Project Title: Management, Use and Control of *Prosopis* in Yemen

Project Number:TCP/YEM/0169 (A)

Mission Report
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Summary

The opportunities for integrated control, utilization and economic development greatly increased with the arrival and utilization of the wood chippers to convert small spiny branches into easy-to-handle wood chips and the hammermills that have been used to grind pods for livestock use. This latter process accomplishes 2 objectives, (1) it makes the protein in hard seeds available in the digestion process and (2) it destroys the seeds so unlike ingestion of unground pods which results in large quantities of germinating seeds in the livestock feces, no seedlings emerge from the feces of animals that have eaten ground pods. The arrival of long handled pruning poles along with local purchase of gloves and safety glasses makes the harvest of the spiny stems safer and more convenient. Good progress was also achieved in eliminating resprouts from harvested *Prosopis* stumps by combinations of kerosene applications followed by burning. Processing trials of the pods of a sweet local strain of *Prosopis* (1 out of 72 trees examined) into traditional bread at the Post Harvest Research Center in Aden gave excellent taste panel tests. In contrast, use of the local unimproved variety unfortunately provided negative taste panel tests. One log was processed into boards suitable for small craft projects and also a turned flower vase and illustrated the great potential of *Prosopis* for high value applications. Now that valuable products are being produced, i.e. chips, boards, turned articles, pod flour for livestock use, the priority should be placed on stimulating the market demand of these products to create revenue, employment and economic incentives to manage the weedy *Prosopis* stands. In Texas similar stands of small diameter trees contained from 30 to 60 tons of green biomass per hectare.

The research and development is being conducted in 5 major agricultural centers. The wood chipping and flour processing is being conducted; (1) on the west coast at the Tihama Agriculture Development Authority in Al Hodedah, (2) along the south coast at the Abyan at El Kod Research Station, and (3) at the northeastern interior region at the Hadramaut Governate at the Seiyun Research Station. Supporting research and development on the human use of the flours is being conducted at the Food Research & Post Harvest Technology Center in Aden. The development of the mist system propagation system for the superior local sweet clone is being done at the main agricultural research center in Dhamar.

As it was necessary to adapt integrated *Prosopis* management and weed control to Yemeni ecological, cultural and economic conditions, the majority of the training activities including the development of the training manual has not yet been completed. For example the costs for the only herbicides demonstrated in scientific journals to kill *Prosopis* stumps, i.e. clopyralid and triclopyr would cost about US 250/ha while if a combination of kerosene and burning can be proven effective, this cost for the same number of stumps per ha would only be only US 5/ha. Ongoing research at Hodedah and Abyan will verify if this treatment is successful by measuring lack of stump resprout in long term trials(3 and 6 months after treatment). Furthermore the economics of *Prosopis* management will radically improve if markets can be obtained for the chips resulting from the recently imported chippers. This improved market scenario will need to be included into the training manual. As information becomes available to the international consultant from the national coordinator and Director of Research, Dr. Mohamed Al Nassiri, this will be included in the training manual.

Technical narrative and recommendations

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Phase I Weed control through collection and utilization of the pods containing seeds, thus reducing dissemination of seedlings normally distributed in the feces of livestock.

The principal cause for the dissemination of the *Prosopis* is the consumption of the sugary pods by domestic livestock and the passage of the scarified seeds through the animals digestive tract which results in the germination of the seeds in the moist feces. Thus the collection and utilization of the pods (after destroying the seeds through grinding) would greatly reduce the spread of *Prosopis*.

This past year, 4 hammermills were purchased, 3 with FAO funds and one with funds allocated to Dr. Mohamed Al Nassiri. The 3 hammermills purchased with FAO funds were equipped with a diesel motor that will permit them to be transported to locations without electricity. The hammermill with the electric motor was assigned to the Food Research and Post Technical Center at Aden for research on human food applications.

These hammermills can be used to process pods either for human food use or for livestock feed. For human food use applications, a screen with 10 mm diameter holes is first used. This avoids destruction of the large endocarp containing the seeds and also bruchids. After this coarse grinding this material, a normal plastic kitchen type screen (ca 1 mm) is used to separate the endocarp material from the finer material. For human food applications, the screen in the hammermill is then changed to one having less than 1 mm openings and the material reground to provide a flour that will pass about a 60 mesh screen.

For livestock feed applications, only one screen of about 2 mm is used which destroys the seeds. A typical sized bag of pods shown below contains about 12 kg of pods with about 1.2 kg or 42,000 seeds. If a bruchid predation rate of 99.9% were obtained, there would still be 42 viable seeds per bag or enough to colonize half a hectare at a 10 m by 10 m

spacing. In contrast after grinding there are zero seeds. Thus if markets, and a strong demand can be created for the ground pods, this would eliminate 100 % of the viable seeds and help to eliminate the spread of *Prosopis*.

At Abyan, many farmers initially came to have their pods ground, but as they were not dry and clogged up the machine, they were told to take the pods home, dry them and return to have them ground. It would seem advantageous to provide a complete service to the farmers that included drying and grinding. The small plastic tunnel observed at Aden seems to be a good way to start since pod temperatures of only 55 C for 12 hours are required. To calculate the size of the plastic sheeting and tunnel that would be necessary, the pod grinding rate of 72 kg per hour at Abyan and 40 kg per hour at Hodedah was used. Since the air humidity at Hodedah is much higher leading to higher moisture content pods, this could be the reason for the lower grinding rate. These grinding rates for 7 hours per day, would equal daily processing of from 280 to 500 kg of pods. At Hodedah one sample of pods was found to have a density of 450 kg per cubic meter. Thus a volume of 0.62 to 1.11 cubic meters of pods need to be dried per day. If the pods were spread on a plastic sheeting 3 cm thick, this volume would be contained in a plastic sheet 2 m wide and 10 to 18 m long. A width of 2 m is suggested as this would be easy to reach the pods from both sides. It would be advisable to have 2 tunnels of one day capacity, so that one day could be charging and the other day using the pods.

