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Comparison of Seedling Containers on Growth and Survival of *Prosopis alba* and *Leucaena leucocephala* in Semi-Arid Conditions

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ABSTRACT

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The growth and survival of *Prosopis alba* 0166 and *Leucaena leucocephala* K8 were compared under non-irrigated conditions in semi-arid south Texas using contrasting seedling container types. One was a large dibble-tube (Ray Leach Supercell) that was removed prior to transplant. The other container was a cardboard plant-band and was not removed prior to transplant. A poorly prepared seed bed was used to enhance stressful water conditions. In 1983, no rain occurred within 6 weeks of planting and 387 mm occurred in the first 9 months after planting. In 1984, the first significant rain occurred 21 days after planting and 587 mm of rain occurred within the first 9 months after planting. In the driest year (1983), *Prosopis* had about 25% greater survival than *Leucaena* and the plant-bands had 25% greater survival than the dibble-tubes for both *Prosopis* and *Leucaena*. In the wetter year, there were no significant differences in survival among the container types or between the species.

INTRODUCTION

High initial seedling survival in semi-arid forest plantations is an important objective, but one that is difficult to achieve. There are studies comparing growth and survival of seedlings that were planted with various planting containers in temperate (Marion and Alm, 1986) and tropical regions (Walters, 1981), but there are few studies examining seedling containers in the field in semi-arid regions. Mustafa (1983) recently examined various lengths of polyethylene bags and configurations of planting pits for use in transplanting *Prosopis* in semi-arid regions of Sudan. He found that 25-cm and 30-cm-long polyethylene bags gave greater survival than 15-cm-long bags, and that prior soil working of the planting pits also increased survival.

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In order to take advantage of the long tap root of arid-zone species such as *Prosopis* (Felker and Clark, 1982) we used seedlings grown in long containers (30–40 cm). Polyethylene (3 cm × 30 cm) bags were initially used but they had to be handled individually because of their tendency to fall over. Thus they were replaced with cardboard plant-bands as suggested by J.W. Hanover (Dept. of Forestry, Michigan State Univ., personal communication, 1979).

In initial trials (Felker et al., 1983) the plant-bands were removed and irrigation was applied to overcome transplant shock. In later plantings, it was observed that extra seedlings left on-site in a partially shaded environment, with containers still on, were in much better condition than the irrigated seedlings planted without the containers. If the seedlings were to be planted with the plant-bands still on, root development and subsequent growth might be restricted by a root system enclosed by the cardboard. Therefore it was necessary to compare growth and survival of transplanted seedlings in which the containers were removed. It would be difficult to remove the cardboard plant-bands as a commercial practice; therefore the largest removable dibble-tube system was compared to the plant-band system. The plastic dibble-tube system chosen was the Ray Leach (Canby, Oregon) 'Conetainer Supercell' system that was in widespread use in Hawaii (Walters, 1981).

A tractor-drawn tree planter is highly effective since it plants seedlings rapidly and deeply with little drying of the soil profile, but it is usually not available in developing countries. Thus it was of interest to compare manual and mechanical planting methods for the plant bands.

MATERIALS AND METHODS

Prosopis alba Grisebach accession number 0166 and *Leucaena leucocephala* (Lam.) de Wit K8 were the tree species used. The seedlings for both containers were grown in the greenhouse for about 3 months in a peat/perlite/vermiculite soil mix that was amended with macro and micronutrients.

The cardboard container, manufactured by Monarch Manufacturing Co., Salida, Colorado, had dimensions of 3.8 cm × 3.8 cm × 38 cm. The plant-bands were open at the bottom. This size was chosen to that a U.S. standard plastic milk case (30.5 cm × 30.5 cm inside dimensions) would contain 64 seedlings. These containers were left on at transplant. In cool weather this container holds enough water to last the seedlings for approximately 1 week. Coarse soil mixes containing perlite or vermiculite are preferred as they do not fall out of the bottom of the plant-bands when they become dry as readily as do sands. The top 3–4 cm of the plant-bands should not be filled with soil, to allow enough water to be captured during watering to adequately recharge the entire length of the plant-bands.

When the first pair of true leaves occurred on *Prosopis*, the seedlings were about 4 cm tall and the tap root was visible at the bottom of the plant-bands.

