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Factors Influencing the Quality of Nursery Seedlings of *Pinus Pseudostrobus* Lindl.

Pedro A. Dominguez, Jose Navar, Ciro Hernandez, and Jose Tienda

Professor and Research Scientist, Instituto de Ecologia (INECOL), Durango, Dgo., México; Professor and Research Scientist, Facultad de Ciencias Forestales–Universidad Autónoma de Nuevo León (FCF-UANL), Iturbide, Nuevo León, México; Professor and Research Scientist, Instituto de Silvicultura e Industria de la Madera – Universidad Juárez del Estado de Durango (ISIMA-UJED); Forestry Engineer, Facultad de Ciencias Forestales – Universidad Autónoma de Nuevo León (FCF-UANL), Iturbide, Nuevo León, México; Instituto de Ecología, A.C.; Carr. A Mazatlan km 5; C.P. 34000, Durango, Dgo., México;

Abstract

This study presents the results of cultivating seedlings of *Pinus pseudostrobus* Lindl. in nursery conditions for 1 year. Germination and survival were tested in five container types and three substrates. A "mixture" (50-percent peat moss, 25-percent agrolite and 25-percent vermiculite) and the "pine bark" substrates provided better germination than the "forest soil." Survival was better (89 percent) in 100-cm^3 (6-in^3) tubular containers. Seedlings growth was proportional to the capacity of the containers. Most robust seedlings were obtained in 400-cm^3 (24-in^3) plastic bags. However, given the expected economical and environmental benefits, we recommend *Pinus pseudostrobus* be grown in 160-cm^3 (10-in^3) tubular containers with pine bark substrate.

Introduction

With the objective of increasing the forest cover of Mexico, the National Reforestation Program, PRONARE (SEMARNAP 1998) was created in 1989. Since that time, the production of conifer seedlings has greatly increased due to the introduction of technically improved production systems. However, the indiscriminate adoption of methodologies used in advanced countries for the production of seedlings has not always yielded satisfactory results due to different ecological conditions prevailing in several Mexican regions (Cetina et al. 1999; Tienda 2000).

In rural reforestations, it is common to observe low survival rates as a consequence of deficient quality of the seedlings used (Dominguez and Navar 2000). Johnson and Cline (1991) pointed out that high-quality seedlings could survive a prolonged environmental stress and present a vigorous growth after plantation.

This study is aimed at contributing to the design of a technological package for the production of high-quality nursery seedlings of *Pinus pseudostrobus* Lindl. *(P. pseudostrobus)*, using adequate substrates and containers to allow better results in the regional reforestation tasks in Nuevo Leon, Mexico.

Materials and Methods

Experimental site. The nursery of the Faculty of Forestry Sciences, Universidad Autónoma de Nuevo León (UANL) is located in the county of Iturbide, N. L., at 24° 43' N, 99° 53' W and 1,600 meters (5,249 ft) above sea level. According to Garcia (1973), the regional weather is hot—dry with rainy summer. The average annual precipitation is 629.1 mm (2.5 in.), and the average annual temperature 18° C (64.4° F). The thermal oscillation varies from minus 10° to plus 35° C (14° to 95° F).

Experimental material. The experiment was conducted in October 1999 in the nursery of the Faculty. We used three substrates: (1) composted pine bark "MASVI"; (2) a mixture of peat moss, perlite, and vermiculite in proportions of 50 percent, 25 percent, and 25 percent, respectively; and (3) a control represented by natural forest soil. The seeds were placed in four container types: (1) polyurethane planting trays with 108 cavities of 100 cm^3 (6 in^3) each, (2) tubular containers apb® of 100 cm^3 (6 in^3), (3) tubular containers apb® of 160 cm^3 (10 in^3), (4) polystyrene bags of 400 cm^3 (24 in^3), used as controls. Four container types with two substrates plus a control (bags with forest soil) resulted in nine treatments. There were 12 experimental units per treatment, making a completely randomized design.

The treatments were:

T1 = 100-cm³ (6-in³) polyurethane planting trays filled with bark.
T2 = 160-cm³ (10-in³) tubular containers filled with mixed substrate.
T3 = 100-cm³ (6-in³) round tubular containers filled with bark.
T4 = 160-cm³ (10-in³) tubular containers filled with bark.
T5 = 400-cm³ (24-in³) plastic bags filled with natural forest soil.
T6 = 100-cm³ (6-in³) squared tubular containers filled with bark.
T7 = 100-cm³ (6-in³) round tubular containers filled with mixed substrate.
T8 = 100-cm³ (6-in³) squared tubular containers filled with mixed substrate.
T9 = 100-cm³ (6-in³) polyurethane planting trays filled with mixed substrate.

