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TEST OF ALTERNATIVE NURSERY PROPAGATION CONDITIONS FOR *LUPINUS ELEGANS* KUNTH PLANTS, AND EFFECTS ON FIELD SURVIVAL

PRUEBA DE CONDICIONES DE PROPAGACIÓN ALTERNATIVAS EN VIVERO PARA PLANTAS DE *LUPINUS ELEGANS* KUNTH, Y SU EFECTO EN LA SUPERVIVENCIA EN CAMPO

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RESUMEN

En condiciones de restauración ecológica que dificultan el establecimiento de las plantas a partir de semillas, el uso de plantas propagadas en vivero es recomendable a pesar del mayor costo. *Lupinus elegans* es una leguminosa perenne de corta vida que tiene potencial para ser usada en restauración y recuperación ecológica en su área de distribución natural en Norteamérica. El tamaño del contenedor y la edad al momento de transplantar son variables de importancia porque afectan la supervivencia en campo. Los presentes resultados indicaron que las plantas crecidas en contenedores en el rango de 310 a 380 cm^3 con un régimen de fertilización semanal con una dosis de 24 mg de fertilizante por planta, son adecuados para la propagación en invernadero de *L. elegans*. La edad de la plántula al transplante para lograr la máxima supervivencia en campo fue de tres meses.

Palabras clave: *Lupinus elegans*, Fabaceae, restauración, propagación.

SUMMARY

Under ecological restoration conditions that impair plant establishment from seed, the use of nursery propagated plants is recommended despite the increased cost. *Lupinus elegans* is a short-lived perennial legume that has potential for use in restoration and reclamation projects within its distribution range in North America. Nursery container size and age at transplant are key variables influencing survival under field conditions. Our results indicate that plants grown in containers within the volume range of 310 to 380 cm^3 fertilized every week with 24 mg of fertilizer per plant, are adequate for propagating *L. elegans* under nursery conditions. Optimal seedling age at transplant was three months old because it allowed the highest survival rates under field conditions.

Index words: *Lupinus elegans*, Fabaceae, restoration, propagation.

INTRODUCTION

Lupinus elegans is a shrubby legume characteristic of disturbed sites within oak-pine and pine forests in the central region of México at altitudes from 2000 to 3000 m (Sánchez, 1980; McVaugh, 1987). *Lupinus elegans* is particularly abundant in abandoned agricultural fields (*personal observation*). Because of its tolerance to adverse conditions and its nitrogen fixing capability, *L. elegans* has potential for both ecological restoration and agroforestry. Several species of *Lupinus* have been used for human consumption, for improving soil structure, and as ruminant feed (Subramanian and Babu 1994, Huyghe, 1997). Legumes are well known for improving soil conditions (Mislevy *et al.*, 1990), reestablishing the nitrogen cycles (Bradshaw *et al.*, 1982) and improving soil conditions (Ashton *et al.* 1997). Several lupine species are first colonizers after a major disturbance (del Moral and Clampitt, 1985; Halvorson *et al.*, 1992).

Despite the potential of *L. elegans* for ecological restoration of heavily degraded areas where plant establishment from seed is limited or lacking (Blanco-García and Lindig-Cisneros, 2005), use of this species on a large scale is limited because information on techniques for its propagation under nursery conditions is incomplete. Pre-germination treatments have been studied for several lupine species (Mackay *et al.*, 1995; Romme *et al.*, 1995; Rodríguez and Rojo, 1997; Kaye and Kuykendall, 2001; Mackay *et al.*, 2001). Pre-germination treatments have been studied for *L. elegans* as well, and also the effect of different substrates on germination (Medina-Sánchez and Lindig-Cisneros 2005). Techniques for propagating the species under nursery conditions in a cost effective manner have not been developed.

The present study assessed the effect of container size and fertilization regime on nursery performance of *L. elegans*, and the effect of seedling age at transplant on plant survival after five months under field conditions. Although general recommendations exist for container sizes to be used for tree and shrub species (Peñuelas and Ocaña, 1996), determining the optimum size can significantly reduce propagation costs when a large number of plants are to be produced; similarly, determining the optimum fertilization regime and the minimum age at transplant that yields high survival rates in the field, may also reduce

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propagation costs and therefore make restoration efforts more cost effective.

MATERIALS AND METHODS

Optimum container size and fertilizing regime for *L. elegans* propagation under greenhouse conditions was determined through a two factor orthogonal experiment. The factors were container size with three levels (137, 310 and 380 cm^3 container sizes) and fertilizing regime with two levels (fertilization every week and every 15 days); therefore, six treatments were included in the experiment: 137, 310 and 380 cm^3 sizes with weekly fertilization and 137, 310 cm^3 and 380 cm^3 with fertilization every two weeks.

Container sizes were within the range recommended for shrub species by Peñuelas and Ocaña (1996) and the containers were obtained from a local manufacturer (containers for plant propagation, APB Plastics, México City). Each container was filled with a locally available organic-rich synthetic growing medium (Creci-root®, Uruapan, México) mixed with sand (1:1), using 150 containers of each size. Fertilization was carried out with a soluble fertilizer (Miracle Gro®, The Scotts Company, Ohio), which was prepared by adding 10.8 g of fertilizer in 7 L of tap water and the solubilized fertilizer was then evenly distributed among all containers; each plant received 24 mg (N-4 mg, P-7 mg and K- 4 mg) of fertilizer in each event.

