Recommendations for development of *Prosopis* in Pakistan.

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Introduction. From September 20 through October 9 1987 Felker from Texas A&I University, Ostmark from Winrock and/or McNabb from Winrock visited many regions of Pakistan observing problems and potentials of *Prosopis* in semi-arid lands. Slide presentations on the use and potential for *Prosopis*, *Opuntia* and *Leucaena* in semi-arid lands were presented in Quetta, Hyderabad, the Pakistan Forestry Institute and in Islamabad. Field trips were taken around Karachi, Quetta, Hyderabad, Islamabad, Kohat and Peshawar to obtain a better grasp of the problems.

The following report presents the problems and opportunities as discreet components and provides specific recommendations to address those needs.

1 (a) Development of management plans for mature stands of mesquite and Acacias.

In the area between Kohat and Peshawar there are extensive thorn forests at the foothills of the mountains that consist of *Prosopis juliflora*, *P. glandulosa*, *Zyzphus*, and *Acacia modesto* (Figure 1). The *Prosopis* in this area has been cut at the base many times with the result that the trees are multi-stemmed. The young seedling *Prosopis glandulosa* are also multi-stemmed. Stress stimulates multi-stemmed form in *Prosopis glandulosa* but some single stemmed *P. glandulosa* with good form have been observed in Pakistan (especially near the University at Quetta see Figure 2). Therefore it appears that single stemmed *P. glandulosa* suitable for poles could be obtained with pruning and thinning. A species screening trial using partial irrigation at this site had low survival which is understandable given the low rainfall and rocky nature of the site.

For these reasons management of the existing native thorn forest through pruning and thinning, could be a very cost effective alternative fuelwood production system to establishment of new plantations.

Various degrees of thinning and pruning management should be examined before developing formal recommendations. Examples of such treatments could include; (1) control no treatment, (2) prune all shrubs to 1 m tall single stems, (3) Prune shrubs to single 1 m tall stems and then 2 m spacings, (4) Prune and thin to 3 m spacings, (5) prune and thin to 4 m spacings. The closer spaced thinning regime would be examined because of the tendency of closely spaced trees to produce straighter poles through inter-tree competition. Plot sizes should be at least 30 m by 30 m and should be replicated 4 times. The weight of the biomass removed from these pruning and thinnings should be measured. The weight (or volume) of the remaining stems should be estimated from diameter measurements with regression equations (either developed on site or existing *Prosopis* equations from Texas). Re-measurements of these trees in subsequent years would allow the estimation of annual growth rates of these thorn forests. A

Figure 1. Mature Prosopis, Acacia and Zyzphus thorn forest in North West Frontier Province near Kohat.

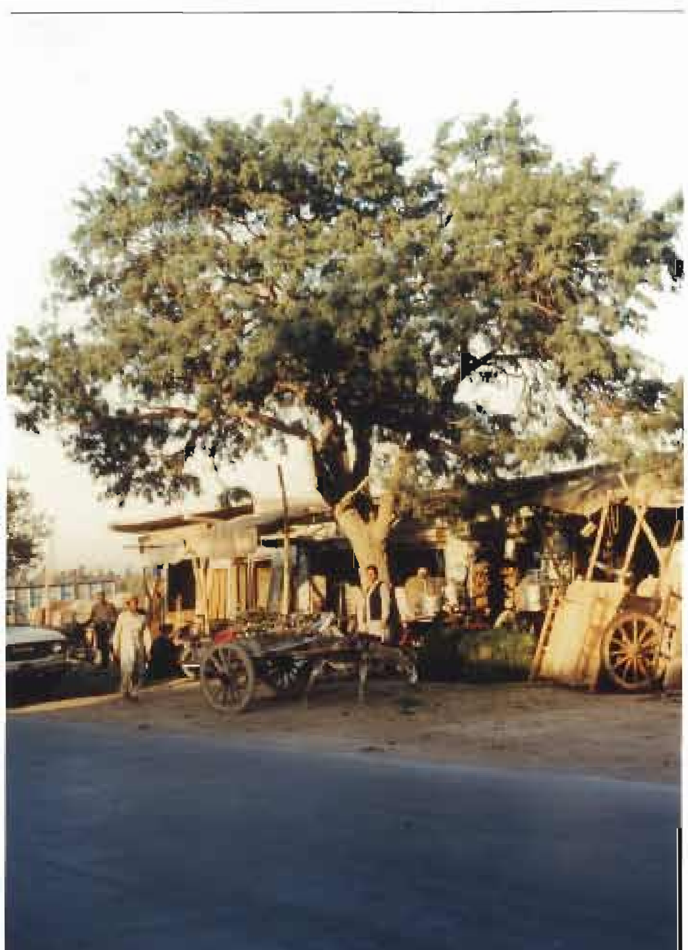

Figure 2. Example of large single stemmed Prosopis glandulosa near the University in Quetta.

