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MANAGEMENT OF NATIVE *PROSOPIS* STANDS AND PROGRESS IN GENETIC IMPROVEMENT

MANEJO DE MACIZOS NATIVOS DE PROSOPIS Y AVANCES EN MEJORA GENÉTICA

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SUMMARY

Over the last 30 years, high quality hardwood lumber is one of the few commodities that have consistently increased in value (Felker, 2000). It would appear that the long-term demand for quality hardwood lumber, should increase, especially in the face of significant tropical deforestation. Of all the potential products of arid lands, *Prosopis* hardwood lumber has one of the highest unit prices of close to \$1000 per ton (at \$2/bd ft or \$856 per cubic meter and a density of 750 kg/cubic meter). Using the scenarios described above, an internal rate of return of 9.3% was calculated for *Prosopis* agroforestry plantations without ascribing any value to pod production or to soil fertility increases and should be an attractive long term, low risk opportunity for institutional investors (Felker, 2000). *Prosopis* lumber could be a valuable asset in assuring the stability of Europe's 60,000 million Euro furniture industries. However before significant quantities of algarrobo lumber, furniture or flooring can be commercialized for export, ecological certification to obtain "A green seal" as outlined by the Forestry Stewardship Council www.certifiedwood.org or one of their approved NGO's, SMARTWOOD- www.smartwood.org, must be achieved.

Key words: Management, weeds, intercropping, fertilization, cloning, selection.

RESUMEN

En los últimos 30 años los artículos de madera de alta calidad son de los pocos que han incrementado de manera consistente su valor (Felker, 2000). Surgiría así que la demanda a largo plazo de artículos de madera de cálidad debería incrementarse, *especialmente a costa de la deforestación tropical. De todos los productos potenciales de las zonas áridas, los artículos manufacturados con* Prosopis *tienen el mayor precio unitario cercano a los $ 1000 por tonelada (a $ 856 por metro cúbico y a una densidad de 750 kg/metro cúbico). Usando el escenario descripto, una tasa interna de retorno del 9,3% fue calculada para* Prosopis *en plantaciones agroforestales sin atribuirle ningún valor a la producción de vainas o al incremento de la fertilidad del suelo, por lo que debería ser un atractivo a largo plazo, con bajo riesgo de oportunidad para inversores institucionales (Felker, 2000). Los articulos de* Prosopis *podrían ser un valioso activo al asegurar la estabilidad de la industria inmobiliaria europea de 60.000 millores de euros. Sin embargo, antes que significativas cantidades de artículos de algarrobo, muebles o parquets, puedan ser comercializados para exportación, es necesario obtener el certificado ecológico o "Sello verde" emitido por el Concejo de Administración Forestal www.certifiedwood.org o uno de los organismos no gubernamentales aprobados, SMARTWOOD- www.smartwood.org,*

Palabras clave: Manejo, malezas, intercultivos, fertilización, clonación, selección.

Introduction

As there has been considerable work published in the international literature in journals not easily accessible outside North America, this communication will summarize key works related to applied research in *Prosopis* native stands, plantations and genetic improvement.

I Management of native stands

(a) Development of techniques

As a prerequisite to installation of treatments in mature *Prosopis* stands, it was necessary to develop simple techniques to estimate the volume and biomass of mature *Prosopis* trees and to develop techniques to accurately measure small increases in diameter. In order to estimate the biomass of large trees, 10 trees ranging from 20 to 50 cm in diameter were harvested, weighed and the sawn lumber volume determined with regression equations on the individual branch segments (El Fadl *et al.*, 1989). Regression equations computed from these data were combined with inexpensive ($2 each) permanently mounted verniers used to estimate volume and biomass of standing trees.

To estimate the tree diameters that might be possible at various spacings, regressions were computed between basal diameter and number of stems per ha in stands that ranged from 10,000 to 5 stems per ha (in the 650 mm annual rainfall region). This regression predicted that minimum sized commercial lumber trees (40 cm in diameter) could not be obtained on spacings of less than 10 m x 10 m (Felker *et al.*, 1990).

