Forest Ecology and Management 260 (2010) 378–383

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

A comparison of pod production and insect ratings of 12 elite *Prosopis alba* clones in a 5-year semi-arid Argentine field trial

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ARTICLE INFO

Article history:
Received 6 March 2010
Received in revised form 22 April 2010
Accepted 23 April 2010

Keywords:
Nitrogen fixing trees
Agroforestry
Salinity
Mesquite
Hardwood lumber

ABSTRACT

Semi-arid adapted nitrogen fixing trees of the genus *Prosopis* have been extensively used in Argentina for soil improvement, luxury quality lumber production and sweet (35% sucrose) pods for humans and livestock. Due to the great demand of *Prosopis alba* for lumber, erect, tall, high pod producing trees of this species have been greatly overharvested, leading to erosion of the gene pool. A previous progeny trial with 57 half sib families identified 12 trees with promise for rapid growth, high production of pods and sweet pods. This trial, on a site with a salinity of 8.6 dS m^{-1} EC and a pH of 7.7, examined clones of these 12 trees in a randomized complete block trial with 8 single tree replications for height, basal diameter, canopy height and diameter, production of pods, sensory characteristics of the pods, disease resistance and insect resistance. In the 5th year of production and 7th year from planting, three clones produced more than 50 kg pods per tree versus 32 kg for check. At this 10 m × 10 m spacing, this yield of 5000 kg/ha compares favorably to many other semi-arid crops, especially given the unfavorable salinity and pH. In contrast to genetic improvement in pod production, the clones had lower diameter, height and canopy growth than the check. The lower biomass production may be due to fibrous root system produced from cuttings, since some of the clones blew over in high winds but none of the checks produced from seed blew over. Companion seed orchards of salt tolerant clones may provide rootstock for these high pod production clones. Significant differences in insect and disease resistance of the clones were observed and full sib crosses were made to study the genetics of the resistance. All clones had good sensory properties for use in human food. This is the first replicated trial with multipurpose clones useful for lumber and human food. The annual diameter growth rates ranged from 2.8 to 4.1 cm $year^{-1}$ which was estimated to produce an internal return of approximately 20% from lumber alone.

1. Introduction

Nitrogen fixing trees and shrubs of the genus *Prosopis* are an important feature of many of the worlds semi-arid ecosystems where they enrich the soil with organic N (Geesing et al., 2000), provide fuelwood to the local population, high sugar content pods for livestock and occasionally human use, and provide lumber for high quality furniture (Pasiecznik et al., 2001; Felker, 2009). Of all the *Prosopis* species, the most commercially valuable is *Prosopis alba* which has provided more than 100,000 tons of logs per year in the Province of the Chaco, Argentina for use in furniture, flooring, doors, and window coverings (M. Bejarano, pers comm, 2000). This extensive use for furniture is attributable to its radial, tangential and volumetric shrinkages of 1.8%, 2.9% and 4.8% respectively (Turc and Cutter, 1984) that are lower than all other hardwoods listed in the tropical timber compendium of Chudnoff (1984). The high sugar content pods of *P. alba*, ca 35% (Oduol et al., 1986) are highly palatable to livestock and humans and were a major source of food for indigenous peoples in Argentina (D'Antoni and Solbrig, 1977). As early as the 1940s, the eminent Argentine botanist Arturo Burkart (Burkart, 1976) decried the selective overharvest of fastest growing, straightest trees and suggested the genetic improvement programs be initiated to select the best trees.

In the 1980s with funding from the Canadian International Development Research Council (IDRC) germplasm collections were made for four of the most economically important *Prosopis* species in Argentina i.e. *P. alba*, *P. chilensis*, *P. flexuosa* and *P. nigra* and half sib progeny trials established for *P. flexuosa* and *P. chilensis* near Mendoza, Argentina (Cony, 1996a,b) and *P. alba* near Santiago del Estero, Argentina (Felker et al., 2001).

In 1990 in Santiago del Estero, Argentina the *P. alba* progeny trial was established in a randomized complete block design with 57 families, 7 replications and 4 trees per replication. In 1997 and 1998 these trees were evaluated for height, basal diameter, and pod

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doi:10.1016/j.foreco.2010.04.030

production. After 9 years, of the surviving 1289 trees in this trial, only 98 trees were more than 4 m in height and only 56 had produced more than 1.75 kg of pods year^{-1}. Of this group only 32 trees had more than 4 m in height and more than 1.75 kg pods year^{-1}. As pods of some species, i.e. *P. juliflora* are so bitter/astringent they cannot be used for human food (Felker, 2009), pods of these 32 trees were ranked as being very bitter, bitter, sweet or very sweet and it was found that only 12 of these 32 trees had pods with a sweet or very sweet non-astringent taste. The 12 trees that possessed the best complement of economically useful characters i.e. that ranged from 6.55 to 14.4, 1.57 to 13.6 and 1.29 to 1.70 times the population mean of pod production (0.29 kg tree^{-1}), biomass (24.2 kg tree^{-1}) and height (3.1 m) respectively were propagated asexually (Felker et al., 2001).

In 2002, a randomized complete block trial with clones of these 12 trees was established in Argentina to compare their characteristics with a random seed propagated selection, to serve as a seed orchard and as breeding population. This paper compares the pod production of these clones to a random seed propagated check and reports initial ranking of insect and disease resistance.