management plan for these thorn forests would then be constructed which would contain; (1) estimated weight/hectare of small diameter branches obtained during initial thinning, (2) recommended spacings for pruned stems, and (3) rotation ages for pole production of various lengths and diameter. Two graduate students with Peace Corps forestry experience in Africa, Joseph Meyer and Steven Gronski, have just completed their Master's degrees on exactly this problem in Texas and I would highly recommend them for several month consultancies to initiate the research in conjunction with Pakistani foresters.

In addition to developing management plans for Prosopis in the rural areas there are considerable thickets of Prosopis in the urban areas (Figure 3). These stands also need to be managed to provide fuelwood and poles. An example of a native Prosopis thicket near Karachi that was thinned and pruned is shown in Figure 4 a,b. While the thickets may be communal in nature, education programs for the immediate area may be of assistance in managing these stands more profitably for all concerned.

Due to the demand for elimination of Prosopis in some areas chemical weed control techniques need to be demonstrated. Specifically the older mesquite herbicides Grazon ET (trichlopyr) and the newer herbicide Reclaim (chlopyralid), made by Dow Chemical Co. need to be evaluated. While these chemicals are expensive on a per gallon basis (Reclaim is over $220/gallon) only a 0.3 % solution is needed. Thus the cost to fill a 2 gallon backpack sprayer which could kill over a hundred small trees would be about $1.25 (about $0.012 per tree).

In the riverine forest areas there are large (8 to 20 inches DBH) Acacia nilotica trees with a dense under story of Salvadora and other small diameter brush. There may also be areas where the Prosopis are of a similar size. In these areas various treatments designed to yield fuelwood, clear lumber, and enhanced soil fertility for increased forage production need to be evaluated. Treatments need to consist of eliminating the dense understory, reducing the number of stems of the desired species to allow for greater volume production in the remaining stems, and pruning the remaining stems to yield higher quality lumber. Spring loaded aluminum bands with verniers inscribed on them (Dendrometers) could be useful in determining the influence of understory competition on fuelwood production in as little as one or two years. All of these treatments would be compatible with enhanced fuelwood production.

1 (b) Assessment of demographics of fuelwood demand in relation to water quantity and quality availability both irrigated and rainfed.

This section seeks to answer the question "Where are the major demands for fuelwood in Pakistan and what are the proximity of those demands to water from irrigation, rainfall, ground water,

Figure 3. _Prosopis juliflora_ thickets growing in urban areas of Karachi where it is harvested for fuel.

Figure 4a. _Prosopis_ thickets near Karachi that have been pruned to enhance form.

Figure 4b.

runoff, snow melt, oceans or brackish water that could be used to grow fuelwood"?

Analyses of this kind helps to assign priorities for R&D. The near-desert areas of Baluchistan may have acute needs for fuelwood but the population densities are low and the water supplies limited. In contrast the population of Karachi is large. Natural gas may supply a significant proportion of the fuelwood needs of Karachi's urban poor, but a small percent of the 8 million people in Karachi that require fuelwood may use a sizable percentage of the country's total fuelwood.

Thus demand analyses through household surveys needs to be carried out in Karachi to determine the fuelwood needs of the city. If substantial needs are identified, there are 2 potential methods by which Prosopis could provide a portion of this fuel wood. There are substantial thickets of Prosopis juliflora in the urban areas of Karachi along roads, in water courses, and in abandoned fields that could be managed through thinning and pruning to provide small diameter fuelwood and poles. The areas and sustained productivities of these urban thickets have not been measured and it may be necessary to establish fuelwood plantation in these areas. Due to the low rainfall in the Karachi area, supplemental water from groundwater, seawater irrigation of special salt tolerant clones, or from groundwater on saline agricultural fields will have to be used.