I very strongly concur with Dr Al Nassiri's suggestion to put these hammermills on private incentive basis- with the operators being not only permitted, but encouraged to charge for this service. In this way the machines would be operating longer hours and the operators would seek clients to have their pod processed. The charges should include funds to pay the operators attractively and also to set aside funds for repairs.

I also very strongly concur with Dr Al Nassiri's suggestion that each of the 3 test locations should take the ground flour to the weekly markets to stimulate awareness and sales. At this time the priority should be on marketing and information dissemination. From the considerable funds remaining in the training budget, I suggest that an inexpensive digital camera be purchased for each of the 3 sites and that the responsible person at each of the 3 sites be required to produce one article every two weeks for the local paper or television on new uses for either the wood chips or the ground flour.

There were comments from Abyan that some farmers complained that the finely ground material clogged the nostrils of the goats. This also was recorded in feeding trials in Sudan. Since the grind flour easily clumps together with the humidity in the air, it would be interesting to experiment with slightly moistening the flour and placing the flour in small moulds of various sizes to determine if pellets or cubes of the flour could be easily made. The Indians in California used to moisten the flour to make balls and stacks of 1 cm thick disks-15 cm in diameter that were later broken and taken along on trips.

Unground pods and ground flour for livestock use near Hodedah.

As noted in the previous report, the collection of pods is a profitable enterprise for the local people. The current selling price for pods in Abyan for livestock feed is 120 to 150 rials per sack of 12 kg or about 10 rials per kg. When the pods are plentiful in the middle of the pod production season, a person can collect 100 kg per day which translates into a revenue of 1000 rials per day or about twice the current daily wage. In the more isolated and drier area of Hadramouth the price of *Prosopis* pods was about double or 200 rials per sack of 10 kg. It is to be noted that the pods currently being sold in the market of Abyan for livestock feed are not ground and surely contribute to the dissemination of new seedlings through their feces. Thus it is important to grind the pods to destroy the seeds.

A brief review of the only replicated scientific animal feeding trials follows below. These results indicate that rations for goats, sheep, beef cattle and dairy cattle can give very good weight gains and/or milk production when about 60% of the diet consists of ground *Prosopis* pods. However, suitable amendments such as urea, cottonseed meal, molasses must be included.

Due to the heavy involvement in the management of the whole tree chippers, stump burning trials, R&D to resolve the bitter pod issue, it was not possible to conduct training on animal feeding in this mission. The scientific data below will provide the necessary background for Yemeni Research Scientists and Technicians to begin a draft of the section of the manual dealing with animal feeding and to conduct the training courses. Dr. Mohamed Al Nassiri, DG of research has stated that he will initiate these animal training sessions in the very near future.

Trial of

Awadelkarim Ibrahim Abdelgabbar
M.Sc Thesis, Khartoum, Sudan 1982

Design; 48 Sudan male desert goats 4 to 6 months of age were divided into 4 treatments. The rations were stated to have been fed as a "mash" twice daily and it is unclear whether the pods were ground.

These results indicate that 100% mesquite pods cannot be fed and that a ration of about 55% mesquite pods, 15% cottonseed cake and 30% wheat bran provides good weight gain.

	Ration A	Ration B	Ration C	Ration D
Mesquite pods	100%	85%	70%	55%
Cottonseed cake	0%	5%	10%	15%
Wheat bran	0%	10%	20%	30%
Salt	1%	1%	1%	1%

	Ration A	Ration B	Ration C	Ration D.
Inital weight (kg)	13.52	15.89	16.97	17.14
Daily gain (kg)	-0.027	+0.010	+0.032	+0.053
Dry matter intake (kg)	0.24	0.51	0.50	0.58
Crude protein digestibility (%)	69.93	72.49	74.38	74.76
TDN consumed	0.17	0.36	0.36	0.43
Nitrogen retained g/kg of initial live weight	0.25	0.55	0.57	0.71

Trial of
Divan Soares da Silva
Masters thesis, Universidade Federal da Paraiba, Paraiba, Brazil 1982.

Design: 20 Nelore non-castrated beef cattle with an initial mean weight of 270 kg of age 21 months were used. There were 5 treatments in randomized blocks and 4 runs.

These results indicate that when ground *Prosopis* pods are included in a balanced diet, they can substitute for up to 70% of the wheat bran with no change in daily weight gain or nitrogen retention.

Rations	Wheat bran	Ground *Prosopis*	Cotton seed meal	Maize	Maize ground with straw & corncobs	Molasses	Percent substitution of wheat bran by *Prosopis*
A	70	0	10	20	0	0	0
B	52.5	17.5	12	18	0	0	25
C	35	35	15	10	0	5	50
D	17.5	52.5	17	5	0	8	75
E	0	70.0	19	0	3	8	100

In addition ground *Pennisetum purpureum* var. Napier was ground and provided daily

	A	B	C	D	E
Initial weight (kg)	272.8	271.5	271.8	268.8	269.3
Daily gain (kg)	0.877	0.827	0.823	0.800	0.871
Dry matter intake (kg)	8.28	8.32	8.56	8.25	8.51
Digestible crude protein intake (kg)	0.51	0.51	0.53	0.51	0.52
TDN consumed (kg)	5.4	5.43	5.60	5.44	5.63
Digestible protein/daily weight gain (%)	0.59	0.61	0.64	0.63	0.59

Trial of
Jose Leite de Queiroz Filho
Masters thesis, Universidade Federal da Paraiba, Paraiba, Brazil 1981.

Design: 20 male, adult castrated sheep of mixed race were used with 5 treatments and 4 animals per replication.

Results: A ration that substituted from 30 to 50 % of the molasses with ground *Prosopis* pods had the best weight gain.