(b) Development of biomass harvester to thin immature stands

After nearly 12 years of research and development in harvesting small diameter brush, a TAMUK prototype finally achieved a harvesting rate of 7,050 kg h^{-1} when harvesting mesquite stands less than 10 cm in basal diameter (Felker *et al.*, 1998). If this material could be sold for \$9/green ton (\$1.00 $kJ^{-1)}$ in the field, there would be no cost to the landowner for the clearing operation. A New Holland square baler made satisfactory 300 kg square bales from these chips. A commercial version of the TAMUK prototype was estimated to cost about \$280,000 and it was estimated that an annual demand of about 12,000 Mg of biomass at \$9 per green ton would be necessary to justify the purchase of the first harvester. In the United States the market potential for non-energy related biomass i.e. potting soil base, landscape mulch, wood chips for bioremediation, mesquite barbecue products, appeared sufficiently great to provide this demand.

(c) Management of mature stands

To answer the question about the most important factors that influence the growth of mature *Prosopis* stands, various treatments were applied to mature *Prosopis glandulosa* in Texas (Patch & Felker, 1997a). It was of interest to know whether competition from other species of woody vegetation, competition from other *Prosopis*, or fertilizer deficits would be most limiting to growth of mature *Prosopis*. As *Prosopis* is a nitrogen fixing plant, and as phosphorus is often the most common limiting nutrient for N fixation, the fertilizer treatment was composed of a 100 kg P/ha application. Five treatments (control, thinning, understory removal, understory removal plus herbicide resprout treatment and phosphorus fertilizer treatments) were applied to 4 replicates of 30 m by 30 m plots. Growth was estimated with dendrometers installed at the base of 20% of the trees. When volume and biomass growth were expressed as a percentage of initial basal area (to correct for differences in stocking rate), some treatments were significantly different. As can be seen in Figure 1, the greatest stimulation of growth resulted from the removal of the understory brush. The understory removal + thinning + herbicide + fertilizer treatment had the greatest mean percent weight growth (28.3%, SD=3.0647) and percent volume growth (34.9%, SD=3.9790) over the nine-year time period, and was significantly (*P*=0.0001) different from the control percent weight (11.1%, n=4, SD=0.5315) growth and control volume (13.3%, n=4, SD=0.7124) growth. Thus it appears as if phosphorus fertilizer is also important for growth of mature *Prosopis* stands. The annual diameter increment for the fertilizer treatment

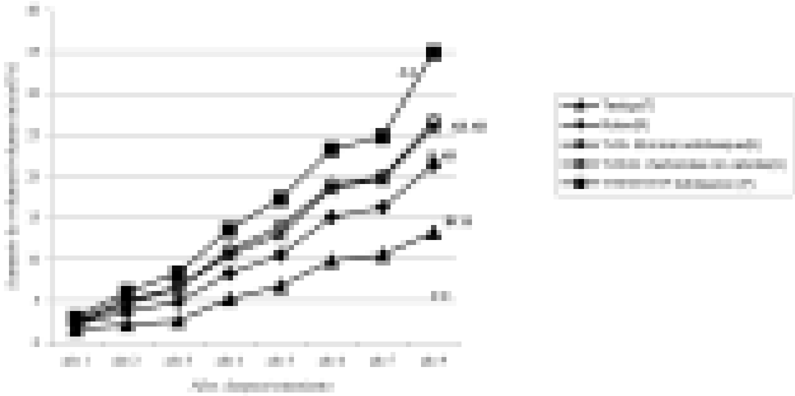

Figure 1. Influence of understorey removal, thinning, herbicide treatment and P fertilization on growth of mature *Prosopis glandulosa* stands in Texas

Figura 1. Influencia de la remoción del sotobosque, aclareo, tratamiento con herbicida y fertilización con P sobre el crecimiento de macizos maduros de Prosopis glandulosa *en Texas*

was 0.27 cm year^{-1}, n=4, SD=0.898, which is comparable with other mature commercial hardwood forests.

(d) Management of immature stands

A second field study examined factors influencing growth of immature (< 4 cm diameter), dense (>10,000 stems/ha) stands of *Prosopis glandulosa* (Patch & Felker, 1997b).