Providing fuelwood needs in the rural, low rainfall areas such as occur in Baluchistan Province will be a real challenge. In these desert areas a team approach would be most appropriate. This team should consist of a (1) geologist/ hydrologist to identify sources and salinities of groundwater and water harvesting yields (2) a sociologist/anthropologist to determine the demographics of fuelwood consumption and prices that would be paid and (3) a forester to determine suitable species and planting techniques that would be consistent with the constraints developed above. This team should identify areas with both a high demand for fuelwood and a substantial possibility for success in producing rapid growth of fuelwood.

As a rough guide for establishing trees which can produce several feet of growth per year one or more of the following conditions must be met; (1) greater than 300 mm of rainfall, (2) intermittent additional sources of water concentration from drainage channels, dikes, or water catchment basins that are derived from snow melts or rainfall or (3) groundwater within 30 feet of the surface that is typically less than 15,000 mg/l total dissolved solids. This latter category might occur as a result of a perched water table from irrigation in the immediate area.

Figures 5 and 6 show aerial photos of dikes used to concentrate runoff water by Pakistani farmers. Figure 7 illustrates the fact that natural drainage channels also serve as water harvesting

Figure 5. Examples of small dikes used to capture water and sediment runoff from the mountains.

Figure 6. A large catchment dike set up to capture runoff from the mountain.

techniques and that trees occur in drainage channels in the interior deserts of Baluchistan province. Man made water harvesting techniques have also been described in the excellent publication on arid zone afforestation by Sheikh. The soils in the drainage channels and/or water harvesting devices should be near field capacity at the time of transplanting for the trees to survive. There should be several hundred mm of water available in the top 2 to 3 m of the soil profile for reasonable growth to occur. It is important to know how often such an event might occur in these desert areas. Hopefully knowing the average snowfall on the mountains and the slope and permeability of the soils, a geologist could calculate the probability of achieving the conditions described above which would lead to a good tree survival and growth.

One area where runoff could be used to provide needed fuelwood would be on the alluvial fans from the mountains just south of Quetta (Figure 8). The rainfall in this location is too low to support Prosopis survival and growth but substantial runoff from snow melt appears to occur that might be sufficient to grow trees. The presence of Afghan refugee camps in this area intensifies the fuelwood need.

1 (c) Dissemination of information on the feeding value of Prosopis pods with suggested management techniques.

Several manuscripts have been left in Pakistan that contains information on the feeding value of mesquite beans (See especially the review "Legume trees in semi-arid areas"). This information states that mesquite beans can be toxic if fed as the sole source of feed for more than a month. This means that other rations are required to balance the diet. Spineless cactus would be an excellent dryland fodder compliment for Prosopis pods. There are other publications on the feeding value of mesquite beans. There is an excellent Mexican publication which has been translated that gives ration formulations for cattle, chickens, goats and other animals. A Sudanese Masters thesis gives the result of feeding various percentages of mesquite beans to goats as well as the meat characteristics of these animals (after slaughter). A publication by Saunders at the USDA Western Regional Laboratory in Berkeley California gives methods for fractionating the mesquite pods into high sugar fractions, high protein fractions, high fiber fractions and high galactomannan gum fractions. These techniques can be economical if mesquite pods are available at a low price. In Mexico, cooperatives have been established to purchase mesquite pods and process them into animal food.

There is also the possibility of processing the mesquite pods into human food. Felker enjoys spice-apple-nut-muffins in which 1/3 of the whole wheat flour has been replaced with mesquite bean flour. The large percentage of sugar in the flour (about 35 %) adds to the sweetness. There is a rich aromatic smell associated

Figure 7. Occurrence of trees in natural drainage channels in deserts of Baluchastan Province.

Figure 8. Potential reforestation site in Quetta area in which runoff from the mountains would be used to provide the soil moisture.

with the baking which is quite pleasant. The USDA has conducted taste panel tests with the mesquite pods and finds that chapitis prepared with considerable mesquite flour have a high rating. Mesquite bean jelly is currently being produced in the United States from boiling the mesquite beans and is in high demand in health food stores. In Peru, a molasses like product is prepared from boiling the mesquite beans. Extensive tests at the USDA have found no cyanogenic glucosides in mesquite beans. However phytohemagglutinins and trypsin inhibitors are present in mesquite seeds as are also present in soybeans, navy beans etc. These latter compounds are deactivated on heating.

