JOJOBA WATER HARVESTING AGRISYSTEM
EXPERIMENT, PAPAGO INDIAN RESERVATION,
SELLS, ARIZONA

by

C. Brent Cluff
Water Resources Research Center
University of Arizona
Tucson, Arizona

Paper prepared for
August issue of
Jojoba Happenings
August 1978
Introduction

The Jojoba plant is found in a four to 18 inch precipitation zone. In the lower rainfall zone plants are limited to sites where rainfall is concentrated by arroyos or on alluvial fans at the base of mountains (Gentry, 1958). Gentry has also observed in a 4.3 inch rainfall zone in Joshua Tree National Monument the tremendous difference in growth and production between two Jojoba plants, one growing near a road pavement which served as a watershed and the other plant growing away from the road was dry and nearly leafless.

The author has similarly noticed this disparity in growth in the Sahuaro National Monument west of Tucson. There are several Jojoba plants in front of the Nuart Photo Shop on East Speedway that receive ample water and therefore maintain a high production level in both size and quantity of Jojoba beans whereas the production of natural stands in the surrounding desert are subject to variation in rainfall. Lower intensity, deeper penetrating winter rains coming near the flowering season are much more important to the survival and production than are the higher intensity, summer convectional rains. Sellars (196) has determined there is more variability in winter rains totals than there is in summer rain. The chances are greater for a completely dry winter than a completely dry summer.
In view of the foregoing in 1972 a paper was written illustrating how water harvesting techniques could be used to concentrate the rainfall to increase the production of Jojoba. The excess runoff water is stored in a reservoir and pumped back during winter and spring to maximize bean production (Cluff, 1972).

In 1974 the concept became a reality with the construction of an approximately one-acre water harvesting system which was built on the grounds of the Baboquivari High School in Sells, Arizona as a cooperative project between the Papago Tribe, the Bureau of Indian Affairs, Baboquivari High School and the Water Resources Research Center and Office of Arid Lands Studies of the University of Arizona. This paper describes this project which was funded primarily from the U.S. Department of Health, Education and Welfare.

**Site Selection and Method of Construction**

The site was accepted primarily due to its accessibility and ease in maintenance. The soils are somewhat sandier than would have been selected otherwise. There is less than 10 percent clay. The average difference from four soil samples between field capacity and the wilting point was only 2.6 percent. This low soil moisture holding capacity indicated the need for auxiliary storage particularly during the early years of the project.

It was decided that three leading catchment treatments would be tested for raising Jojoba. There are: (1) sodium chloride, (2) asphalt-plastic-asphalt-chip (APAC) and (3) paraffin wax. Consequently, the approximately one acre catchment was divided
into three parts and treatment made in accordance to Figure 1. Each treatment covered a 60 x 270 ft. area or 16,200 ft$^2$ or 1800 yd$^2$.

Each treatment contained two drainages spaced at 30 feet. Side slopes were constructed at approximately 10 percent. The drainages ran into storages. The smaller storages of 13,000 gallons were constructed primarily for flow measurement purposes and for collecting water samples. The major storage was approximately 167,000 gallons. A pumpback system consisting of a two inch electric submersible pump and two inch polyethylene plastic line was installed. The construction of this project predates the evolution of the concept of the compartmented reservoir (Cluff, 1978). However, the three reservoirs could be operated as a compartmented reservoir system. The two smaller reservoirs are lined with plastic and coated with reinforced mortar. The larger reservoir was constructed using the APAC method with polypropylene matting. The sides of the reservoir were later coated with reinforced mortar to help stabilize the banks which had a slope of two vertical to one horizontal.

All three subgrades were prepared in the same way. Shaping was done using a road grader. Final smoothing was accomplished using a PTO operated rock rake (Cluff, 1974). Sodium chloride was applied to the three plots at the rate of five tons per acre using a conventional fertilizer spreader. The salt was mixed into the soil using the rock rake which also smoothed the surface. Following a one-half inch rainfall the catchment was compacted by running a $\frac{1}{2}$-ton pickup truck back and forth across the surface.
This was the final treatment for the salt treated catchment. The APAC system was laid down on top of the salt treated subgrade. This installation was made using an asphalt "boot" truck, a dump truck with a chip spreader and a jeep equipped with a plastic dispenser roller. The installation of the APAC catchment is more fully described in Frobel and Cluff (1976). The size of catchment was erroneously placed at 20,000 ft$^2$ in this publication.