As opposed to *Prosopis alba* and somewhat similar to *P. ruscifolia*, *P. glandulosa* can colonize abandoned pastures with very high plant densities. The goal of this research was to evaluate silvicultural/agroforestry techniques for their potential in maximizing lumber production while minimizing the weed problems with *Prosopis glandulosa*. The control plot was not manipulated. All the other treatments included above-ground removal of all the trees (with a 225 kW swath harvester described above) except for crop trees that were located in 2 m by 2 m squares on 10 meter centers. To prevent reestablishment of *Prosopis* in the interstitial areas, treatments were examined that included spot sprayed with herbicides, disking or disking and seeding with rye grass. In three of the treatments the crop trees were pruned to a single stem. A randomized complete block design was used with 4 replicates and 6 treatments. At both the 2.5- and 9-year evaluation, significant treatment differences were found for growth of basal diameter; growth of basal area; and growth of dry weight (Figure 2). The greatest crop tree growth occurred in treatments that were pruned with interstitial

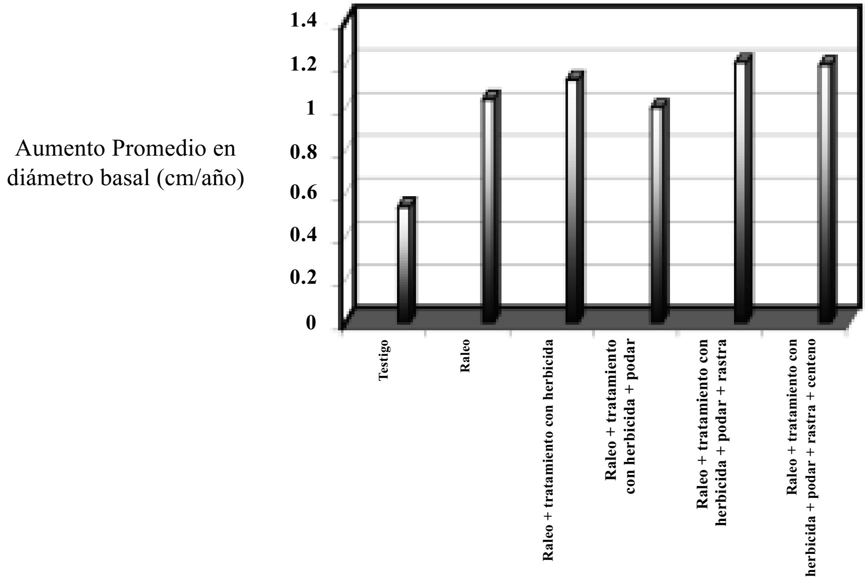

Figure 2. Influence of thinning, pruning and intercropping on growth of sapling *Prosopis glandulosa* in Texas

Figura 2. Influencia del aclareo, poda e intercultivo sobre el crecimiento de árboles jóvenes de Prosopis glandulosa en Texas

competition suppressed. Mortality was greatest in the dense control treatment, while reestablishment of mesquite was greatest in the more open treatments. The greatest basal diameter growth of 1.21 cm $year^{-1}$ in the disked and pruned treatments was comparable to other fine hardwoods in temperate and dry tropical forests.

II Plantation establishment

(a) Effect of soil working on growth

As the vast majority of arid lands do not have irrigation water available for growth of tree crops, and as irrigation is by far the most costly input into arid "agriculture", all of our work has focused on maximizing the efficiency of utilization of rainwater. The extensive French work over many decades in managing soil moisture for annual crop plants in Sahelian West Africa is particularly relevant to managing soil moisture for *Prosopis* plantings. Nicou (1986) reported on the effect of soil working on bulk porosity, root biomass, and above ground biomass of nearly 250 trials with dryland cereals, groundnuts and cotton in Africa. Nicou (1986) reported significant linear correlations between increased soil porosity and root density, weight of vegetative aerial parts and grain yields of these crops. He also reported "most field trials examining soil physical properties and tree growth have revealed the superiority of subsoiling over hole digging".

(b) Effect of seedling container geometry on growth and survival of *Prosopis*

This work was confirmed by Felker *et al.* (1987) in a study of survival and growth of *Prosopis* seedlings as a function of container type and planting method. After 9 months growth, seedlings that were planted with a subsoiler had 235% of the biomass of seedlings planted in a hole made by hand. In a dry year, a 25% survival advantage (with 100% survival) was obtained with 3.8 by 3.8 by 38 cm cardboard containers that were left on at transplant, versus seedlings grown in a 20 cm long, 4.0 cm diameter plastic tube that was removed at transplant.

