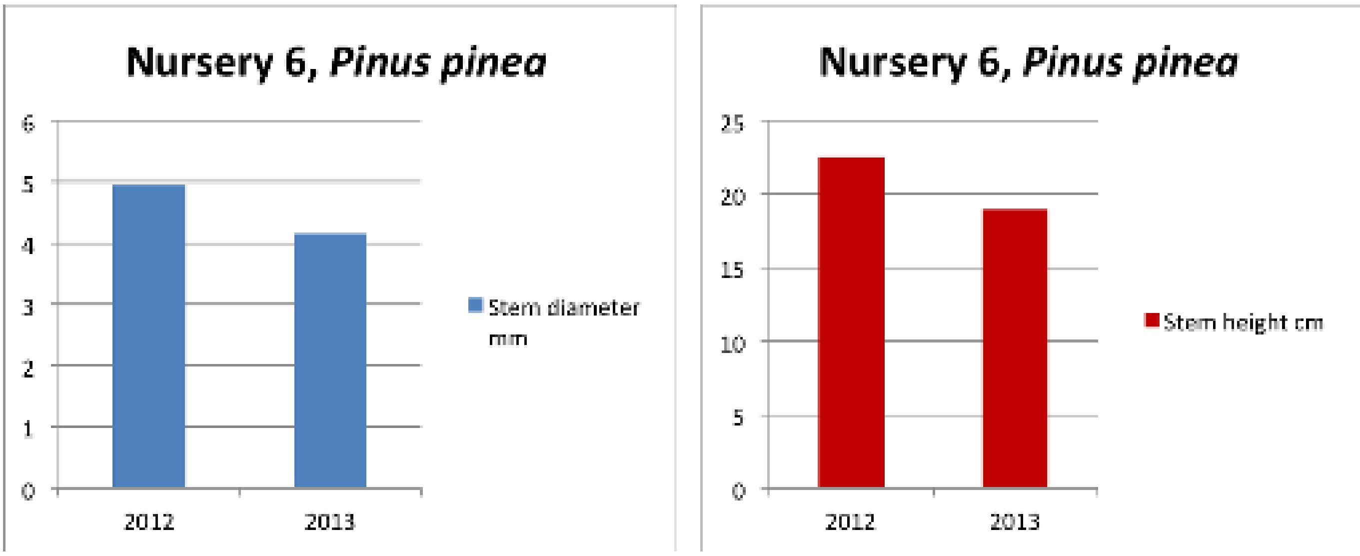


Figure 8 – Comparison of Pinus pinea seedling growth between October 2012 and October 2013.

E. Irrigation management

Irrigation is another critical factor for proper seedling growth and reaching ideal targets shown above in Table 2. Irrigation practice in the past was controlled simply by feel of soil moisture, which often resulted in uneven water delivery and uneven seedling development throughout the growing season. To address this issue, LRI-supported native nurseries introduced a simple irrigation management approach. It required regular monitoring that was not undertaken in previous irrigation efforts.

The block weight method focuses on the development of a gravimetric weight scale to determine irrigation timing and frequency. The method is discussed in more detail in "A Guide to Container Tree Seedling Production," Section 5.1. Table 2 specifies the block weight percentages per species and per stage of the growing season. Irrigation timing is based on block weights of individual trays, starting from sowing phase until hardening phase. Table 5 defines the block weight percentages throughout the growing season, according to each species. At the early stage (from sowing to the first flush of needles or true leaves) irrigation should be maintained at high levels reaching 85 to 90%. The surface of the growing media should always be kept moist. During the growing phase (where 2/3 of the seedling target height is achieved), irrigation should be ample with block weights between 80 to 85%. During this phase the seedlings should not experience moisture stress.

Table 5 – Gravimetric weight scale throughout the growing season used in irrigation management .