Some agency needs to review these documents and prepare extension publications for distribution to the farmers.

2 (a) Asexual propagation of thornless high biomass producing Prosopis clones.

Three years of progeny testing in the hot (107 F July daily max) California Imperial Valley identified a series of high biomass producing clones. Further field testing of these clones in Texas led to the identification of a thornless *Prosopis alba* clone B_2V_{50} as possessing cold tolerance to minus 12 C (10 F), high survival (> 95 %), and rapid growth under rainfed conditions (21 dry metric ton per hectare in third growing season). Several years of research have led to techniques to allow commercial production of rooting of cuttings for this clone. Thus this clone would appear ideally suited to fuelwood production on small farms in Pakistan. Since production of rooted cuttings still requires a fair degree of sophistication, it is proposed that about 200 rooted cuttings inoculated with rhizobia specific for *Prosopis*, be produced in Texas and air freighted to Pakistan for consumer evaluation. These consumer evaluations could be conducted in Dr. Michael Doves villages that have been stratified according to income, regions, and social conditions. If a demand exists for these trees after 1 or 2 year evaluation by the farmers, rooting of cutting production facilities should be established in Pakistan.

It appears that the logical place for these rooting of cutting facilities would be at the Pakistan Forestry Institute at Peshawar. Mr. Sheikh, Director General of the PFI wishes to pursue development of greenhouse and mist propagation facilities at Peshawar. He would also like to see development of such facilities at the Miani station near Hyderabad and at D.I.Khan. The cost of a greenhouse with a 25 ft by 95 foot greenhouse with heating and cooling, double polyethylene roof and simple controls is about $12,000 in the United States. Mist propagation facilities including lights, timers and thermostats would cost about 3,000 for each site. The forest geneticist at PFI, Dr.Shams-Ur-Rehman would appear a likely Project Leader for this new research endeavor.

Significant advances in forestry are being made worldwide through rooting of cutting techniques. For example clonal seed orchards of pines have been established in the United States. The Brazilians have made tremendous gains in Eucalyptus productivity through selection and propagation of naturally occurring hybrids. The productivity of clonal Eucalyptus plantations in Brazil is approaching 70 to 80 cubic meters per hectare per year. Researchers at PFI have been able to obtain some rooting of their prime timber species, *Dalberghia sissoo*. Progeny trials of *Acacia nilotica* may yield outstanding individual trees that should be cloned. Thus in addition to cloning of *Prosopis* a thrust into factors affecting success of clonal propagation of important Pakistani fuelwood trees, multipurpose trees and commercial timber species would be a very useful endeavor.

The high biomass producing thornless *Prosopis* alba clone B2V50 as well as some other thorny salt tolerant and high pod producing species have been left with Dr. Ostmark to be sent to Dr. Shams-Ur-Rehman, Forest Geneticist at the Pakistan Forestry Institution Peshawar. He has agreed to plant the clones in larger pots and begin to multiply them.

2(b) Examination of fast growing thornless P. alba clone B2V50 in selected villages to determine acceptance for farm forestry.

USAID's mandate is to plant trees to develop fuelwood supplies for the small rural farmer. *Prosopis alba* clone B2V50 is a thornless cold tolerant (-12 C) fast growing selection developed in the U.S. Department of Energy's program for renewable energy production in southwestern United States. This nitrogen fixing tree has dense wood that makes excellent firewood and that if allowed to mature makes an excellent shade tree.

This advanced clone was developed and evaluated in southern California and southern Texas in similar climatic and edaphic factors to Pakistan. Thus it would appear prudent to test the performance of these clones directly in farmers courtyards. Dr. Michael Dove, Project Anthropologist with Winrock has carefully selected villages in Pakistan for fuelwood survey purposes that are stratified according to; education, land tenancy, land size, irrigation capability, salinity, waterlogging, and proximity to roads and towns. No villages are located in Sind Province but the other Provinces of Northwest Frontier Province, Punjab, and Baluchistan are represented.

It would be recommended to distribute 3 seedlings of clone B2V50 to each of 60 villagers distributed throughout these provinces. The biology and productivity of the clones are reasonably well documented, but the acceptance of this clone by the rural fuelwood poor is not known. The social success of this social forestry experiment could best be assessed in conjunction with Dr. Doves study of these villages. If this experiment is successful socially and biologically, arrangements can be made to economically produce the clones en masse in Pakistan.