2. Materials and methods

While cuttings can be rooted from fast growing, greenhouse grown *P. alba*, it is virtually impossible to root cuttings of mature field trees. Thus scions were taken from 12 mature elite trees in the progeny trial of 57 half sib families (Felker et al., 2001) and grafted by the techniques of Wojtusik and Felker (1993) onto greenhouse grown stock plants which were then used to produce rooted cuttings (Felker et al., 2005). A clonal evaluation/seed orchard was established in Fernandez, Argentina on grounds of the Universidad Catolica de Santiago del Estero(UCSE), Experiment Station (27°56′10.21″S, 63°52′37.73″W) on 21 January 2002. This is summer and the rainy season in this part of Argentina. The rainfall measured at the Research station in Fernandez was 771 mm in 2002, 410 in 2003, 709 in 2004, 402 in 2005, 750 in 2006, 674 in 2007 and 678 in 2008. The field was irrigated by flood irrigation of about 100 mm the first spring after planting on 23 September 2002. Thereafter, every year (except for 2005 and 2006) in late winter (August) a similar single irrigation was made.

Based on data from a meteorological station at this site, generally every month from September (spring) through March (fall) has one day with a maximum temperature of 38 °C with yearly maximum temperatures of 43–46 °C occurring from December through February. The first significant rains normally occur in late October, and they end in mid April, with a peak in December/January with pod maturation. Flowering generally occurs in September before the start of the rains but sometimes high winds, late frosts or unusual early rains adversely affect flower fertilization and subsequent pod production.

A randomized complete block design was used with 8 blocks and a single tree per block. A 10 m × 10 m spacing was selected since this was predicted to be the closest spacing necessary to obtain commercial lumber production (Felker et al., 1990) i.e. 40 cm diameter trunks. The codes for the clones were for the family, block and tree of the field position where they were cloned. Thus there were two individuals represented from family 5, family 6 and family 12. Eight replications were used for all 12 clones except for F4B2T3 as we were only successful in making one cutting of that clone. A check variety was included that came from seed of trees collected in the vicinity of the UCSE field station.

On March 20, 2006 soil samples were taken from these plots and the following values were found; 0–30 cm depth – EC 8.6 dS m^{-1} and pH 7.7, 30–60 cm depth EC 10.3 dS m^{-1} and pH 8.3 and 60–90 cm depth EC 9.0 dS m^{-1} and pH 8.6. Prior to planting, the field was disked, the herbicide treflan applied at 6 l/ha and incorporated with a disk and harrow. In a one meter line where the trees were to be planted, the herbicide norfluorazon was applied at 3 kg a.i. ha^{-1}. Norfluorazon, when used at 4 kg ha^{-1}, was found to provide season long control of troublesome weeds such as nutsedge (*Cyperus*), johnsongrass (*Sorghum halepense*) without phytoxicity to *Prosopis* (Felker et al., 1984). Prior to planting 50 g of diammonium phosphate was applied to the bottom of each planting hole. The first year weed control was provided by disking. In subsequent years, weed control was provided by a tractor powered rotary mower between the rows, some weeding around trees with machetes and use of glyphosate under the canopies (in the summer of 2007/2008). In 2003, staking and pruning was initiated. Trees that were blown over in high winds (only those from rooted cuttings-none of the checks) were pulled up and staked.

Probably due to the fact that *P. alba* evolved in northwestern Argentina, an intense suite of insects and fungal pathogens that attack mature and immature leaves and flowers co evolved with *P. alba*. A fungal pathogen of the genus *Pestalotiopsis* is responsible for defoliation in some clones (Cecilia G. Diaz, Department of Plant pathology Universidad Nacional de Tucuman, unpub obs, 2009) and psyllid insects (*Prosopidopsylla flava*) are responsible for defoliation in other set of clones (Lucia Claps, Facultad Ciencias Naturales-Universidad Nacional de Tucumán, pers comm).

In 2003, during the summer growing months, weekly applications of the insecticide Lambda cyhalothrin (synthetic pyrethroid) were made to control sucking and chewing insects. In 2004, cypermerthrin was also used. In the spring of 2007 (September and October), to avoid abortion of flowers from full sibling crosses due to infestation of insects in immature floral inflorescences, lambda cyhalothrin and the systemic insecticide acephate were applied, but did not provide satisfactory control. In 2008 in addition to lambda cyhalothrin, imidacloprid was also used. In 2008 extensive damage to the pod production occurred from wild parrots that have been declared a national plague in Argentina. Scarecrows and repellents were examined for control but without success. An electric fence was installed around the trial in 2007. Pod harvest per tree for yield measurements typically began about the third week in December and was finished by the end of the first week in February. Biomass estimates were obtained using the previously described regression equation: log fresh wt (kg) = 2.7027 log diameter (cm) − 1.1085 (Felker et al., 1989).

As in two previous trials (Alban et al., 2002; Felker et al., 2001) more than 50% of the trees in the penultimate selection were rejected for cloning due to bitter/disagreeable tasting pods, the pod flavor of these trees was ranked. Two local people familiar with the flavor of *P. alba* pods (*P. alba* pods are highly esteemed among the local population) ranked the pods in the laboratory as very sweet, sweet, slight sweet taste, no taste and disagreeable/bitter.

3. Results

The mean pod production per tree and associated 95% confidence intervals are shown in Fig. 1. Two of the clones had lower production in the 7th year's growth than the control, some of them were slightly higher, and some of the clones had almost double the yield of the control i.e. F5B1T4, F6B1T3, F6B7T4, F9B5T2, F12B6T1, and F52B1T3. Second in importance is that in the low pod producing year of 2007 (for the control and some clones), three clones F52B1T23, F5B1T4 and F6B1T3 maintained high pod production. As would be expected from clones, rather than obligately outcrossed species, there is a tendency for the variability to be less in the clones than in the check. As can be seen in Fig. 1, the 95% CI is about half the mean for the check variety, while in some of high producing clones the 95% CI is about a quarter of the mean.