Those treatments are conventionally used in several nurseries in northern Mexico, and the experiment was intended to test their adequate applicability for the production of seedlings.

Statistical evaluation and measures. We made weekly observations beginning with the date of seeding, recording the emergence of the seedlings (percent), the temperature, and the precipitation. We also analyzed substrates to determine their more important physical and chemical characteristics. We determined the responses of the seedlings to the substrates and the container types on the velocity of the germination and the development of the seedling heights through variance analyses and confidence intervals.

After a 12-month period of cultivation in the nursery, we randomly selected 15 seedlings per treatment and performed a biomass analysis. For each seedling, we recorded diameter, stem, and root length; number of secondary roots; and weight (g) produced in the aerial and radicular portions. These parameters were considered as indicators of the quality of the seedling. We evaluated the registered variables through variance analysis and a means comparison with the Tukey test, following conventional statistical methods.

Results and Discussion

Germination evolution of seedlings for all the treatments is shown in figure 1.

During the first 20 days of observation, the mixed substrate yielded the highest percentage of germinated seeds (55 percent), while the bark and natural forest soil substrates yielded 28 percent and 16 percent, respectively. The last two values are statistically different from the first one (***P***=0.05). The highest germination rate observed in the mixture substrate was probably due to the high content of organic matter (14 percent) and to the proportion of organic and inorganic materials (50:50) used in this study.

An acid substrate (pH between 5.0 and 6.0) with an organic matter content around 14 percent fosters germination (Landis et al., 1990). The substrates used in this study did not simultaneously present these two conditions. The mixture and the forest soil were alkaline, while the bark substrate was acidic. Organic matter content was higher in the substrates mixture and forest soil.

The alkalinity and the lower percentage of organic matter in the forest soil, probably affected the germination rate and efficiency. At the end of the study, the germination levels in the substrates mixture (90 percent) and bark (89 percent) were higher compared with the percentage in the forest soil (78 percent). Their final values, however, were not significantly different (P^{in}=0.05). All of the these values can be considered highince they are superior to those reported by Prieto and Trujillo (1999) for *Pinus engelmannii* and Prieto et al. (1999) for *Pinus cooperi,* using the substrates mixture and bark respectively in each species. The survival rate of the seedlings grown in all the different treatments is shown in figure 2.

Figure 1: *Germination rate of the seedlings of* P. pseudostrobus *in three substrate types. Grown in the nursery of the Faculty of Forestry, FCF/UANL.*

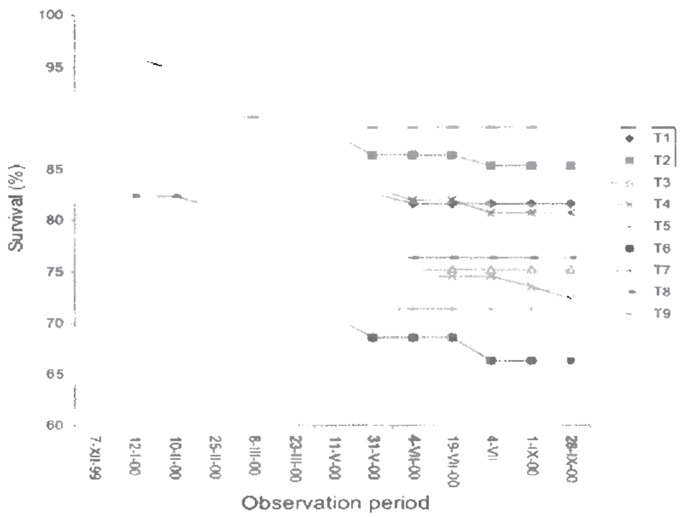

Figure 2: *Survival rate of* P. pseudostrobus *seedlings grown in five different containers and three different substrates, at Iturbide, Nuevo León.*

Two periods can be observed with a decrease in the survival rate in almost all of the treatments. Mortality was probably caused by the low registered temperatures (-2°C) and also by damping-off negatively affecting all seedlings. At the end of the 12-month observation period, the best survival rate (89 percent) was shown by the seedlings grown in trays filled with the mixture (T9) and the poorest (71 percent) was registered in the tubular 100-cm^3 (6-in^3) containers with the mixture (T7). The variance analysis indicates significant differences (***P***=0.05) in this parameter for the different treatments.

Better survival rates were observed in the shorter seedlings, which were grown in the lower capacity 100-cm^3 containers (T1and T9). The benevolent conditions in the nursery allowed the observation of acceptable survival percentages in all treatments. However, the quality of these seedlings was lesser than that of those observed under other parameters (table 1).