3(a) Initiate collaborative efforts with Dr. Rafiq Ahmed, University of Karachi, to examine irrigation of Prosopis clones with 100 % seawater along the coast.

Dr. Rafiq Ahmed, Head of the Botany Department of the University of Karachi has been active for over 10 years in development of plants and irrigation systems to grow plants along the coast with seawater. Dr. Ahmed has successfully grown Prosopis with brackish water (about 1/3 seawater) and has grown many plants at half seawater. To date he has not grown plants with 100 % seawater.

With funding from the AID office of the science advisor, Prosopis alba, P.juliflora, and P. flexuosa clones were identified in the greenhouse at Texas A&I University that survived and grew at 100% seawater.

Thus an excellent potential exists for growing Prosopis forests along the entire Pakistani coastal desert using seawater. This proof of concept urgently needs to be tested under field conditions. Clonal propagation facilities costing about $2,000 needs to be established at the University of Karachi. Support for a vehicle, manpower and controlled irrigation systems to establish several hectares of clonal trials near important areas of fuelwood demand needs to be provided.

In addition Felker and Ahmed intend to submit a joint research proposal to AID or NSF to investigate some of the technical issues raised by this project. For example nitrogen fixation is very sensitive to drought stress, and while the seedlings grew at the greenhouse at Texas A&I on full seawater, it is not known if they can fix nitrogen under such stressful conditions. Further it is not known if nodule development can occur at these high salinities or if the nodules have to be established at low salinities first. A rhizobia exists that can grow in seawater but no mycorrhizae have been reported to grow at such high salinities. Published work from the previous grant from the AID science advisors office indicates phosphorus and the trace element zinc are important in reducing the stress of high salinity.

It is important to continue to build a solid technical base for development efforts towards establishing forests of nitrogen fixing trees with seawater irrigation. Felker and Ahmed intend to apply for funding in this endeavor. Assistance from USAID in locating funding sources and/or obtaining mission approval would be sincerely appreciated.

<u>3(b) Examine phosphorus fertilization, trace element fertilization, leaf nutrient correlations, and plant growth under high salinity, high alkalinity, water logged and low fertility desert conditions.</u>

Phosphorus is the nutrient that most severely and frequently limits nitrogen fixation in legumes. Phosphorus availability to the plant greatly decreases as the soil becomes more alkaline and various calcium phosphate salts begin to precipitate from solution. While the trace elements Fe, Zn, Mn and Cu are not required in large amounts they rapidly become unavailable as the pH increases and the various oxides and/or carbonates of these metals precipitate from the soil solution. Micronutrient deficiencies may be corrected by inexpensive sprays containing as little as 2 lb of the nutrient per acre.

To make matters worse, arid soils experience the greatest soil temperatures (due to low soil moisture) with the result that the organic carbon and nitrogen of arid soils is much lower than the more temperate soils. Thus tree plantings in semiarid soils are at more of a disadvantage than in more moist soils due to the very low fertility levels. These unsupplemented soil fertilities may be so low, especially on gravel alluvium from the mountains, that some plant nutrient supplementation may be necessary to achieve minimally acceptable survival and growth.

Thus simple biomass production trials on the most apparently deficient soils should be examined by treatments consisting of (1) control no fertilization (2) phosphate fertilization, (3) fertilization with a commercial blend of all micronutrients and (4) phosphorus plus micronutrients.

There is another soil problem associated with water logging/salinity that needs to be addressed. This problem occurs in the interior of the country and is associated with the irrigated soils. As opposed to the coastal sand dunes where internal drainage is excellent, poor internal drainage on heavy clay soils may be a compounding salinity problem in the interior irrigated portions of Pakistan. Nevertheless <u>Prosopis</u> seems to do quite well on these sites and may be useful in dropping water tables or in reducing the amount of drainage water that it is necessary to dispose of. Due to the different nature of this problem scientists such as Dr. Riaz Qureshi, Dept of Soil Science, University of Agriculture at Faisalabad or from the Soil Biology Division of the Nuclear Institute for Agriculture and Biology in Faisalabad would be appropriate to consult.

<u>4 Other</u>

<u>4 (a) Tissue culture research.</u>

Dr. Shams-Ur-Rehman is conducting tissue culture research on Dalberghia sisso at the Pakistan Forestry Research Institute at

Peshawar. Photographs of very nice shoot production from hypocotyl explants were observed.