When *Prosopis* seedlings grown in plant bands were excavated after 2 years in the field, the lateral roots originated below the bottom of the plant-bands. More degradation of the plant-bands has occurred under the moist high-temperature (35 °C) environment of the nursery than in the field. If the seedlings are over-watered in the nursery, the plant-bands will lose their rigidity and form. During subsequent handling this can lead to plant-band breakage, loss of soil from the plant-band, and loss of structural integrity of the root system.

The other container was a 20-cm-long plastic dibble-tube that is removed prior to transplant. This container was 4.0 cm dia at the top, tapering to a 2.9-cm outside dia 18 cm from the top.

A randomized complete-block design with four replicates was used. Each replicate consisted of a row of 12 trees. The between-row spacing was 1.5 m, the within-row spacing 1.0 m. Except for the hand-planted *Prosopis* in 1984, a previously described heavy-duty tree planter (Felker et al., 1984) was used to transplant the seedlings. An adverse site was chosen on an Orelia soil series (Typic Ochraqualf) with a dense, dark-gray sandy clay loam B horizon and poor internal drainage. After the measurements were taken on the trees in December 1983, the site was moldboard-plowed to remove existing trees; the same site was then planted in 1984. The growth of both *Leucaena* and *Prosopis* had been marginal on a previous planting adjacent to this site. To provide a more stressful condition that would fully test the advantage of these container systems, only 3 diskings were performed prior to planting in 1983, and no cultivation or weed control was provided prior to planting in 1984.

In 1984, conditions were so poor that the tree planter brought 20–40-cm-dia dry clods to the surface and prevented the packing wheels on the planter from adequately compressing soil around the seedlings. The period following planting was drier in 1983 than in 1984. In 1983 no rain occurred on the site in the first 6 weeks after planting, and the rainfall from May through November was 387 mm. In 1984 a light rain (1.2 mm) occurred on May 8 about 12 days after planting and a heavy rain (23 mm) occurred on May 17. The rainfall from May through November 1984 was 587 mm. Thus the 1984 plantings went only 3 weeks without rain while the 1983 plantings went 6 weeks without rain.

In 1983, the top 7.5 cm of soil was air-dry, and the 30-cm depth had an average gravimetric soil water content of 18.9%. In 1984, the soil water contents were 6% for the top 15 cm, 8% between 15 cm and 40 cm, and 13% between 40 cm and 60 cm. Judging from other clay loams (Richards and Weaver, 1944) we would suspect that the 1.5-MPa permanent-wilting point occurred at a gravimetric moisture content of about 8–10%. Thus in 1984 much of the soil profile was at or near the 1.5-MPa permanent-wilting point at the time of planting.

In 1984, manual planting was compared to machine transplanting using the best *Prosopis* seedling container identified in the 1983 trials. Post-hole diggers were used to make 40-cm-deep, 12-cm-dia holes in which *P. alba* 0166 seedlings were planted with the cardboard plant-bands left on. Ten trees were planted in each of the four blocks using this technique.

Survival counts and basal diameter measurements were conducted 4 months and 9 months after planting in both 1983 and 1984. Dry biomass was calculated from basal diameter measurements, using previously described regression equations (Felker et al., 1982). For the survival measurements the level of significance for treatments was based on the arcsine-transformed data. However, the untransformed means are listed in the Tables. To assist the reader in gaugeing the significance of the data, the 90% confidence intervals are listed for percent survival and biomass per tree.

RESULTS AND DISCUSSION

With the exception of *Prosopis* in the plant-bands, the percentage survival for *Prosopis* and *Leucaena* was greater in 1984 than in 1983 (Table 1), presumably because of the early rain in 1984. In contrast, biomass production was less in 1984 than 1983. Perhaps the lower growth rates in 1984 were the result of the lower initial soil moisture content and the poorly worked soil with large clods around the seedlings.