	Ration				
	A	B	C	D	E
Molasses (%)	68.45	55.49	40.30	22.55	0
Ground *Prosopis*(%)	0	14.91	32.40	51.55	76.39
Urea(%)	5.74	5.60	5.45	5.20	4.88
Cottonseed meal (%)	25.81	24.00	21.85	20.70	18.73

In addition ground *Pennisetum purpureum* var. Napier was ground and provided daily

	A	B	C	D	E
Initial weight (kg)	20.87	21.55	22.22	22.20	23.72
Daily gain (g)	90.4 a	95.2 a	140.4 a	131.9 a	79.0 a
Percent of crude protein digestible (%)	80.5	80.6	82.2	79.7	84.0
Percent dry matter digestibility (%)	58.4	57.0	55.5	54.3	55.3

Trial of Fernando Viana Nobre
Masters Thesis, Universidade Federal da Paraiba, Paraiba, Brazil

Design: The milk production was examined in Twelve Holstein-Zebu milk cows in a switch back design in which each of 4 rations was examined 12 times.

Results: The ration with the greatest ground *Prosopis* had significantly greater total milk production, greater milk production corrected to 4% fat, greater fat content and greater total solids content than the ration with the corresponding wheat content.

	Ration A	Ration B	Ration C	Ration D
Ground wheat (%)	60	40	20	0
Ground *Prosopis* (%)	0	20	40	60
Cottonseed meal (%)	10	16	23	30
Maize grain (%)	15	13	10	5
Peanuts grain (%)	7	5	3	1
Molasses (%)	5	2	1	1
Meat & bone meal (%)	2	3	2	2
NaCl (%)	0.5	0.5	0.5	0.5
Bone meal (%)	0.5	0.5	0.5	0.5

	Milk production per day- not corrected for fat (kg)	Milk production per day corrected to 4% fat (kg)	Milk fat content (kg)	Total milk solids per day (kg)
Ration A	10.788^{bB}	10.574^{B}	0.409^{bB}	1.239^{B}
Ration B	11.422^{aAB}	11.435^{A}	0.459^{aAB}	1.379^{A}
Ration C	11.538^{aA}	11.582^{A}	0.465^{aA}	1.394^{A}
Ration D	11.646^{aA}	11.787^{A}	0.482^{aA}	1.436^{A}

Values with same letter were not significantly different at 5% level.

Use of *Prosopis* flour for human food applications.

Yemen is indeed fortunate to have such excellent scientists as Dr. Mohamed S. Al-Mussali and Dr. Omer Salini Khanbari, leading the research initiatives of the Food Science and Post Harvest Technology Laboratory at Aden (FRPT@y.net.ye). As Yemen is only 8% sufficient in wheat production, and imports 1,200,000 tons of wheat grain per year and 300,000 tons of wheat flour per year, this research center is working on ways to reduce wheat imports by mixing it with other grains. As Yemen produces 800,000 tons per year of grain sorghum this could be mixed with the wheat flour.

Dr. Al-Mussali's commented that when he made breads from the very bitter flour processed last year at Seiyun, none of the people at his location found it to be acceptable. As some people at Seiyun found the bread made there to be acceptable, Dr Al Mussali

suggested that possibly this was due to a higher concentration of fat, sugar or black cumin

Thanks to the efforts of Mr. Mohsen Bazara of Abyan, who tasted the pods of 72 trees, one tree was found that did not have bitter pods. The pods collected from this tree, shown below were processed into human flour. As it was unclear to Research Center personnel how to produce a flour from the mesocarp without incorporating the endocarp, we used the hammermill with a screen with 10 mm diameter holes to first break up the pods, a 1 mm screen to separate the endocarp portion from the flour portion and a second mill to finely regrind the material that passed the 1 mm screen(see below). We tried the saponin test with 500 mg of flour in 5 ml of water, but both the very bitter flour we made in Seiyun one year earlier and the new flour had the same foam height. However the Seiyun flour was much more bitter than that of the improved variety.

Sweet pods of *P. juliflora* ready for processing at Food Research and Post Harvest Technical Center with Dr. Mohamed Al-Mussali, Dr. Mohamed Al Nassiri and Mr. Mohsen Bazara

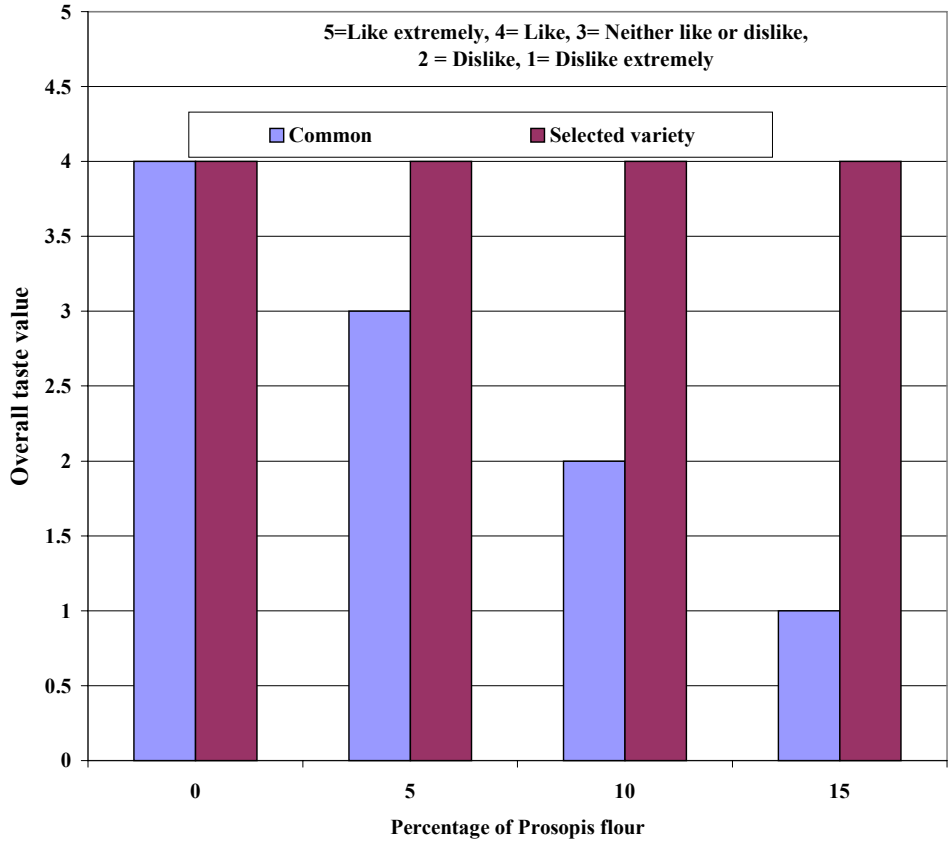
Fine flour made from pods of a selected tree of *P. juliflora* with sweet pods