The precarious quality of seedlings, together with the poor soil conditions of the planting sites in this region (heat and drought) suggest that these seedlings should not be planted here since they would be very susceptible to drying out (Domínguez and Návar 2000).

In table 1, the morphological parameters of 12-month nursery seedlings are shown. The results of the variance analysis indicate that there are significant differences in all of the registered parameters (***P***=0.05). In general, it was possible to observe that the containers capacity influenced the size of the seedlings and, therefore, also the biomass production. This can be observed in the treatments with greater containers (T2 and T4 with 160 cm^3, and T5 with 400 cm?^{3}).

Those results are coincident with the ones reported by Aguirre (2000) for seedlings of *P. pseudostrobus* of similar age grown in containers of the same capacity and with substrates similar to those used in the current study. It is interesting to note that the length of the root system observed in the seedlings grown in the containers previously described, is greater than the root length recorded in the seedlings of the rest of the treatments. Similar results were reported by Aguirre (2000) for *P. pseudostrobus* in containers of the same capacity and are also included in the rank mentioned by Montoya and Cámara (1996) for seedlings intended to be established in dry sites, since these can absorb moisture from greater soil depths. Montoya and Cámara (1996) presented similar observations for seedlings that were to be established in dry sites, in which seedlings were ranked for moisture absorption at greater depths.

The number of secondary roots also increases the moisture absorption capacity of the seedling. In this experiment, seedlings grown in larger volume containers had more secondary roots. These characteristics of the radical systems are important, taking into account northeastern Mexico's irregular precipitation.

The average basal diameter of the stems at the end of the nursery phase is shown in figure 3. The variance analysis indicates that there are significant differences (***P***=0.05) between the average diameters of the seedlings of different treatments. The best results were observed with the seedlings cultivated in the larger capacity containers (T2, T4, and T5), in which seedling diameters were greater than those observed in the other treatments.

The diameter is also considered to be an indicator of the quality of the seedling, and it is related to the growth of the radical system (Prieto et al. 1999); therefore, its dimension can influence the behavior of the seedling in the planting site.

Mexal and Landis (1990) pointed out that it is possible to ensure a survival rate superior to 80 percent in the field if the seedlings leave the nursery with stem diameters between 5 and 6 mm. The same authors indicate that the

Table 1. *Treatment effects on morphological parameters and biomass production of* P. pseudostrobus *seedlings at 12 months age in the forestry nursery of the Faculty of Forestry, FCF/UANL.*

Treatments	Dry weight biomass (gr)			Diameter (mm)	Length (cm)		Average secondary roots
	Tallo	Raíz	Total		Tallo	Raíz	
100-cm^3 tray with bark (T1)	0.8	0.4	1.2c	1.2	6.3	11.2d	14d
160-cm^3 tubular container with mixture (T2)	3.3	2.6	5.9a	1.7	10.5	20.1b	20c
100-cm^3 round tubular container with bark (T3)	2.5	1.8	4.3b	1.5	9.1	11.4	20c
160-cm^3 tubular container with bark (T4)	3.7	2.3	6.0a	1.7	11.4	18.7c	26b
400-cm^3 plastic bag with forest soil (T5)	4.5	2.1	6.6a	1.8	14.1	26.4a	30a
100-cm^3 square tubular container with bark (T6)	2.6	2.0	4.6b	1.5	9.01	13.9d	24b
100-cm^3 round tubular container with mixture (T7)	2.1	2.0	4.1b	1.5	8.6	10.3e	25b
100-cm^3 tubular container with mixture (T8)	2.0	2.0	4.0b	1.4	8.1	12.8d	21c
100-cm^3 tray with mixture (T9)	2.0	1.3	3.3c	1.7	9.0	9.4e	17d

survival rate is increased from 5 to 7 percent for each millimeter increase in the diameter of the seedling.

- The diameter differs among individuals of the same species and also among the species themselves. So for example, Rodriguez (1993) and Aguirre (2000) reported larger dimensions for seedlings of the same species than the dimensions reached by the seedlings in this study. Prieto et al. (1999) also mention larger diameters for *Pinus engelmannii* and *Pinus arizonica* grown in conventional systems, in contrast with seedlings grown in other containers and with other substrates.

The development in height of the nursery seedlings is shown in figure 4. In the first 5-month observation period, the increment in height is barely perceptible in all treatments. Probably low temperatures prevented the growth of the seedlings. However, once the average temperature reached values above 12 °C, a generalized increase in the height was observed in all of the treatments.

Variance analyses performed for height showed significant differences (P=0.05) among treatments beginning with the 7th observation (8 March 2000). From this date until the last observation, four groups of treatments can be distinguished whose heights are not statistically different (P=0.05).