In 1983, *Leucaena* in the dibble-tubes had almost double the biomass of *Leucaena* in the plant-bands. However, *Leucaena* is sensitive to competition under

TABLE 1

A comparison of survival (%) for *Leucaena* and *Prosopis* using different seedling containers

	4 months after transplant		9 months after transplant	
	1983	1984	1983	1984
	Mean ± CI	Mean ± CI	Mean ± CI	Mean ± CI
Prosopis				
plant-bands machine-planted	100 ± 0**	88 ± 19	100 ± 0**	88 ± 19
dibble-tubes machine-planted	75 ± 8	93 ± 10	75 ± 8	94 ± 11
plant-bands hand-planted		100 ± 0	—	100 ± 0
Leucaena				
plant-bands machine-planted	73 ± 9**	96 ± 6	73 ± 9**	93 ± 5
dibble-tubes machine-planted	46 ± 17	80 ± 18	46 ± 17	80 ± 18

90% confidence level intervals are provided. ** Indicates the treatment differences (i.e. between container types for same species) were significantly different at $P < 0.01$.

water-limited conditions, and the fewer surviving dibble-tube seedlings may have been larger due to lack of competition.

In 1984 there were no significant differences in biomass per tree between the container types, but the plant-bands yielded greater biomass than the dibble-tubes, for both *Prosopis* and *Leucaena* (Table 2). The largest difference in biomass production occurred between machine-planted and hand-planted *Prosopis*. Machine-transplanted *Prosopis* had 235% of the biomass of the hand-planted, which we attribute to the action of the subsoiler in breaking up the hardpan to allow the roots better access to moisture and nutrients.

In the driest year, 1983, significant survival increases (approximately 25%) were observed for both *Prosopis* and *Leucaena* when planted in cardboard plant-bands, as opposed to exposed root systems from dibble-tubes. However, if the survival of *Leucaena* in dibble-tubes was used as the base for the calculations, a 59% increase in survival would be obtained by changing to plant-bands. In the lower-rainfall year of 1983, *Prosopis* proved to have about a 25% increase in survival over *Leucaena*. In 1984, with less-stressful conditions, *Prosopis* survival was only slightly greater than *Leucaena*. Some growth depression observed for *Leucaena* in the plant-bands was not observed for *Prosopis*.

Prosopis survival when hand-planted was 100% and thus greater than when machine-planted. This is certainly due to the large clods (about 20-cm wide), pulled up by the tree planter, which were packed around the trees versus the much smaller clods obtained when post-hole diggers were used to make the

TABLE 2

A comparison of tree dry biomass production (g; Mean ± CI) for *Leucaena* and *Prosopis* using different seedling containers

Treatment	4 months after transplant		9 months after transplant	
	1983	1984	1983	1984
Prosopis				
plant-bands machine-planted	98 ± 23	52 ± 26	600 ± 90	470 ± 230
dibble-tubes machine-planted	92 ± 15	53 ± 15	730 ± 140	410 ± 80
plant-bands hand-planted		25 ± 19		200 ± 140
Leucaena				
plant-bands machine-planted	190 ± 66**	83 ± 56	1150 ± 140**	680 ± 280
dibble-tubes machine-planted	362 ± 38	66 ± 20	1920 ± 590	630 ± 260

90% confidence intervals are provided. ** Indicates the treatment differences (i.e. between container types for same species) were significantly different at $P < 0.01$.

holes for hand-planting. This experiment demonstrates that hand-planting is a viable option in semi-arid developing countries where heavy machinery is not available for tree-planting. Hand-planting this same seed lot, in the same containers, in Haiti was nearly a total failure, but the cardboard plant-bands had been removed, and the root systems were bent to fit in a 20-cm-deep hole.

Plant-bands appear to be the seedling container of choice for both *Prosopis* and *Leucaena* on difficult droughty sites. It is possible that the dibble-tubes may yield better results under a more thoroughly prepared seed bed with more moisture.

We have used cardboard plant-bands in conjunction with a heavy-duty tree planter fabricated from a subsoiler to plant the seedlings (Felker et al., 1984). With this system the plant-bands have routinely yielded greater than 95% survival without irrigation (Felker et al., 1984). However, an intensive site-preparation initiated 6–8 months prior to planting involved frequent mechanical cultivation and subsoiling, so that the previous year's rains recharged the top 50 cm of the soil profile. This system has the added advantage of being able to routinely plant about 350 trees/h on a 3-m×3-m spacing.

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