Flat bread made with *Prosopis* flour of a sweet tree from El Kod. On the far right is the control bread made with 100% wheat flour, next from the right is bread with 5, 10 and 15% *Prosopis* flour respectively. Note the darker tan color with increasing concentrations of the *Prosopis* flour.

Flat breads were made from both the unselected mixture of many pods collected at Seiyun and of the improved variety with sweet pods at zero, 5, 10 and 15% *Prosopis* flour concentration. The flat breads of the improved variety are shown above. Taste panel tests were done on both the flat breads. The results expressed in the graph below shows that for overall taste, the improved variety had a "like" flavor across at all concentrations while the unimproved variety decreased strongly to extremely dislike at the 15% concentration. The color and aroma of the improved variety ranked higher than the 100 % wheat control bread. Dr. Al -Mussali, Director of the Post Harvest Center was visibly excited with the positive results of the sweet pods and expressed his belief that it would be very easy to commercialize the flour from the sweet pods through his industry contacts.

The obvious dilemma is what can be done with the more than 95% of the trees that have bitter pods. The research group decided to examine influence of various factors on the bitterness of breads such as;

(1) Sugar and fat content of dough
(2) Yeast concentration and fermentation time (since yeast are incredibly rich in enzymes and might degrade the bitter compounds)
(3) Effect of time and temperature on the roasting of the flour.
(4) To conduct proximate analyses (sugar, protein, fat, condensed tannins etc) and other tests to try to correlate bitter flavor with a rapid chemical test.
(5) To request Ing Nora Grados to bring flour of Peruvian varieties for comparisons.



Until satisfactory resolution of the issue of use of the bitter pods in human food preparations is resolved, it would be best to suspend training sessions with use of the pods for human food preparations.

For the flour from the sweet pods, it will be important to refine and expand the uses of *Prosopis* flour for human applications taking into account the unique technical characteristics identified in the Ph.D. thesis of Daniel Meyer which include; (1) effect of ground *Prosopis* flour in five fold reduction of long term rancidity of wheat flour, (2) significantly higher consumer acceptance of extruded maize tortilla chips with *Prosopis* flour than without the flour, and (3) greatly improved dough and bread physical properties of *Prosopis* flour with addition of 1% guar gum(to overcome lack of glutenin). Additionally the demand for the flour in the gluten free market should be examined.

Phase II. Research and demonstration on weed control, integrated management, chipping, and marketing.

Texas A&M University and the Texas Agricultural Experiment Station have been the leaders in developing technology to kill *Prosopis*. The current Texas Extension Service program designed to kill *Prosopis* is known as Brush Busters and is designed for control of individual plants with mixtures of either RECLAIM (clopyralid) or REMEDY (triclopyr) in diesel. For plants less than 4 cm in diameter a mixture of 15% RECLAIM in diesel was recommended ,while for stems from 4 to 10 cm in diameter a 25% RECLAIM

mixture in diesel was recommended. In 1996 the cost of RECLAIM was $20 per liter. If one assumes that a minimum of 20 ml is used per tree that is 25% RECLAIM then the cost per tree for the herbicide is $0.10. The cost for the kerosene per tree at 20 ml per tree and 17 rials/liter (US 0.10 per liter) is about $ 0.002 per tree. In the dense *Prosopis* stands, stems could easily occur on 2 m by 2 m spacings for 2500 plants per ha for a RECLAIM cost of $250 per ha. The kerosene cost for 2500 plants would be $5 per ha. Since fire has been very effectively used to kill young *Prosopis* stems, given the low cost of kerosene compared to herbicides the priority should be placed on developing kerosene or diesel treatments in combination with fire.

Trials with kerosene with or without burning were observed at Abyan and Hodedah. Partly due to this writers unclear suggestions, rates from 1 to 40 ml of kerosene per cut stump were used (the suggestions were intended to be doses of 1x, 2x etc times what was found to be reasonable for the small stems). At both locations, the lower doses were found to inhibit sprouting on the top of the cut surface. However when fire was not used, sprouting occured between the cut surface (generally 15 cm above the soil line) and the soil. However with 40 ml of kerosene and burning, no resprouts occured.

The following photos taken at the Hodedah trials

One ml of kerosene without burning

One ml of kerosene with burning.

40 ml of kerosene with burning.

The results with 40 ml and burning are most encouraging. It is suggested that future trials center around this technique. Variables that need to be examined include; number of resprouts that occur at long periods after the treatment, for instance one month and 6 months and applications at various times of the year i.e. spring, summer, fall and winter. It would also be interesting to compare mixtures of used oil and kerosene since this mixture would penetrate more deeply and the fire would last longer. However, as the kerosene in Yemen is so cheap, it would be good if this mixing could be avoided and only one kerosene used.

Small branch chipper demonstration

The arrival of the wood chippers has provided an opportunity to create cash flow from the harvest of the *Prosopis* to finance the thinning and pruning. The objective of the use of the chippers is to convert dangerous long thorny branches, that are difficult to transport, into a non-thorny, product that is denser and easier to transport and handle. Texas research found that similar dense stands to those reported here contained from 30 to 60 tons of green biomass per hectare(equivalent to 15 to 30 tons of dry biomass). Thus it seems prudent to find uses for this rather than pay to destroy it without receiving any benefit.