	Month											
Species	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Cedrus libani			85	85	85	85	80	75	70	65	60	
Pinus pinea						85	85	80	75	70	65	60
Pinus brutia					85	85	80	75	70	65	60	
Quercus sp.	85	85	85	85	85	85	80	75	70	65	60	
Abies cilicica		85	85	85	85	85	80	75	70	65	60	
Ceratonia siliqua				85	85	85	80	75	70	65	60	
Laurus nobilis				85	85	85	80	75	70	65	60	
Acer sp.			85	85	85	85	80	75	70	65	60	
Arbutus andrachne			85	85	85	85	80	75	70	65	60	
Celtis australis			85	85	85	85	80	75	70	65	60	
Cercis siliquastrum			85	85	85	85	80	75	70	65	60	

Amygdalus			85	85	85	85	80	75	70	65	60	
Pyrus syriaca				85	85	85	80	75	70	65	60	
Pistachia palaestina				85	85	85	80	75	70	65	60	
Sorbus sp.		85	85	85	85	85	80	75	70	65	60	

During the last "hardening" phase – when seedlings are weened to field conditions – irrigation should be slowly and gradually reduced. The decrease in water provided will divert shoot growth to stem and root growth, thus preparing the seedling for harsher field conditions post-planting, shown in Figure 9.

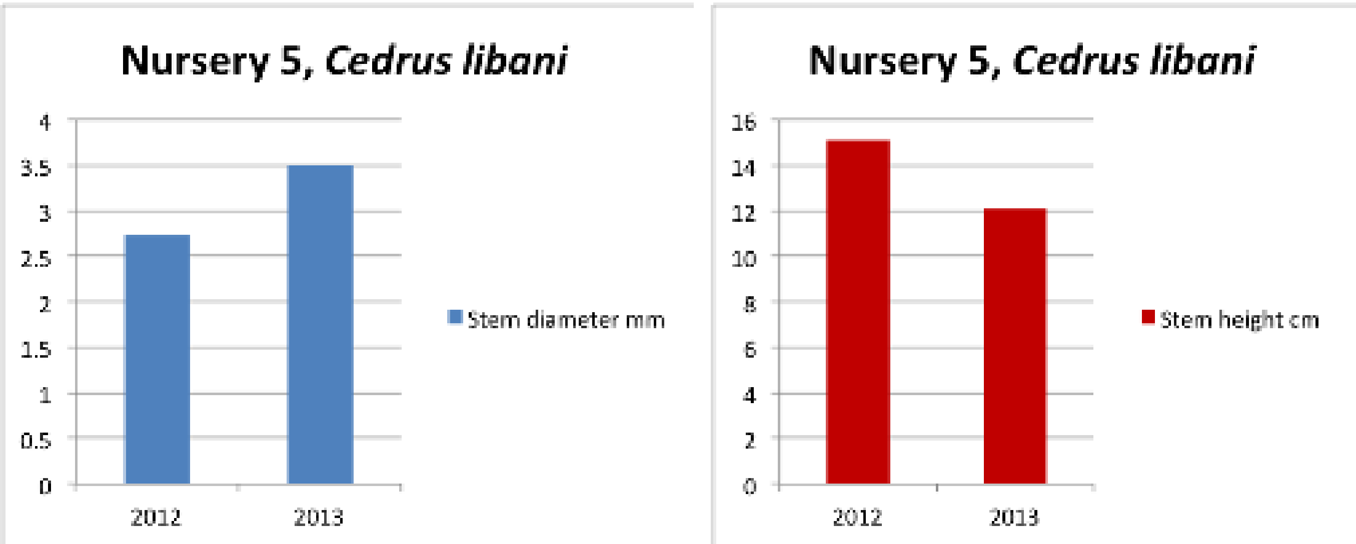


Figure 9 – Comparison of Cedrus libani seedling growth between August 2012 and August 2013.

Figure 10 illustrates the resulting decreased height due to limited irrigation during the growing phase, where block weights reached values below 80%. The seedlings did not reach 2/3 of the target height; however, the growth diverted to increased stem diameter and better root development.