Given the excellent start of tissue culture of Dalberghia sisso and the potential of tissue culture to provide a million seedlings in one year from a single outstanding tree, this research holds promise for genetic improvement of shissam. Even if tissue culture is not used for operational plantings, it might be valuable in rapidly multiplying plants for clonal seed orchards or in shipping pathogen free materials across international borders.

The focus of this tissue culture effort should be directed towards the rapid production of superior clonal propagules. Since shoots produced directly from callus are highly variable (i.e. not clonal) and since the genetics of shoots produced from hypocotyl explants depend both on both male and female parents, the vast majority of the tissue culture effort should be directed towards shoot multiplication from axillary buds. This is because shoots produced from pre-existing primordia in the buds have been shown to exactly reproduce the parent plant with very low variation.

Since hundreds of axillary buds will need to be used per experiment, this will require clonal stock plants of superior genotypes to be established to supply axillary buds for the experiments. Typically these will be established in 5 gallon pots in the greenhouse or nursery. Since previous studies have identified Dalbergia with superior form, and since production of rooting of Dalberghia shoot cuttings has been reported, this will pave the way for establishment of superior clonal stock plants.

The PFI has made a substantial commitment to the tissue culture research in the form of an incubator, autoclave, transfer room and several staff persons. Provision of a small laminar flow transfer hood for about $2,000 and shelves with ordinary fluorescent lights for several hundred dollars would be an excellent investment as it would greatly increase the productivity of the existing staff and facilities. (Since the laboratory is now air conditioned, temperature controlled incubators are no longer required. Shelving with lights placed around the room would allow many more explants to be evaluated and is all that is needed for nearly all tissue culture needs.)

This tissue culture research should be supported in the interest of long term research and development with a small percentage of the forestry research budget.

Since the completion of this report it has been learned that a Phd thesis has been completed on the tissue culture of <u>Dalberghi sisso</u> at the University of New Delhi India. Many of the tissue culture problems have been resolved and it would be highly recommended that substantial communications be initiated with the New Delhi researchers.

4(b) Jojoba trials.

The tropical desert vegetation at Kohat and steep stony hills are very similar to the native habitat of jojoba in southern California and Baja Mexico. Jojoba seems to require a slight chilling effect for good seed set but it cannot tolerate temperatures of minus 6 C without severe damage. The presence of frost sensitive species such as Prosopis juliflora, Acacia nilotica, and jacaranda all indicates temperatures of minus 5 C seldom if ever occur in Kohat. Pilot scale plantings of jojoba(1-2 acres) are highly recommended for the Kohat area.

4 (c) Need for progeny testing Acacia nilotica.

Acacia nilotica (Babul) is a most important tree in Pakistan. In southern Pakistan it is used in plantations (Hurys) to produce mine props and in the northwest frontier province it is extensively used as a multipurpose tree at the edges of farmers fields. Due to the widespread use and importance of this tree, genetic improvement for volume production, form (especially in Hurys for mine props), salinity, and tolerance to freezing weather would be an important contribution to Pakistan forestry.

To illustrate the gains that might be possible with this program consider the gains made with Leucaena pulverulenta. The cold hardy, low mimosine species Leucaena pulverulenta has become naturalized in Texas throughout a region that is 150 miles north to south and east to west. Seeds were collected from 85 individual trees throughout the range and the growth of their progeny examined in a field trial. A 500 % range in biomass tree was observed at 2 years of age. If these trees had been bulked by region (provenance) this large variation would not have been observed.

About 100 individual trees of Acacia nilotica should be collected across the full range of site conditions in Pakistan. Progeny of these trees should then be examined in trials with 4 replicates of 7 trees per replicate in row plots. Four trials should be examined in (1) moderately saline areas of Sind or Punjab, (2) a Barani area near Kohat northwest of Islamabad (3) an area that experiences frequent frost (minus 3 or 4 C) and (4) a non-saline good quality site typical of a Hury. After the trees are evaluated for frost and/or growth form, trees should be heavily thinned to provide a seed orchard for future plantations.