(c) Effect of mechanical and chemical weed control on growth and survival of *Prosopis*

Considering the fact that conservation of 1 mm of rainfall per hectare is equivalent to 10,000 liters of water or 100 liters per tree (at density of 100 trees/ha), the advantages of controlling competing vegetation are obvious. A combination of both mechanical and chemical weed control is most useful. Mechanical control is more economical but not always possible when intensive rains stimulate dense weed growth while the soil is too wet to permit entry of tractors and cultivators.

Our strategy in developing chemical weed control techniques was to identify short residual, low-plant toxicity herbicides for preplant and the first 60 to 90 days after transplant, and then to use longer-residual, inexpensive herbicides (for which patent protection had expired) 90 days after transplant (Felker *et al.*, 1986). Trials in 1983 and 1984 examined 12 combinations of cultivation (single row sweep cultivator) and herbicides for survival and growth of *Prosopis*. Figure 3 shows a fivefold difference in growth of the trees as a function of weed control. By simply providing weed control with a sweep cultivator a 300% increase in biomass was observed. The herbicides linuron, diuron and oryzalin provided the best growth. Oryzalin, a chemically similar herbicide to trifluralin (Treflan) has the advantage of not having to be incorporated. Unfortunately oryzalin is not available in Argentina. As diuron is readily available and inexpensive (about $10/kg or $15/ha at the 1.4 kg active ingredient dose) it is a herbicide of choice. In fields where particularly troublesome perennial weeds such as *Sorghum halepense*, *Cynodon dactylon* or solanum species were present, the more expensive herbicide, norflurazon ($25/kg), could be used at high doses to control these weeds for extended periods (Felker *et al.*, 1986). While herbicides are often criticized as being too expensive and not appropriate for developing countries, it is important to point out that manual weeding of plantations even with Argentine labor

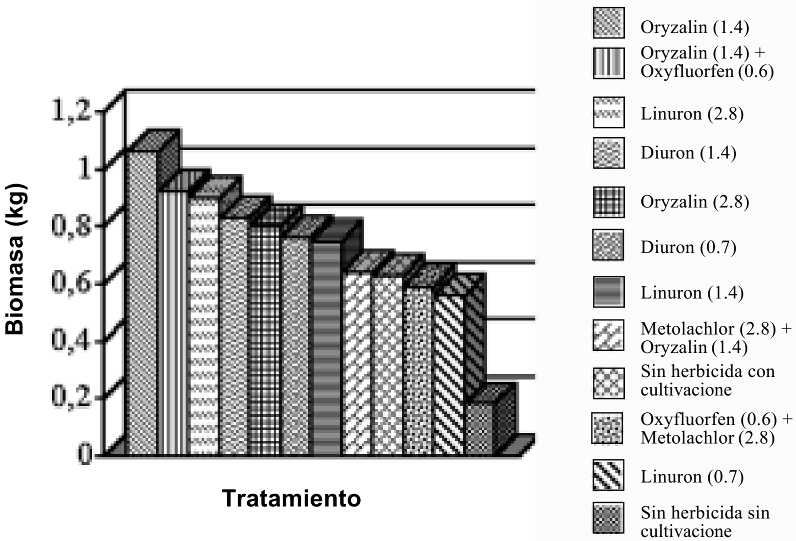

Figure 3. Influence of mechanical and chemical weed control on growth of *Prosopis alba*
Figura 3. Influencia del control mecánico y químico de malezas sobre el crecimiento de Prosopis alba

rates as low as $15/day are not competitive with herbicides. Furthermore herbicides free the small farmer for other tasks and provide weed control when it is not possible to enter the field due to adverse moisture conditions.