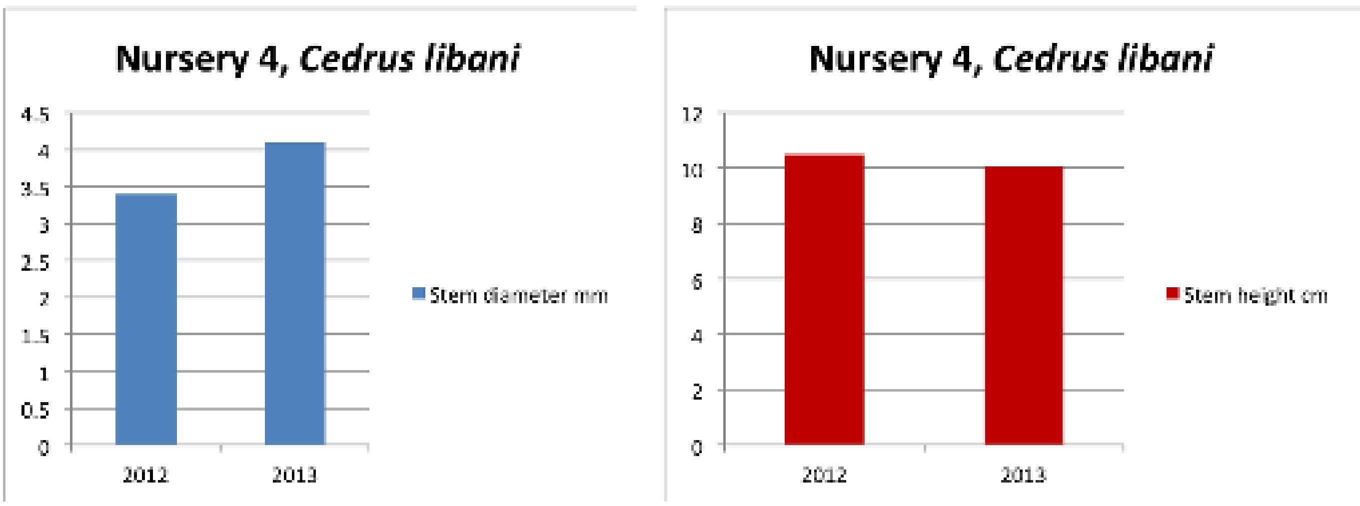


Figure 10 – Comparison of Cedrus libani seedling growth between October 2012 and October 2013.

Irrigation zoning

Different native tree species have different watering requirements. Designing irrigation zones is important to achieve uniform seedling production and uniform distribution of water within the nursery. While designing irrigation zones within the nursery, several factors should be considered:

- Container volume

- Morphological characteristics of species

- Sowing time

In Table 6, species are divided according to the three factors listed above. Before the start of the growing season, nursery growers should design the distribution of species within the nursery according to irrigation zones available and species specifications.

Table 6 – Zoning of species in the nursery.

			Growing pattern		
Species	**Sowing time**	**Container vol.ml**	**Fast**	**Medium**	**Slow**
Abies cilicica	February	120 – 350			x
Sorbus flabellifolia	February-March	250 – 450			x
Sorbus torminalis	February-March	250 – 450		X	
Styrax officinalis	February-March	250 – 450		X	
Acer tauriculum	March	250 – 450		X	
Acer syriacum	March	250 – 450		X	
Arbutus andrachne	March	250 – 450		X	
Cedrus libani	March	250-450		X	
Celtis australis	March	250 – 450	x		
Cercis siliquastrum.	March	250 – 450	x		
Laurus nobilis	March	250 – 450	x		
Malus trilobata	March	120 – 350			x
Ostrya carpinifolia	March	120 – 350			x
Ceratonia siliqua	March-April	250 – 450		X	
Pistacia palaestina	March-April	250 – 450		X	
Pyrus syriaca	April	250 – 450	x		
Alnus orientalis	April	400 – 700	x		
Cupressus sempervirens	April	400 – 700	x		
Fraxinus angustifolia	June	400 – 700	x		
Fraxinus ornus	June	400 – 700	x		
Pinus pinea	June	400 – 700	x		

Pinus brutia	May	400 – 700	x		
Pinus halepensis	May	400 – 700	x		
Quercus brantii	December-January	400 – 700	x		
Quercus cerris	December-January	400 – 700	x		
Quercus calliprinos	December-January	400 – 700	x		
Quercus infectoria	December-January	400 – 700			