To facilitate harvest of the branches from an upright position, and also a safe distance from the trees, long pruning saws were purchased whose use is shown below. In addition the project purchased gloves, safety eye protection etc. Due to the special importance of safety issues, this is treated as a separate section.

Long handled pruning saws used to harvest *Prosopis* from an upright position distant from the tree base.

After the branches were harvested they were fed into the branch chipper shown below that was powered by the tractor's PTO shaft. Unlike the hammermills that only need about 12-15 hp, the energy to chip the branches is much greater requiring from 30 to 50 hp. As the cost to provide a motor of this size would be on the order of $8000 it was decided to purchase a chipper without an auxiliary motor. This has the added advantage of separating the maintenance issues of the motor and chipper. Branches up to about 10 cm in basal diameter and of length up to 7 meters were fed through the chipper.

Harvested branches being fed into the chipper at Hodedah. The chips were blown onto a plastic tarpaulin

There are two basic types of chippers- a drum chipper that does not provide uniform chip sizes, and that forcibly jerks the branches from the hands of the operator, and a disk chipper that provides chips of a uniform size and that does not jerk the branches from the operator. It should be clarified that the chip sizes are uniform when chipping the solid wood branch parts. Due to the presence of leaves, small green branches, small woody branches (< 1.5 cm diameter) and larger woody stems (up to 10 cm diameter) the composition of the chips varied considerably. A screen was used to make separations into the fractions below of entirely leaves and small green stems, mixtures of small stems and wood chips, mixtures of large wood chips and small green pieces and virtually all larger wood chips. If it were desirable to obtain a fraction without leaves, the harvested branches could be left in the sun for about 1 week until the leaves fell off.

The percentage of these various fractions changed with tree basal diameter. For the larger tree sizes much more of the large wood chip fraction was present. Probably because *Prosopis* is a N fixer, other studies have shown that even the wood is relatively high in protein, i.e. about 10%, while the young leaves were close to 26% protein. If there were no allelopathic effects of the green leaves, this fraction would be a useful green manure. After a considerable number of larger trees were chipped the overall appearance became more like that of the larger chips as can be seen below.

At first the farmer and scientists were concerned that the chips were too small to replace their traditional fuel sources that consist of larger size classes. However as they began to reflect they had the following suggestions for uses of the chips;

(a) Industrial wood furnaces(in the last report it was noted that in Hadramouth there were 45 lime-making furnaces in Hadramaut that currently use used motor oil, tires and palm tree residue for fuel)
(b) Mulch around houses for flower beds and shrubbery
(c) For use as a filler for cushions
(d) Fire starters
(e) Green manure since the leaves are 4% N
(f) Improving soil structure and lowering bulk density for potting soil mixes.
(g) Insulation
(h) For traditional home round ovens
(i) For the black smith
(k) For fuel for egg hatchery heaters

Since large trees can provide competition to provide young trees from invading (dense immature stands are never observed under canopies of large trees), the harvesting of the trees for this chipping trial was done in such a way as to thin the trees to the point where the canopies almost touched. Later on as the canopies close again, it will be necessary to conduct another thinning. A photo illustrating this thinning is shown below in which both

the large single stemmed trees where left and in the foreground dark black spots occured where the very young sprouts were burned after a kerosene application.

Prosopis stand after harvesting and thinning for the chipper demonstration. Note in the lower left one group of small seedlings that were burned and a large burned stump below the man at the far left. The background vegetation is typical of the stand before thinning.

Another thinning plan that should be evaluated is thinning to rows of 10 m where it is possible or desirable to intercrop, for example with sand millet. The annual cultivation will provide the needed mechanical disturbance to prevent new seedlings from becoming established. An example of this method in Hodedah is illustrated below

An example of the use of annual disking to eliminate young *Prosopis* seedlings. This system might prove useful in agroforestry systems with sand millet for example.

The concluding discussion of the chipper training workshop, after observing the long handled pruning saws, safety equipment and chips is shown below. Also seen in this photo are the examples of the boards and turnings made from a local *Prosopis*. The general mood of the training session was very reflective. The farmers and scientists were continuously generating new ideas for the uses for the chips, and also for the small boards and wood turned on the lathe, seen for the first time. The village chief was very optimistic for the uses and ensured the organizers that they would find new ways to use these products and went so far to state that if these markets were successful he would even consider planting the *Prosopis*.

Wrap-up discussion for the integrated harvesting, kerosene treatment, stump burning, thinning, pruning, and chipping of *Prosopis* in Hodedah. Note the *Prosopis* board and turning article.

Production of solid wood articles from *Prosopis*.

In Argentina, Mexico and southwestern United States, *Prosopis* lumber is very highly regarded due to its outstanding 3 dimensional stability and above average hardness and commands good prices of about $800 per cubic meter. In spite of the lack of large trees in Yemen, one small log was obtained from which various boards and an article turned on a lathe were made**.** As most Yemen cities have abundant furniture shops that manufacture furniture and turned articles for staircases, if *Prosopis* could be processed into boards or squares suitable for turning, valuable products could result. An example of the sawing of a log with a very inadequate saw is shown in the figure below. Obviously if the *Prosopis* industry is to grow, much more suitable equipment will be necessary.

Prosopis trunk being sawn to produce a small diameter short log for boards and a turning article.

Wholly inadequate equipment was used to convert a round log to boards and a turned piece shown below. After a 4 sided cant was made on a table saw with a circle blade, the 12 cm square cant was cut into boards using a shaper with a horizontal circular blade. As the blade could not reach through the cant, it was cut from both sides. After the boards were made they were surfaced using a planer that evidently was too dull or run too slow and as result there was considerable chipout of the boards. All this not withstanding, if suitable equipment were available, excellent products could be obtained.

Approximately 10 cm wide boards made from the *Prosopis* log above. After sawing the boards were planed and a clear lacquer without stain applied to the bottom half. The yellow portion is the sapwood that should be eliminated as it has a different expansion coefficient than the heartwood and is also very susceptible to powder post (Lyctus) beetles. *Prosopis* flooring that is tongue and grooved and 12 mm thick sells for $25 per square meter in the USA.