(d) Fertility influences on growth of *Prosopis*

Due to the extensive occurrence of alkaline soils in arid regions, and the decreasing availability of phosphorus and the trace elements, Fe, Zn, Mn and Cu with increasing pH, Cline *et al.* (1986) examined growth and leaf tissue levels of *P. alba* as a function of increasing pH. This study was conducted in the greenhouse and used calcium hydroxide to change the pH from 6.5 to 8.9. At the highest pH of 8.9, addition of micronutrients was essential to growth of *Prosopis*. At this high pH, without micronutrients, the dry weight decreased from 4.5 to 2.1 g while the leaf sodium content increased from 0.46 % to 1.9%. This suggested that micronutrients were important in sodium exclusion processes for *Prosopis*. These authors suggested that the following nutrient concentrations might be useful as minimum levels for *P. alba* leaves: N-3.0%, P-0.16%, K-1.2%, Ca-1.2%, Mg-0.23%, Fe-130 mg/kg, Mn-70 mg/kg, Zn-27 mg/kg, Cu- 17 mg/kg and leaf Na levels below 0.8%.

Cline *et al*. (1986) found a highly significant correlation between leaf P and leaf N that had a slope of nearly 6 to 1 and 36 to 1 for N/P and protein/P respectively, suggesting that small P increments would greatly stimulate crude protein production. This is to be expected from the stimulating effect of P on N fixation. Geesing *et al.* (2000) found a similar regression between N and P for mature trees, but the slope was not as great (Figure 4).

In a study of N fixation in mature trees, Lopez-Villagra *et al.* (1997) found a highly significant inverse relationship between tree size and the percentage of nitrogen of the tree that was derived from N fixation. This they attributed to inhibition of N fixation with increasing soil nitrogen build up as the trees became older. Geesing *et al.* (2000) confirmed this relationship and found highly significant negative correlations between soil nitrate levels under the canopy and the percentage of tree N derived from N fixation.

III Cloning and genetic improvement of Prosopis alba

California progeny trials in the late 70's (Felker *et al.*, 1983) identified elite families and clones of *Prosopis alba*. When one of these clones was combined with the site preparation, seedling containers, weed control and fertility package described above, a standing biomass of 39 dry ton/ha was obtained in the third year with no supplemental water in any part of the process (Figure 5) (Felker *et al.*, 1989). The third year's growth in this study was 20 ton/ha. The mean diameter growth was 2.5 cm/yr. These authors attributed half of the excellent growth to intensive dryland management tech-

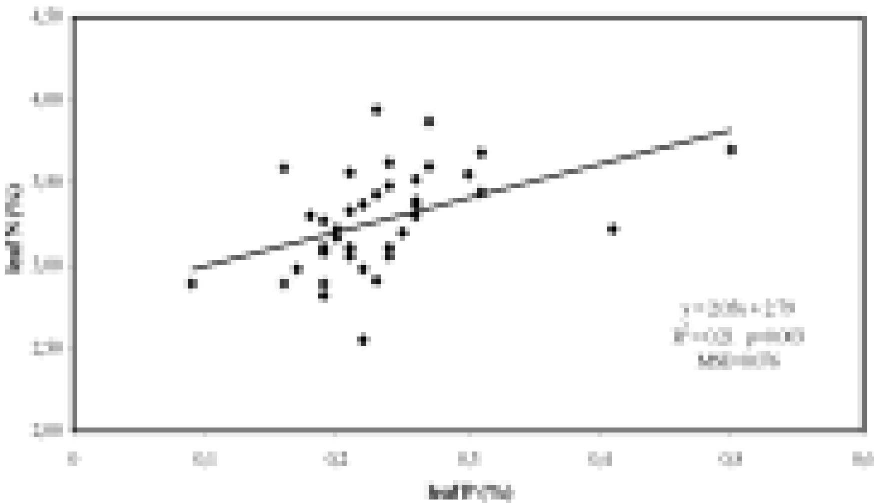

Figure 4. Correlations between leaf N and leaf P among *Prosopis glandulosa* stands in Texas.
Figura 4. Correlaciones entre N y P foliar sobre Prosopis glandulosa *en Texas*