F. Fertilization Management

Previously, there was a lack of proper fertilization management and a lack of understanding between nutrient availability and crop development. This resulted in weaker and uneven seedlings that could not adapt rapidly to field conditions. An optimal fertilization program provides seedlings with all essential macro and micro-nutrients throughout the growing season. Fertilization is discussed in "A Guide to Container Tree Seedling Production in Lebanon" in section 6.1. Native tree nurseries have different technical capacities and, thus, several factors should be considered to achieve desired seedling growth rates:

- Available equipment at the nurseries, i.e is fertization delivery possible?
- Available labor throughout the nursery growing season
- Length of the growing season
- All essential nutrients need to be provided throughout the growing season, in relation to the seedling growth stages

Based on experience over the past two years at LRI-supported nurseries, a fertilization program using Basacote Plus 6 M proved highly effective. Basacote Plus 6 M utilizes a controlled release system of all essential nutrients over a six-month period, approximately the length of a growing season in a nursery. It is mixed with the growing media prior to sowing. It facilitates fertilization management in several ways:

- It can be used in all types of production nurseries, from basic to more developed ones
- It decreases labor costs by reducing the amount of time for ongoing fertilization inputs.

The recommended rate is 6 grams of Basacote Plus 6M per 1 liter of growing media.

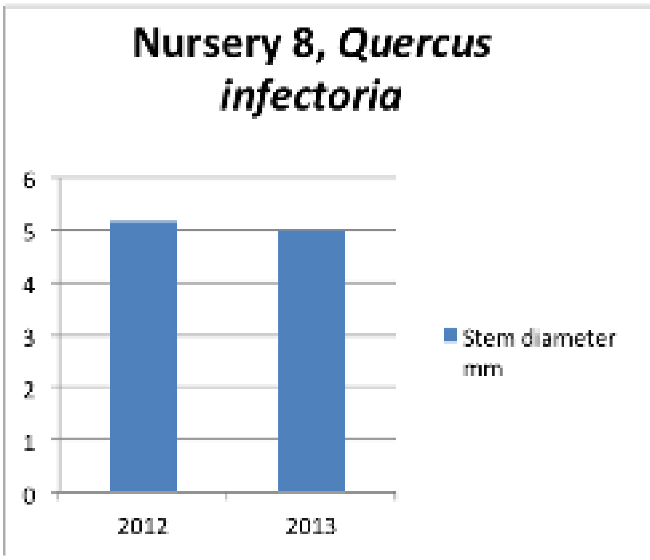
Table 7 – Examples of tissue analysis for three coniferous species, showing adequate nutrient uptake by seedlings for proper growth.

Species	Date collected*	N %	P %	K %	Ca %	Mg %	S %	Zn ppm	Mn ppm	Fe ppm	Cu ppm	B ppm
P.pinea	25-11-13	1.85	0.18	1.23	0.34	0.21	0.22	25.8	179.7	36.5	4.54	18.1
C.libani	27-11-13	1.7	0.16	0.98	0.54	0.41	0.16	25.6	87.22	34.94	2.72	23.6
C.libani	27-11-13	1.52	0.2	1.36	0.46	0.28	0.2	37.8	187.7	45.64	5.05	32.8
P.brutia	28-11-13	1.82	0.21	1.13	0.72	0.15	0.16	20.1	130.3	58.2	4	17
Internationally recommended rates		N %	P %	K %	Ca %	Mg %	S %	Zn ppm	Mn ppm	Fe ppm	Cu ppm	B ppm
		1.5	0.2	1	0.5	0.2	0.1	30-150	100-250	40-200	4-20	20-100

*Tissue samples collected at the end of the growing season, following hardening.

G. Pruning

Other seemingly more modest nursery practices can also affect quality of native tree seedlings and their relative ability to adapt to field conditions post-planting. Pruning of broad leave seedlings such as *Quercus* sp. helps maintain heights to recommended standards. The last pruning is usually done one month before the start of the hardening phase, usually starting in August, depending on the particular species. Figure 11 shows how proper pruning decreased stem height, while maintaining stem diameter at the same levels between 2012 and 2013. The stem height was still within the recommended standards, and the need for water post-planting decreased, giving seedlings a higher chance of survival in arid planting sites.