Pine geneticists recommend a minimum of 30 non-related trees in a seed orchard to avoid inbreeding depression in the progeny. When these many trees are used the genetic gains may be reduced because the performance of the progeny approaches the population mean. The vigor of Prosopis juliflora that was introduced from small populations to Pakistan, India, Sudan and Senegal does not appear to be reduced as a result of inbreeding depression. Perhaps the weedy colonizing species such as Prosopis, Leucaena, and Acacia do not suffer from inbreeding depression as do out crossed pine species. Thus I would recommend thinning these progeny trials to the top 1 % of trees with the best desirable character (form, production etc.)

A similar progeny test is currently being conducted jointly between Dr. McNabb of Winrock and PFI.

4 (d) Salinity training workshop

Foresters in all provinces consistently discussed the need for species adaptable to saline/brackish water where high water tables occurred. Little distinction is made by the foresters on the degree of salinity that exists on potential planting sites and there is little knowledge or experience on how to measure soil salinity. Given the ease by which soil salinity can be measured and the enormous variation in soil salinity in these regions, training should be provided to foresters in this area.

For example, soil salinities of 2,000 to 3,000 ppm total dissolved solids (TDS) makes them too saline for many agricultural crops. Thus it might be tempting to use very salt tolerant plants on these fields such as a triplex, jojoba or mesquite. These plants are really extremely salt tolerant plants capable of surviving salinities of 20,000 to 30,000 ppm TDS (32,000 ppm is seawater) and it may not be necessary to use such highly salt tolerant plants.

Techniques to measure total salinity are quite simple using an electrical conductivity meter. In this technique two platinum electrodes spaced 1 cm apart are placed in the test solution. A dial is then rotated until an electronic eye matches the salinity of the solution to the resistance reading on the dial. The solution is obtained by adding distilled water to the dry soil until a "saturated paste" that just glistens is obtained. This is then filtered and measured on the electrical conductivity meter.

A 1 day workshop would be most appropriate in which a morning session would be devoted to presentations on measurements of soil salinity by electrical conductivity, tolerance of cultivated and non-cultivated plants to salinity, calibration and maintenance of electrical conductivity meters and preparations of filtrates from saturated pastes. The afternoon session would consist of taking samples in the field, bringing them to the laboratory, preparing calibration standards, cleaning of the electrodes, measurements of electrical conductivity, conversion to ppm TDS, and recommendations for plants that could be grown on the land. At least one laboratory EC meter, and 2 portable meters should be distributed to each Provincial Forest Officer and their work plans should be amended to include measurements of soil salinity at each site before planting. Either Dr. Rafiq Ahmed at the University of Karachi or Dr. Riaz Quershi, Dept of Soil Science Islamabad have excellent credentials to conduct these workshops.

4 (e) Examination of fruit, fodder and vegetable production from Opuntia species (prickly pear cactus) in semi-arid Pakistan.

The prickly pear cactus have a special kind of photosynthesis that allows them to be 3 or 4 times more efficient in converting water to dry matter than grasses or forbs. Spineless cactus cultivars have been developed in Brazil, Chile, Mexico, and South Africa for a variety of purposes. Opuntia cultivars have been established in hundreds of acres in Chile and thousands of acres for fruit production. In Mexico special thornless Opuntia cultivars with prolific small pads are in commercial production on hundreds of acres for vegetable production. The young tender regrowth of these cacti have a taste similar to okra and green peppers and are cooked in omelette like preparations in Hispanic cultures. Prickly pears with large (40 cm long) thick (3 cm) pad shave been selected in South Africa for use in dryland fodder production. Many of these spineless cultivars have low tolerance to freezing weather and care should be adopted in widespread planting of these cacti until their frost resistance is examined under local conditions for several years.

Spineless fruit, fodder and vegetable types have been brought to Pakistan in very limited quantities. Some of these were distributed to the Forest Station at Miani in Sind Province and the remainder were left with Dr. Ostmark. If deemed useful, further genetic materials in larger quantities could be made available from single stemmed segments 30 cm across or from tissue cultured plantlets about 2 cm tall. The latter would be sterile and would eliminate the risks of introduction of pests and pathogens.

4 (f) Evaluation and distribution of cold tolerant Leucaena pulverulenta seeds.