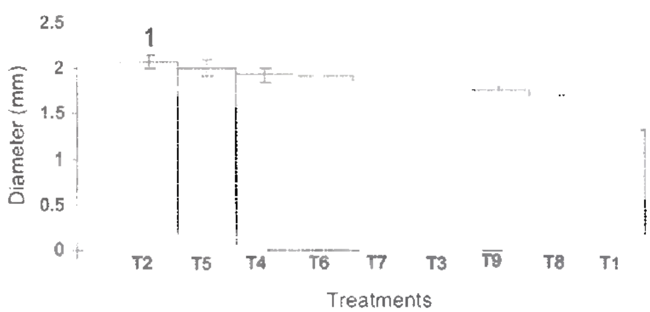

Figure 3: *Average diameter and confidence intervals for seedlings of* P. pseudostrobus *at the end of the nursery phase, reached at the age of 12 months in the nursery of FCF/UANL.*

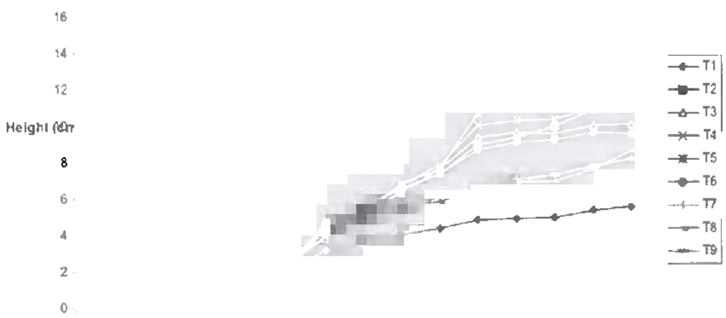

Figure 4: *Growth in height of seedlings of* P. pseudostrobus *cultivated in five different containers and three different substrates in the nursery of the School Forest of the FCF/UANL.*

The first group, with height of 5.6 cm (2.2 in), is made up of the seedlings from the treatment 100-cm^3 (6-in^3) tray with bark (T1). The seedlings from the 100-cm^3 (6-in^3) tubular container with mixture (T6) and 100-cm^3 (6-in^3) planting trays with mixture (T7) treatments constituted the second group with the heights reaching approximately 8.0 cm (3.1 in) at the end of the study. The third group, with height of 10.1 cm (4 in), was conformed by the plants from the 100-cm^3 (6-in^3) tubular container with bark (T3) treatment. The seedlings of the 160-cm^3 (10-in^3) tubular container with mixture (T2) and 160-cm^3 tubular (10-in^3) containers with bark (T4) treatments reached about 11.0 cm (4.3 in.), and they were the second tallest seedlings.

The last group was composed of the treatment bags with forest soil (T5), which produced the tallest seedlings, reaching 13.6 cm (5.3 in) at the end of the study. The height of the seedlings in this last treatment can be considered acceptable, and it is very similar to that reported by Aguirre (2000) for the same species in identical growth conditions.

Dominguez and Navar (2000) pointed out that the height of the seedlings is strongly influenced by the capacity of the containers and that it is a function of the growth rate of the species. This coincides with the results obtained in the current study, where we observed taller seedlings in the larger volume containers.

Regarding Mexican pines, Prieto et al., (1999) report lesser heights for *Pinus engelmanni* and *Pinus arizonica* and greater heights for *Pinus durangensis* of the same age and grown in conventional systems, in comparison with the heights reported for *P. pseudostrobus* in the present study.

Conclusions and Recommendations

On the basis of the results of the present study, we conclude that the substrate mixture and bark substrate are the best media to accelerate the seed germination, a factor that may shorten nursery production cycles. The observed high germination percentages and the statistical similarity registered in the tested substrates allow us to recommend the utilization of composted pine bark. This could reduce production costs because this substrate is less expensive than the components conventionally used for planting substrate mixtures (perlite, agrolite, peat, etc.). In addition, the utilization of sawmill waste could contribute to increase income to logging communities in the region.

Seedlings survival in the nursery phase was not show to be dependent of any specific treatment. However, it was possible to confirm that the nonwoody stems of the seedlings grown in smaller containers were more susceptible to drying out.

In regard to dimensions and biomass production the superiority of seedlings cultivated in larger capacity containers was evident. Among them, the seedlings grown in the conventional system of bags with forest soil (T5) and secondly the seedlings grown in tubular containers of 160 cm^3 (10-in^3) were outstanding, given their strength. The low cost and easier management of the seedlings in the nursery using these containers and substrates makes them our recommended choice. However, it is important to point out that the utilization of larger tubular containers (more than 250 cm^3 (15 in^3)) and the application of agrochemical products will produce better quality seedlings, increasing the success probabilities of rural plantations in this region.

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