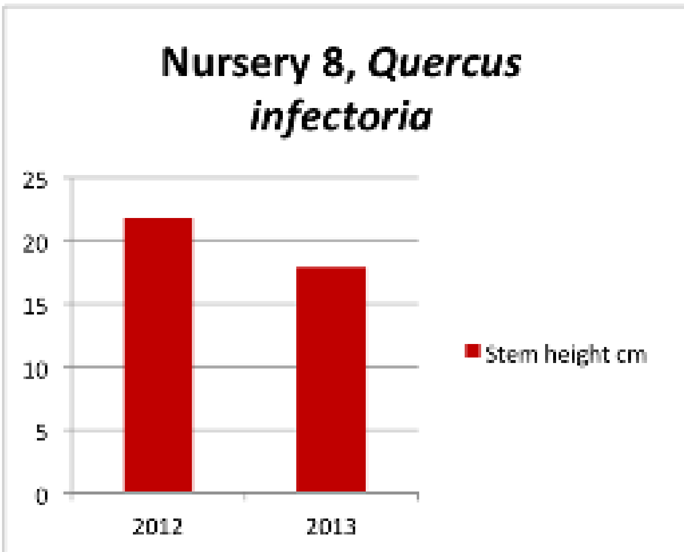


Figure 11 - Comparison of Quercus infectoria seedling growth between August 2012 and August 2013

H. Monitoring of the growing season

Developing and implementing proper nursery practices for the production of good quality seedlings should be complemented with daily and weekly monitoring and recordkeeping throughout the growing season. Keeping records of all nursery practices is crucial and discussed in Section 2 of "A Guide for Container Tree Seedling Production in Lebanon," including:

- Sowing time per species: helps in reaching target seedlings pre-planting by providing data for needed adjustments to sowing and plant care decisions.

- Daily checklist for daily tasks such as weeding, pruning and other activities throughout the growing season, again to provide needed data for optimal nursery management.
- Daily irrigation log: helps in maximizing water uptake by seedlings with minimal loss
- Fertilization: to ensure the optimal fertilizer is used and that all macro- and micro-nutrients are available for the seedlings.
- pH and EC: helps in maintaining proper nutrient uptake by the seedlings.
- Stem height and diameter: The measurements help in achieving target seedlings before the outplanting season.
- Root development: helps in monitoring optimal root growth and pruning requirements.

During the past several growing seasons, three systematic measurements were taken by LRI-supported nurseries to reach targeted seedling quality pre-planting:

1- pH and EC are used as indicators of nutrient status and growing conditions in the media. Nutrient absorption is influenced by pH. Throughout the growing season the pH of growing media should be maintained between 5.5 and 6.5 to ensure all nutrients are absorbed. EC is a measure of electrical conductivity. Salts such as fertilizers are good conductors of electricity. EC values are influenced by the amount of fertilizers in the growing media. When fertilizers in a solution increase so do the EC values. EC values should range between 0.5 to 4 mS/cm. Lower values are sufficient for early phase and higher values are good for middle phase of the growing season of seedlings. pH and EC values were taken at all native nurseries every 10 to 14 days. Overall, values were within the recommended standards, however two cases were observed:

   - High EC and low pH values: This indicated a higher fertilizer concentration in the growing media than is optimal. This was also noticeable in tissue analysis results with N > 3% (recommended = 1.5%). Frequent flushing with water was required to decrease the fertilizer concentration in growing media.

   - Low EC and higher pH values: This indicated a lower fertilizer concentration in the growing media. In the tissue analysis results, N percentage was equal to 0.8% (recommended = 1.5%). Top coating of fertilizer was required to reach recommended levels. Amounts of fertilizers needed were calculated per container, depending on the volume.

   The methods of pH and EC measurements are discussed in “A Guide to Container Tree Seedling Production,” Section 6.2 “Measuring pH and EC.”

2- Stem height and diameter: Reaching target stem height and diameter is crucial pre-planting to achieve higher survival rates post-planting. Table 8 and Table 9 compare the final stem height and diameter for nurseries to the recommended rates. Overall, all nurseries were within the recommended ranges. In Tannourine, the decreased stem height was due to a lack of irrigation during the growing phase. The height of *Ceratonia siliqua* at Native Nurseries was also higher than the recommended one, however it was sown in D40 containers and grew with a proper root-to-shoot ratio.