The paraffin wax treatment of 1.25 lbs/yd$^2$ was put down on the salt treated subgrade by personnel from the Water Conservation Laboratory of Tempe, Arizona. It was hand sprayed after being melted in a 400 butane heated gallon distribution tank. It required about 3 hours to head the wax and hand spray it. Less time would be required if a regular asphalt boot truck and spray bar was used.

A cost estimate summary of the system made in 1974 is given in Table 1.

Planting of Jojoba

The Jojoba was planted in late May 1975 (Jojoba Happenings, No. 13). One row of each treatment was planted with potted seedlings raised in the greenhouse of the Vocational Agriculture Department of the Baboquivari High School. The second row of each treatment was direct seeded using five seeds per site. Germination of one to three seeds occurred in 50 percent of the sites. A 5.0 and 2.5 ft spacing was used in the potted and direct seeded rows respectively. The plan was to thin the direct seeded plants back to a five foot spacing after the sex of the plants was determined. With this thinning a planting rate
of 324 plants on the 1.12 acre system or approximately 290 plants per acre would be achieved. In most cases natural attrition has reduced the plant density to less than a five foot spacing so that the thinning was not needed.

The survival rate of the first planting was relatively high. However later, when the summer rains started, many plants drowned due to the flat slope of the drainage ways in the lower parts of the wax-treated and, to a lesser extent, on the APAC and sodium-treated plots.

A second planting of approximately 200 plants was made in May of 1977. These plants were six to eight inches high in gallon cans. They were obtained from a commercial nursery. The survival rate of this second planting was much lower than that of the initial planting particularly on the wax treated catchment. This die-off was encountered even though the drainage problems had been corrected. A combination of high temperature, encountered shortly after planting, and perhaps insufficient water, as well as too much disturbance in transplanting, all contributed to the more than 75 percent die-off of this second planting.

**Plant Survival and Production**

As of August 8, 1978, 219 sites contained viable plants. The inventory is given in Table 2. Most of the surviving plants appear to be in good condition. Some of the original planting are 3-4 feet high and feet in diameter. Out of the remaining 27 bore seed for the first time in the 1977-1978 season.
The salt treated catchment appears to be very adequate for raising Jojoba. The salt is still effectively shedding water and has done a good job controlling weeds on the slopes. There has been, however, considerable weed growth in the drainage ways and a suitable herbicide needs to be used. The APAC catchment is weathering well except for areas where initial chip treatment was inadequate and localized areas where the runoff has eroded the chip cover.

The wax treatment on this particular soil type in the rates applied does not seem to be very long lasting. Initially a precipitation total of 0.05 inches would cause runoff on the wax and APAC treated plots. However, by September of 1977 this threshold on the wax plot had increased to several times that amount. Visually there is little evidence that any wax has survived the three years. Cracking occurred after installation which perhaps caused the subsequent erosion of the wax material. It does appear there has been more erosion from the plot than the salt treated plot. The efficiency presently appears to be similar to the sodium treated plot indicating that the subgrade treatment is controlling the runoff. Personal communication with Keith Cooley of the Water Conservation Laboratory indicates that perhaps a heavier initial treatment of wax would have been more satisfactory.

Assuming \( \frac{1}{2} \) of the surviving 219 plants are female and will produce at 10 lbs per plant, the average production at maturity would be about 1095 lbs. At the current market price of $1.50 per pound the gross return would be $1642.5 per acre.
If the plot is replanted to its original intended density of 324 and a ratio of one male to five female plants is established, the potential gross return at today's prices would be $3888 per acre.

An updated computerized design of a salt treated Jojoba water harvesting agrisystem which includes the use of a compartmented reservoir is described by Cluff and Foster (1978). This design would be more cost effective than the design used at Sells.

In summary, the research results presented herein, together with the growing economic potential, indicate that larger installations of Jojoba water harvesting agrisystems are justified.