Field research at Texas A&I on the local subtropical Leucaena pulverulenta has identified seed lots with about 50 % of the height growth of Leucaena leucocephala k8 but with substantially greater cold tolerance (A published paper concerning this has been left in Pakistan). Leucaena leucocephala freezes to the ground at minus 5 C whereas L. pulverulenta is undamaged by this freeze. Freezes of minus 8 C have not damaged L. pulverulenta while L. leucocephala has been frozen to the ground. Severe freezing weather such as occurred in Texas in 1983 that included 100 consecutive hours of below freezing weather with a minimum of minus 12 C killed both L. leucocephala and L. pulverulenta to ground level but they both resprouted from the base the following spring. The very slow growing Leucaena retusa was not damaged by this latter freeze and supposedly forms interspecific hybrids with the other 2 species.

L. pulverulenta would appear to have the greatest potential in higher elevation and more northerly semi-arid regions in Pakistan where frequent light frosts occur. Only about 1 kg of this seed has been obtained at Texas A&I. Contracts could be arranged to collect more seed in the summer of 1988. Seeds of L. pulverulenta accession number 1001 have been left with foresters in all of the provinces.

5 Recommendations for an ad-hoc committee chaired by Dr. G.R.Sandhu, Member of the Pakistan Agriculture Research Council, for a coordinated country wide Prosopis program involving PFI,University of Karachi, Farm Forestry & Energy Projects, USAID,appropriate anthropologists, Nuclear Institute for Agriculture and Biology, and selected District Forest Officers.

The disciplines, problems and potential areas in which Prosopis could positively impact the Pakistan economy are varied. As a result the skills needed to take advantage of these opportunities are located in different agencies. For example management of native Prosopis stands and genetic improvement of indigenous and exotic stands is most appropriately handled by the Pakistan Forestry Institute, irrigation of salt tolerant clones with seawater is best handled by Dr. Rafiq Ahmed at the University of Karachi, the Nuclear Institute for Agriculture and Biology has a strong program in reclamation of salt affected soils, and USAID's farm forestry and energy deals with supplying fuel to the very poor people. Throughout all these technical discussions it is important that the anthropological considerations be dealt with so that the resulting technical solution will be socially acceptable and will be located in the area with the greatest possible human impact.

For these reasons it is recommended that an ad-hoc committee be formed that will represent these concerns and develop an overall management plan to coordinate the development of Prosopis in Pakistan. Dr. G.R. Sandhu, Member of the Pakistan Agricultural Research Council (PARC) has graciously consented to chair this ad-hoc committee.

This report suggests members who would be excellent ad-hoc committee members. There are many people who have expressed an interest in developing the potential of Prosopis and who would make excellent contributions but who are too overburdened to serve on this committee. Given these considerations the following persons would be recommended for this committee: Dr. Rafiq Ahmed because of his interest in seawater irrigation with Prosopis; Dr.M.M. Siddiqui, PFI because of his involvement with both PFI and USAID's forestry program; Dr. Shams-Rehman, PFI because of his training in plant genetics; Mr. Khalid Latif, District Forestry Officer Gujrat because of his knowledge of the prices of Prosopis fuelwood of various size classes; a representative of the Nuclear Institute for Agriculture and Biology; Dr. Afzal Chaudry,Farm and Energy Forestry Advisor because of his involvement with the private forestry sector; Dr. Michael Dove because of the need to include to an anthropologist; and Dr. Ken McNabb because of the liaison with the AID research team. The Inspector General of Forestry should be asked to nominate someone to serve on his behalf.

An obvious lack is the involvement of the Provincial Chief Conservators of Forests. To keep the committee small in size and to avoid having to choose one representative from the four, it is recommended that the Chief Conservator of Forests be asked to send their recommendations to the ad-hoc committee. Mr. Shamsul Haq Memon has already forwarded an excellent set of recommendations to USAID.

Conclusions:

Prosopis has provided considerable fuel to both the urban and rural poor in Pakistan. *Prosopis* has also been of considerable assistance in stabilizing sand dunes, especially in Baluchistan Province. Undeniably there are instances in which *Prosopis* has also been an undesirable weed. Nevertheless *Prosopis* is very well adapted to some of the most difficult sites in Pakistan. Prosopis coud be much more beneificial. The goal should be to harness the tenacity of *Prosopis* with better genotypes having greater fodder and fuel potential and to develop management techniques for existing *Prosopis* stands. Given the widespread distribution and use of *Prosopis*, even small improvements in management techniques or genetic improvement should have large impacts in Pakistan.

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