3- The selection of nursery practices dictates seedling growth and quality, more importantly root structure and development. Root development was monitored throughout the growing seasons. In all nine LRI-supported native tree nurseries, root systems were vigorous and well-developed, increasing the chances of survivability in the field (Figure 12).

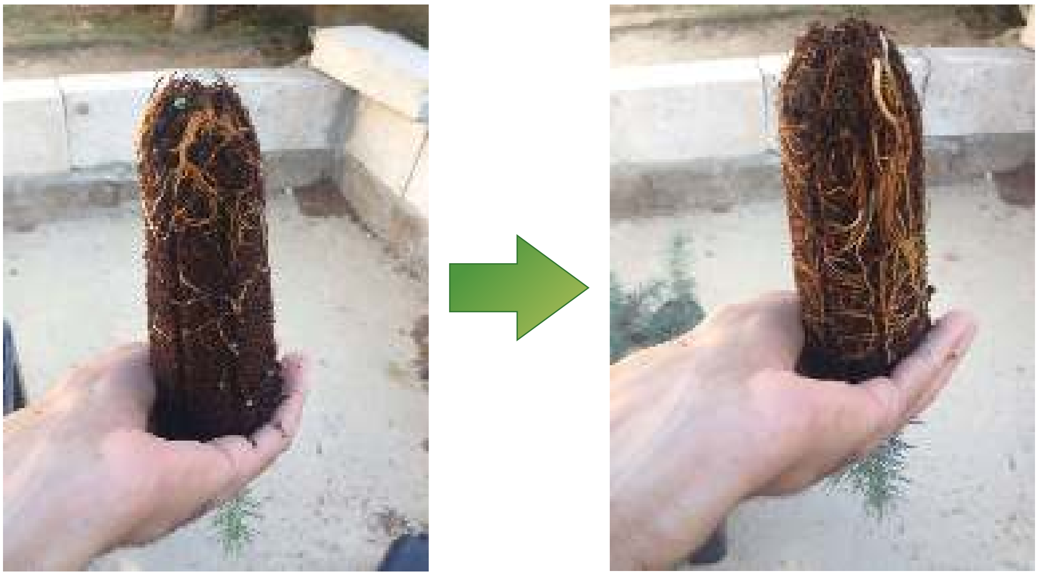


Figure 12 – Root development throughout the growing season in D27.

Table 8 – Average stem height per species pre-planting fall 2013 (cm).

Species	Height standards	AFDC	NN	APJM	Tannourine	Bcharre	Bkessine	NCC	Kouroum
Cedrus libani	15 cm minimum	14.2			10.05	21.35			
Pinus pinea	15 – 30 cm	21		28			19		16.05
Quercus sp.	15 – 30 cm	25.3	25	26.95	23.95				18.2
Pinus brutia	15 cm minimum							11.35	
Abies cilicica	10 cm minimum		12.8						
Ceratonia siliqua	10 – 15 cm		20.8						
Crataegus sp.	15 – 30 cm		26.5						
Pyrus syriaca	15 – 20 cm								18.1
Pistachia palaestina	15 – 20 cm		16.3						

Table 9 – Average stem diameter per species pre-planting fall 2013 (mm).

Species	Diameter standards	AFDC	NN	APJM	Tannourine	Bcharre	Bkessine	NCC	Kouroum
Cedrus libani	2 mm minimum	4.25			4.1	4.55			
Pinus pinea	3 mm minimum	4.73		5.282			4.15		4.5
Quercus sp.	4 mm minimum	4.66	4.5	5.6	5.45				4.885
Pinus brutia	3 mm minimum							3.05	
Abies cilicica	2 mm minimum		5.1						
Ceratonia siliqua	2.5-3 mm minimum		5.4						
Crataegus sp.	3 mm		4						
Pyrus syriaca	3 mm								3.95
Pistachia palaestina	4 mm minimum		3.5						

IV. CONCLUSION AND RECOMMENDATIONS.

The main objective in choosing the above discussed practices was not only to increase seedling quality, but also to create sustainability in production and quality that will ensure sustainability for reforestation in Lebanon. The LRI-supported native tree nurseries have produced more than 500,000 seedlings under the new practices since 2012. After several years of onsite trainings and workshops, nursery growers implemented all practices according to specified timelines and standards.