A turning from the small *Prosopis* log above that was finished with a clear lacquer without stain and demonstrates the beauty and high quality finish that can be obtained**.**

The wood used for the products in the photos above has a value ranging from about $400 to $800 per cubic meter or about $500 to $1000 per ton at a specific gravity of 0.8. There are few other products from arid lands that command such a high value. Developing this potential will be a major investment in staff time and financial resources requiring acquisition of small-log sawmill equipment, ancillary sawmill equipment after the principal log has been squared, kilns, humidity measurements, etc and training to operate such equipment and marketing. Dr. Mohamed Al Nassiri, Director of Research for Yemen and Dr. Hashim A-Shami, FAO Representative Yemen have requested this writer to assist in the preparation of a major follow on grant to fully develop this important resource.

Safety issues in harvesting and processing of *Prosopis*.

The harvesting of spiny branches of *Prosopis* possesses hazards related to foot punctures, scrapes on the arms, and eye punctures. These problems are compounded by the customary long-flowing clothing/head protection and open-toed, light-weight rubber sandals. While it may be possible to harvest spiny branches for several hours without major problems, for daily harvest it will be essential for the workers to wear the most appropriate attire consistent with their common culture dress.

An additional hazard occurs when operating the chipper as branches may be rapidly drawn into the machine. If traditional flowing head protection should become entangled in the thorny branches, this head gear could be drawn into the machine. While the opening of this chipper is too small for body parts to enter, the head and upper body parts could become badly scratched should the "turban like" head protection become entangled in thorny branches as they entered the chipper.

It is suggested that the work be done early in the morning or preferably in winter months, when it is possible to comfortably wear extra thick protective clothing. It would be best if protective boots, a construction hard hat or baseball cap, moderately tight fitting long sleeve shirts, heavy duty trousers, gloves and eye protection could always be worn. Eye protection should be worn when harvesting in the brush, since rapid head movements or falling thorny branches could puncture the eye.

It is recommended that someone in the research team be assigned to be responsible for continually evaluating and updating safety procedures. This person should also be responsible for routinely monitoring harvests, conducting interviews of the harvesters to learn how harvests can be conducted more safely, and suggesting ways in which the costs of protective clothing can be financed.

Integration of management results.
It is highly recommended that throughout the life of this project, weekly contact be maintained among the research centers by email as described below. Positive results on chipping by one group can then be integrated with positive results on stump killing by other groups and new market development from other groups. During Felker's next visit, it is recommended that a 2 day information exchange workshop be held in which all 4 research centers will share their findings.

Research and demonstration on new uses for the chipped products, milled pods, lumber and turned articles.

This project has resulted in many new possible uses for the ground trees, ground pods, lumber and turned articles. A mixture of applied research, economic analyses and marketing will be necessary to fully take advantage of these results**.** For example, the leaves and twigs have high protein levels and could be an interesting green manure if no allelopathic effects are present. Various fractions need to be sent to soil scientists to evaluate the green chips as a green manure and to evaluate the larger woody chips to use to decrease soil bulk densities in potting soil mixes and as decorative mulches around shrubs.

Suggestions were made that perhaps the ground chips could be used as a livestock food in the form of feeder blocks after incorporation of molasses and other additives. A symposium at Texas Tech University in Lubbock, Texas in 1982, Edited by H. Parker reported trials of feeding ground branches and leaves to ruminants. Most of this work reported that it was necessary to treat the ground branches with steam or ozone to achieve

acceptable results. However, these papers need to be reviewed more carefully for their application in Yemen.

This system should produce about 1 ton of chips per hour. At a labor cost of $0.60/hr (100 rials/hr) per person and a crew of 10 people, the total hourly labor charge would be $6. With a diesel consumption of 15 liters/hr and a cost of $0.10 /liter, the fuel costs would be $1.50 per hour. The tractor in the demonstration rented for 1000 yr/hour or $6 per hour. Thus the total costs would be $13.50 per hour for 1000 kg or a break even cost of $0.014/kg or 2.5 yr/kg. High quality firewood has a value of 10 yr/kg or $55 per ton.

To develop the markets it will be necessary to take the products every week to the market and explain the benefits to the people present. For people that purchase the products, it will be necessary to visit them to examine the advantages and shortcomings of the products. The shortcomings will need to be resolved in the applied research centers. The advantages need to be promoted by taking photographs and writing articles for local papers, farm press articles, magazines and television. To facilitate these efforts it is recommended that one digital camera be provided to each of the 3 sites. It is recommended that one of the major responsibilities of the leaders at the 3 sites is to document that they have submitted an article on different uses every 2 weeks.

Integration and cooperation among Yemeni research, extension and demonstration personnel.

It will be of great importance to facilitate the ease of communication among the *Prosopis* researchers at the 4 major sites and thus it is recommended that an internet "discussion group or bulletin board" to exchange research results, new sources of literature and to share ideas on new approaches be established. This could very easily be done as a Yahoo discussion group. FAO Yemen staff are well acquainted with this technique and could establish this working group in less than 30 minutes. As a minimum it is recommended that at least one person at each of the research stations at Al Hodedah, El Kod, Seiyun and the Food Science and Post Harvest Technology Laboratory at Aden be designated to open the email site once a day and share the information with the other researchers.

Notes on *Prosopis* taxonomy.