Acknowledgments

Special acknowledgment is extended to Dr. Edward Hasse previously with the Office of Arid Lands Studies and Dr. Gordon Dutt, Department of Soils, Water and Engineering, University of Arizona, for their help in the design and planting stages.

Appreciation is expressed also to Harley Cox, Mike Henry and Frank Molina, Vocational Agriculture instructors of Baboquivari High School who have supervised maintenance of the project over the past four years.

Finally, the help of the Bureau of Indian Affairs for furnishing equipment and the U.S. Public Health Service for providing the necessary funds for establishing the water harvesting system is gratefully appreciated.
TABLE 1
COST SUMMARY (1974)
JOJOBA - WATER HARVESTING PLANTATION

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catchments (Three 1800 yd^2 each)</td>
<td></td>
</tr>
<tr>
<td>Compacted Earth Salt Treated (CEST)</td>
<td>$212.00</td>
</tr>
<tr>
<td>Asphalt Plastic Asphalt Chip (APAC) (4 mil polyethylene plastic)</td>
<td></td>
</tr>
<tr>
<td>Subgrade</td>
<td>212.00</td>
</tr>
<tr>
<td>Surface</td>
<td>650.00</td>
</tr>
<tr>
<td>Wax Coated CEST Catchment</td>
<td></td>
</tr>
<tr>
<td>Subgrade</td>
<td>212.00</td>
</tr>
<tr>
<td>Wax</td>
<td>435.00</td>
</tr>
<tr>
<td>Storage</td>
<td></td>
</tr>
<tr>
<td>Excavation</td>
<td>660.00**</td>
</tr>
<tr>
<td>Lining:</td>
<td></td>
</tr>
<tr>
<td>Two 13,000 gallon tanks (Reinforced Mortar Coated Plastic)</td>
<td>770.00*</td>
</tr>
<tr>
<td>One 167,000 gallon tank (APAC sealed)</td>
<td>1100.00**</td>
</tr>
<tr>
<td>Fencing</td>
<td>932.00***</td>
</tr>
<tr>
<td>Grand Total</td>
<td>$5193.00</td>
</tr>
</tbody>
</table>

*These tanks are needed only because it is an experimental facility.
**These costs are size and site dependent.
***Fencing costs are size dependent and would be lower if conventional barbed wire was used instead of woven wire with welded H corner posts and iron pipe gate.
TABLE 2
INVENTORY OF SURVIVING JOJOBA PLANTS, AUGUST 1977
JOJOBA WATER HARVESTING SYSTEM,
SELLS, ARIZONA

<table>
<thead>
<tr>
<th></th>
<th>Salt Treated</th>
<th>APAC</th>
<th>Wax Treated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seeded*</td>
<td>65</td>
<td>42</td>
<td>23</td>
</tr>
<tr>
<td>Potted</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seedlings**</td>
<td>44</td>
<td>23</td>
<td>22</td>
</tr>
<tr>
<td>Total</td>
<td>109</td>
<td>65</td>
<td>45</td>
</tr>
</tbody>
</table>

*Planting rate was 108 plants per row on a 2.5 foot spacing.
**Planting rate was 54 plants per row on a 5.0 foot spacing.

One-half of the surviving plants are on the salt treated plot whereas only 65 plants have survived on the APAC plot and 45 on the wax plot. As indicated earlier, most of the mortality of plants on the wax and APAC plots was due to flooding. Photographs taken in the fall of 1977 are shown in Figures 2 and 3.

Discussion and Conclusions

Although receiving a minimum amount of maintenance (due primarily to the lack of funds) the Jojoba water harvesting agrisystem established at Sells in 1974-1975 has demonstrated the potential of the method. Most of the attrition that occurred in the original planting was due to drowning by ponded water. The high mortality of the second planting was due probably to the method used by an inexperienced crew maintenance and timing of the transplant.
Figure 2. Jojoba Water Harvesting Agrisystem Sells, Arizona showing 2 year plants on salt treated area.

Figure 3. Jojoba Water Harvesting Agrisystem Sells, Arizona showing storage reservoir in foreground.


Jojoba Happenings, No. 13, Office of Arid Lands Studies, University of Arizona, November 1975.