Figure 13 – Onsite technical trainings and workshops.


Figure 14—Sustainable seedling quality and production capacity.

Generally, the results show consistency in seedling production per species in the nurseries, with no significant differences between 2012 and 2013 stem heights and diameters. However, stem diameters tend to be higher in 2013. This is likely due to better implementation of the hardening phase than in 2012, allowing seedlings to grow more in diameter and less in height pre-planting, thus decreasing the need for water post-planting.

Overall, the adopted practices resulted in a sustainable production of good quality seedlings (Figure 14):

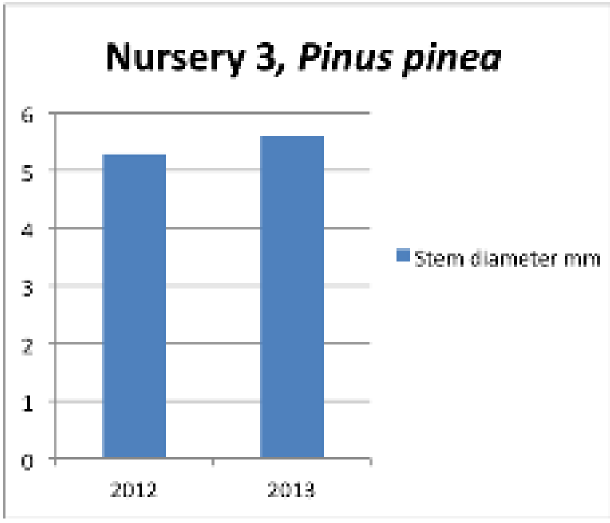
1. All material and equipment are locally available
2. The containers selected are long lasting (minimum of five years)

3. Nursery growers are working with measurable quantities of material facilitating the management of the growing season

4. The practices are easy to follow over the years and the methodology used is reproducible

5. Higher number of seedlings are produced in 1 m^2

Figure 15 shows there are no significant differences between 2012 and 2013 seedlings when all practices are well implemented. In both years, practices were implemented following recommended protocols with reproducible methodology. Average stem height and diameter were constant both years before planting, concluding that seedling production was sustainable and proper for successful reforestation efforts.



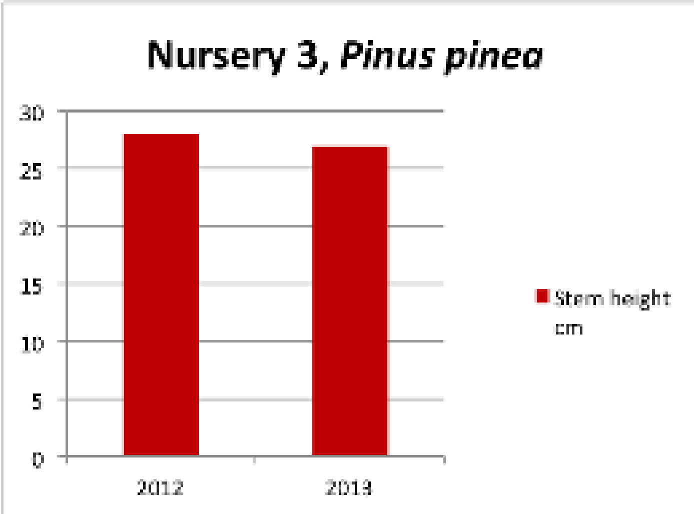


Figure 15 – Sustainability in Pinus pinea seedling production between 2012 and 2013

Significant and sustainable improvements in seedling quality and production capacity were achieved at all nine LRI-supported native tree nurseries, bringing them all to international standards of seedling production. Coupled with advances in outplanting approaches, the nursery developments will contribute to improvement of reforestation efforts and success in Lebanon and by extension throughout the Mediterranean basin.

V. REFERENCES

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