Before planting, the seeds of *L. elegans* were scarified with concentrated sulfuric acid for 30 min (Medina-Sánchez and Lindig-Cisneros, 2005). Two seeds were sown per container to have at least one seedling; if both seeds germinated, the second one was eliminated. Containers were watered as needed when plants showed signs of water stress. Variables recorded were: seed germination (as seedling emergence), and seedling height every 15 d.

In order to determine the optimal plant age for transplanting *L. elegans,* a field experiment under restoration conditions was set-up at Nuevo San Juan Parangaricutiro (19° 30' 42.4" NL, 102° 12' 03.0" WL and 2450 masl). The restoration site is covered with volcanic ash, practically without vegetation cover (Blanco-García and Lindig-Cisneros, 2005), and surrounded by pine and oak-pine forests. For this trial *L. elegans* plants were previously propagated in 310 cm^3 containers and fertilized weekly, sowing at different dates so that seedlings were 15, 45, 90 and 180 d old at transplanting time, which was at the beginning of the rainy season (June 2003). In addition to these treatments scarified seeds were also planted. Plants and seeds were planted in two blocks, each with 100 plants (20 per treatment). In each block, four quadrants arranged in a latin-square design were included, with five plants per quadrant. Blocks were protected from small rodents by fencing them with chicken wire, because in previous experiments in the same site small rodents severely damaged lupines (Blanco-García and Lindig-Cisneros, 2005). Five monthly visits allowed for the registration of survival and times of flowering and seeding.

For germination and survival data, generalized linear model (GLM) analyses for binomial distributed data were applied (Kutner *et al.*, 2004). Growth was analyzed by analysis of variance (ANOVA) and multiple comparisons were carried out with the Tukey test (Underwood, 1998). A complete statistical model to test main effects and interaction was used both for GLM and ANOVA analyses; only significant effects or interaction are reported here. All analyses were carried out using the S-Plus 2000 software (Statistical Sciences, 1999).

RESULTS AND DISCUSSION

Germination significantly varied among container size treatments ($P = 0.001$). Lowest germination percentage was obtained in 137 cm^3 containers (52 %), followed by germination in 380 cm^3 containers (64 %) and the highest germination rate (72 %) was obtained in 310 cm^3 containers. Damage by fungi was common in seeds planted in small containers; and it was observed that the substrate remained wet for a longer time in 137 cm^3 containers than in larger containers of the other two sizes tested. Plant infection by pathogens of plants growing in organic-rich substrates has been reported for other legume species under nursery conditions (Gonzalez and Camacho, 2000), being this factor the probable cause for the observed trend.

Seedling growth in the nursery after 60 d differed also among treatments (Table 1), responding both to container size ($P < 0.0001$), fertilizer regime ($P < 0.0002$) and to the interaction ($P < 0.0006$). The tallest plants (39.2 ± 7.8 cm) were obtained in medium (310 cm^3) containers when fertilized every week, according to Tukey test. The second tallest plants were obtained in large containers (380 cm^3) the differences in height between fertilizing regimes being not statistically significant for this container size as shown by the Tukey test. These results indicate that either medium-size or large containers are suitable for propagating this species, although using large containers increases growing media use by 18 %. Weekly fertilization is also recommended.

At the beginning of the field experiment, plant height varied among treatments because of differences in plant

Table 1. Mean height and standard deviation for Lupinus elegans *plants growing under different fertilizer regimes.*

	Container size		
Fertilizer regime	Small (137 cm^3)	Medium (310 cm^3)	Large (380 cm^3)
Every week	31.6 ± 6.2 cm b	39.2 ± 7.8 c	33.3 ± 11.0 b
Every two weeks	23.8 ± 5.7 cm a	31.8 ± 7.1 b	35.8 ± 10.2 b

Means with different letters are statistically different (Tukey, 0.05).

age (1.5 months old, 18.5 ± 1.0 cm; 3 months old, 44.6 ± 1.5 cm; 6 months old, 61.8 ± 1.7 cm). After five-months of growing in the field, the tallest individuals flowered and fructified, at that time the experiment was considered to be finished. Individuals having 3 months and 6 months of age at transplant showed the highest survival (58 % and 56 % respectively), 1.5-month of age plants at transplant showed intermediate survival (37 %) while planted seedlings and seedlings germinated from sowed seeds showed the lowest survival (17 %), being these differences in survival significant ($P < 0.01$). Some 6-month old plants died because of run-off damage that prostrated the plants, but 3-month-old plants did not show this problem because of their smaller size at transplant. It has been shown that taller plants at transplanting suffer less damage from herbivores than small plants (Dunsworth, 1997; Mason, 2001; Howell and Harrington, 2004). According to these results, 3-month old plants are adequate for transplanting this species into the field because they are less prone to damage from herbivores, and are more tolerant to mechanical damage by run-off.

In summary, containers of 310 cm^3 are better for germinating seeds and growing seedlings of *L. elegans* under greenhouse conditions. These containers require 18 % less substrate than larger containers, and facilitate handling during propagation and transplant because the roots can retain the growing medium when extracted from the container for transplant. Fertilizing every week produces taller plants than fertilizing every two weeks, and larger plants are advantageous for transplanting in the field because they would be less damaged by herbivores. The most adequate plant age for transplanting *L. elegans* in the field is 3 months old, because the plants show the same survival rate as 6-month-old plants and require less time in the nursery.

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