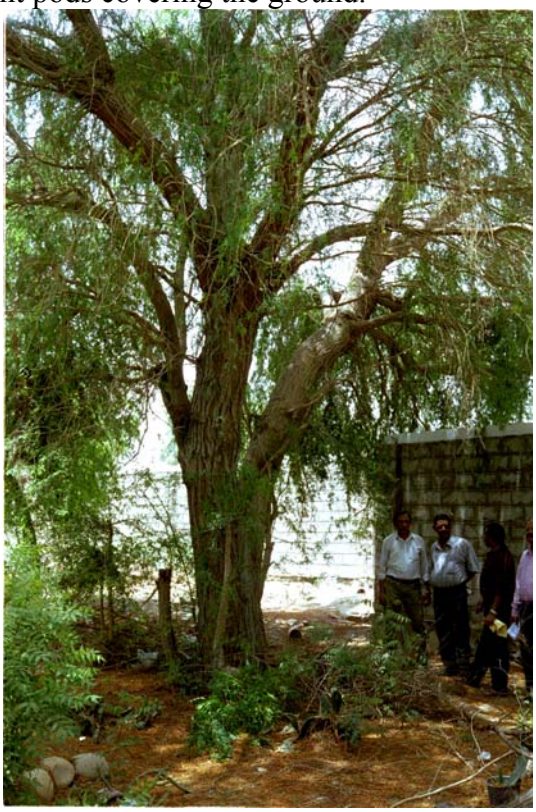
On the trip from Hodedah to Sanaa at about 3000 m elevation in Haraz area, Manacha city was observed a row of *P. chilensis* typical of what would be found north of Santiago, Chile or in extensive areas of the Provinces of Catamarca and Cordoba in Argentina. A photo of the mature trees is shown below.

A row of *Prosopis chilensis* growing near Haraz area, Manacha City

A photo of a branch with pods of the *Prosopis glandulosa var. torreyana* (the California native) common to the Aden area is shown below. Mr. Mohsen Bazara mentioned that he sent this species to Kew Botanic Garden in Great Britain where it was identified as *Prosopis chilensis* From 1977 through 1980 while working at the University of California Riverside I had made major germplasm collections and field trials on P. glandulosa var. torreyana and co authored a taxonomic work on this species (Khidir W. Hilu, Steve Boyd and Peter Felker. (1982) Morphological Diversity and Taxonomy of California Mesquites (*Prosopis*, Leguminosae) Madrono 29(4) 237-254). Having worked with *Prosopis chilensis* in Argentina and in California with *P. glandulosa var. torreyana,* the Kew determination is unequivocally wrong because of branch stem angles, anthocyanin stem coloration, leaflet and leaf morphology, plant overall habit and different pod morphology, color and taste.

Pods and leaves of *P. glandulosa vary torreyana*, the California native species that is abundant in Aden

While not very common in Yemen, one mature specimen of the native P. cineraria was observed on the grounds of the research station in Abyan. In the photo of this below can be seen the very abundant pods covering the ground.



A large specimen of *P. cineraria* native to Yemen growing on the research station grounds in Abyan. Note the extensive quantity of pods lying on the ground.

Literature Citations.

Abdelgabbar, A.I. 1983. Feed utilization and body composition of Sudan Desert Goats fed on mesquite (*Prosopis* chilensis). University of Khartoum, Masters Thesis 130 pp.

Barros, N.A.M.T 1981. Effect of the substitution of molasses with *Prosopis* pods in the nutrition of ruminant animals. (Translation from Portugese) Masters Thesis 97 pp. Joao Pessoa Universidad Federal de Paraiba Brazil).

Silva, D.S.D. 1982 Substitution of wheat bran by ground *Prosopis* juliflora pods in the rations of beef cattle in feedlots(Translation from Portugese) Masters Thesis 50 pp. Joao Pessoa Universidad Federal de Paraiba Brazil).

Nobre, F.V. 1982. Use of *Prosopis* flour as a feed for milk cows. (Translation from Portugese) Masters Thesis 74 pp. Joao Pessoa Universidad Federal de Paraiba Brazil).

Administrative and budgetary recommendations.

In view of the recent awareness of the potential of use of larger logs for lumber, turning squares for staircase parts etc, the continuing need to thin large trees and the wholly inadequate hand saws available as noted above, it is recommended that at least one chainsaw be purchased. This chainsaw would initially be assigned to the group at Abyan as the trees are larger there than other locations. This chainsaw must have one responsible person assigned to check it out to users, and to perform routine maintenance on the saw. A notebook must be obtained with the chainsaw to detail when it was used, by whom, the status of the oil, chains etc, needed repairs and the status of the chainsaw before and after each use. If this chainsaw is loaned to the other locations, they also must assign a responsible person to maintain a similar records.

Due to the high priority assigned to developing markets for all product types, and the high cost of film and processing, it is recommended that one digital camera either be purchased or made available for use at each of the 3 sites. Inexpensive digital cameras were observed at the computer store near FAO HQ in Sanaa for $180.

Dr Al Nassiri has requested a no cost extension to be able to continue with this project until next June. As the project had a late start and only in July 2003 were the chippers available, Dr Al Nassiri's request makes a great deal of sense and the International Expert concurs with this request.

Dr. Al Nassiri will be requesting the FAO representative for a rebudgeting of some activities in order to allow for a 4th visit by the international expert in approximately March/April of 2004. This would be most helpful to have more time for each of the centers to gather data, develop new products and markets and gauge the impact of these new technologies before writing the final report. As the FAO representative has requested the international experts assistance in preparing a larger proposal for the amount of approximately $2 million, this 4th visit would provide an opportunity to review the details of this proposal with the FAO Representative.

Statistical information related to *Prosopis* distribution

The Research Department has excellent GIS maps and capability. There was some discussion about the need to purchase GPS units abroad to obtain a lower price and this has delayed the purchase of the GPS units. During the visit of the International Expert, approval was obtained to purchase the units locally and this should speed this process.

The international expert has noted extensive distribution of *Prosopis* along main roads and throughout the urban areas of Aden and Hodedah. While collectively this area is large, due to the presence of a only few trees at each location, this distribution will be very difficult to quantify.

Training & Training manuals

Due to the complex nature of the *Prosopis* weed/utilization issues it has taken time to adapt USA and Peruvian technology to Yemeni conditions. Problems with cost-prohibitive herbicides to kill stumps, techniques to convert small thorny branches into useful products and techniques to use of bitter pods in human diets have been particularly difficult to resolve. As a result the basic information necessary to conduct training or prepare training manuals is only now becoming available.