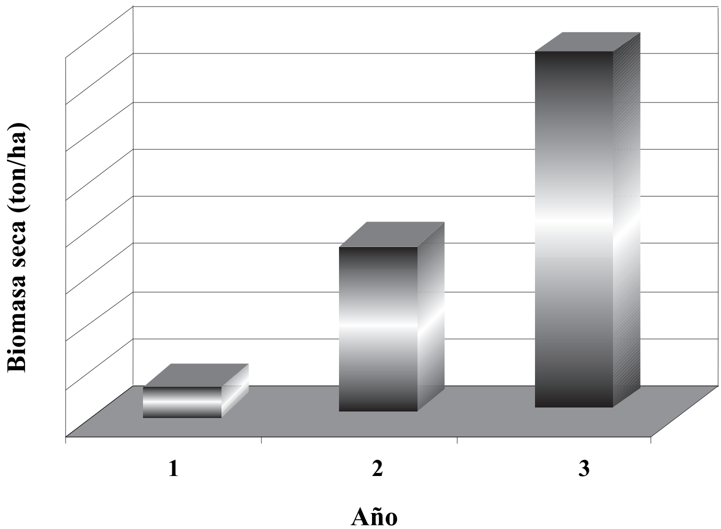

Figure 5. Biomass production of non-irrigated *Prosopis alba* clone B2V50 in Texas
Figura 5. Producción de biomasa de Prosopis alba clon B2V50, sin riego, en Texas

niques and half to genetic improvement. This clearly demonstrates that *Prosopis alba* has the potential to be a highly productive plantation species.

Twenty years after the first *Prosopis alba* clones were made for high biomass production, the first multipurpose "Agroforestry type *Prosopis alba* clones" were made in Argentine (Figure 6) (Felker *et al.*, manuscript in review). This cloning process took advantage of a 10 year old progeny trial of 57 *Prosopis* half-sib families. Since pod production is important in both human and livestock applications, the selection criteria also included pod criteria for both production and sensory analysis. The sensory analysis was important as some pods have bitter/astringent flavor components (in addition to the approximate 30% sucrose concentrations). A food chemistry group consisting of G. Fabiani, H. Boggetti, B. Mishima and P. Felker at the Universidad Nacional de Santiago del Estero is working to identify this compound. As can be shown in Figure 6 less than 1% of the trees that were planted were cloned.

To accomplish the cloning, scions from the mother trees were first grafted onto common rootstock to revert the tissue to a juvenile state. Cuttings were then taken from the clonal stock plants and are in the process of being multiplied by rooted cuttings. M. Ewens of the Universidad Católica de Santiago del Estero has recently made excellent progress in rapidly grafting 1.5 mm diameter, 30-day-old *Prosopis alba* seedlings (Felker *et al.*, 2000). In one to two years, small commercial quantities of the new

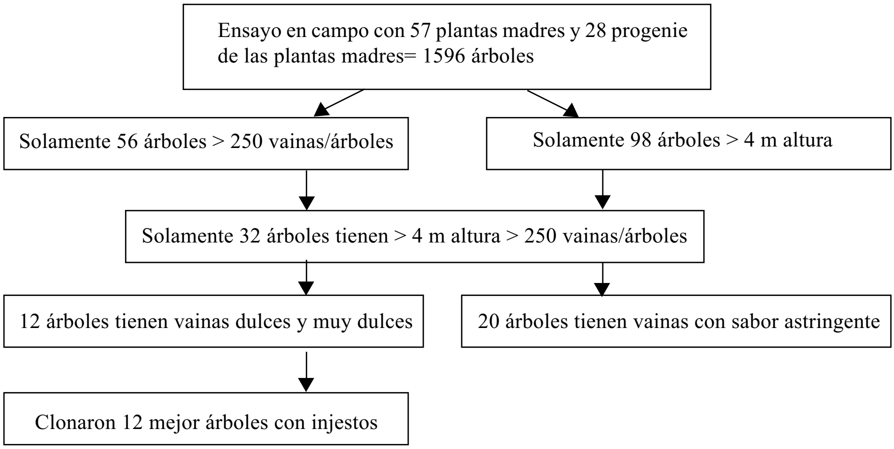

Figure 6. Strategy for selection and cloning of multipurpose *Prosopis alba* for agroforestry applications
Figura 6. Estrategia para la selección y clonación de Prosopis alba *multiple propósito para aplicaciones agroforestales*

grafted seedlings should be available. In about 5 years, seeds from a clonal seed orchard of these 12 clones should also be available.

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