However, a training demonstration course was held for farmers to show them how to use the hammer mills to grind pods for animals (11 farmers participated).

A training course for utilization of the sweet pods for human consumption organized in the Abyan area. Further training of women on the human uses of the pods would best wait until better techniques to include the pods in human food preparations are developed (which are almost all very bitter).

One training course, described above on integrated thinning, pruning, management and use of the chippers was conducted near Hodedah with about 4 scientists, and 25 farmers participating. As the chipper arrived late and only 4 days before the International consultants departure, no more of this type of training course was provided by the International expert. However representatives from 2 of the 3 other centers participated and plans are underway to conduct training with this chipper and the long handled poles at the other 2 sites.

One month after the chippers have been working at all 3 sites and from 4 weekly visits to the farmers market, a reasonable awareness of the potential markets for the chips known, it is suggested that a combined chipper/pod milling training workshop be conducted in Abyan (Aden, Abyan & Lahej), and Hadramouth (including Shabwa). This workshop has already been conducted at Hodedah.

During the third visit of the international expert, a major training/information exchange workshop will be held in which about 5 representatives from all of the 4 sites will share their results in the management, new product development, marketing, and overall perspectives. The collective results with photos will be published using funds from the training budget.

Scientists fully acquainted with *Prosopis* management techniques through on the job training include Dr. Mohamed S. Al Nassiri on all aspects, Dr Ali A. Shurai National Coordinator (Tihama) on wood chippers spacing, pruning, Dr. Mohamed Al-Mussali, Director of the Food Research and Post Harvest Technical Center from pod processing technology, Mr. Mohsen Bazar and other BS level scientists form Abyan

Development of National *Prosopis* strategy

With regard to the Country Draft Strategy, the Yemen Director General of Research, Dr Mohamed Al Nassiri was with the International consultant continuously on this visit. As the new opportunities for management, utilization and marketing of both pods and wood products became available they were continually discussed. These concepts were discussed on numerous occasions with both Dr. Ismail Muhram, General Director of Research and Extension Authority and Eng. Abdul Hafid Karhash, General Director, Ministry Agriculture and Irrigation. On the last day a formal seminar was held presided by Asst. Deputy Minister Saleh M. N. Al Beshi in which representatives of all the government agencies and universities were present. After considerable discussion that recounted the initial objective of virtual complete eradication, there was a new consensus that in a country with such low wood and animal feed resources that every effort should be made to capitalize on the utilization of *Prosopis*. Now that this decision has been taken, the road is prepared for a written draft strategy for *Prosopis* management.

With regard to village mills established to convert *Prosopis* pods to flour, 3 mills have been established at Hodedah, Abyan and Hadramouth as opposed to the 2 mills called for in the proposal. There has been some difficulty in drying the pods for these facilities, but recommendations in this report should resolve this issue.

With regard to training of farmers and national technicians on the use of *Prosopis* for animal feed, a summary of the scientific literature that employed replicated animal feeding trials with *Prosopis* pods is attached. These materials will be incorporated into the extension bulletins and training sessions by MAI and Research and Extension staff.

In addition 3 wood chippers to convert the brushy branches and trees to easily manipulable wood chips have been established as village mills in Hodedah, Abyan and Hadramouth. This is an addition to what was called for in the objectives.

Terms of reference for the International consultant for the second mission

Review project progress and adjust project work plan according to needs.

- Continue studies initiated during the first mission.

  The bread making trials, animal feed processing systems, stump treatment trials, and thinning trials were continued as noted above.

- Monitor and assure that a participatory methodology is applied by MAI throughout the execution of the project's activities.

  The continuous participation of the countries Director General of Research, Dr. Mohamed Al Nassiri and frequent discussions with Dr. Ismail Muhram, General Director of Research and Extension Authority and Eng. Abdul Hafid Karhash, General Director, Ministry Agriculture and Irrigation and Dr. Mohamed Al-Mussali, Director of the Food Research and Post Harvest Technical Center have assured full participation in the management and utilization of *Prosopis*

- Start with counterparts and full involvement of the population, pilot activities of collection and processing of *Prosopis* products. Organize practical demonstrations of pod processing. Supervise the operation, maintenance and management of mills and other project equipment.

  Pilot activities were established and visited at 2 (Abyan and Hodedah) of the 3 locations where pod mills and chippers are located. This work has just really been started and will vigorously expand now that the operational difficulties have been resolved.

- Provide a two-day practical course for 4 scientists and 20 farmers on *P. juliflora* management, harvest and processing.

  As noted above a one day practical course for scientists, and farmers was conducted in Hodedah. As this one day course involved the first time set up of the wood chippers and training of technicians for all sites, only one course was provided during the visit. Many more training sessions will now be provided by National program staff.

- Provide a one-day course on animal feeding with *Prosopis* flour for 4 technicians and 10 farmers or pastoralists.

  Two of the 3 sites with pod grinding mills were visited and minor corrections were made in the drying and grinding. Now that the results of formal feeding trials have been summarized (above) in depth training of technicians and farmers on animal feeding will begin.

- Supervise the preparation of awareness creation material on *Prosopis* use and management.

  Discussions with the technicians and scientists first on the pod utilization and later on the wood chip utilization have identified the major opportunities for awareness creation. This report contains the recommendation for purchase an inexpensive digital camera for the 3 locations and the recommendation that every 2 weeks an article with photographs be submitted to the local press on utilization of the pods and chips.

- Provide guidance to the project staff and counterparts for the preparation of the workshop.

  Plans are being developed for a comprehensive workshop at the end of this grant on the third mission of the International Expert with the full participation of the 3 pod mill/wood chip centers and the Post Harvest Technical Center to compare results and develop a definitive strategy for the future.

- Prepare a report in English and in electronic form with conclusions, recommendations and required follow-up activities to be presented to FAO within 14 days after completion of the consultancy.

  This was submitted within 14 days but due to email problems associated with file size it was not received in 14 days.