FINAL REPORT

USE OF SALINE WATER FOR BUFFALO GOURD PRODUCTION IN NEW MEXICO

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ABSTRACT

New Mexico's underground water resources include over 15 billion acre-feet of saline water of varying salinity levels. Salt tolerant crops that are capable of producing commercial yields economically may displace more conventional crops and spare the state's precious fresh water for higher uses. Cucurbita foetidissima HBK (buffalo gourd) was grown in wooden tubs in an outdoor setting in an effort to determine starch and alcohol yields. Irrigation waters of 500; 2,000; 4,000; and 8,000 ppm total dissolved solids were applied.

Yields of buffalo gourd roots from 2,000 ppm TDS irrigation water were comparable with field trials. Lower root yields were experienced with increasing salinity levels. Alcohol yields were lower for buffalo gourds irrigated with saline water than for field grown buffalo gourds. Results are inconclusive as to why low alcohol yields were achieved.

Key words: buffalo gourds, salt tolerance, ethanol

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INTRODUCTION

This report considers the potential of the buffalo gourd, irrigated with saline water, as a novel crop for New Mexico, primarily as an energy crop that would produce starchy roots for the fermentation to fuel ethanol. Buffalo gourd is a native of New Mexico and several other southwestern states of the U.S., as well a northern Mexico, so it is well adapted to the region. Further, domestication efforts at the University of Arizona have shown that buffalo gourd can produce remarkably high yields of roots with lower water requirements than many conventional field crops.

The buffalo gourd project that is the subject of this report complements more extensive field tests of buffalo gourd grown on a project supported by the New Mexico Energy Research and Development Institute (NMERDI) (Goldstein, 1984). The NMERDI-funded project differs only in the water quality of the irrigation strategy employed. All other materials and methods (e.g., fertilization, plant density, soil types) are similar between the two projects so as to foster comparison. The major difference that may affect comparability is that the results in this report are for buffalo gourds grown in wooden tubs. For the NMERDI project, all plants were grown in fields plots. Thus, this project has much lower total yields of roots and gourds. The low total yields precluded pilot plant runs for ethanol production. However, laboratory tests were performed to determine the relevant chemical properties and comparisons were made on this basis.

The saline water buffalo gourd program was developed to explore the feasibility of irrigating with salinity levels above those typically considered appropriate for irrigation practices. Because buffalo gourd may most likely be commercially grown in the eastern plains region of New Mexico and other areas of the United States dependent on the Ogallala aquifer, it is thought that the substitution of saline water for fresh water will reserve the precious fresh water for more valuable applications. New

Mexico has about fifteen billion acre feet of saline groundwater or enough to cover the state to a depth of 200 feet. Much of this water has a salinity of greater than 3,000 ppm Total Dissolved Solids (TDS) and thus cannot be used for potable water nor traditional agricultural activities. If this extensive resource could be used to grow commercially valuable crops, the fresh water of the Ogalalla aquifer would be spared and the economic base of eastern New Mexico can be maintained and even expanded. The specific objective of the project is to demonstrate and evaluate the feasibility of producing sustainable commercial yields of a nontraditional crop using saline waters and soils common to much of New Mexico.

BACKGROUND

The buffalo gourd (Curcubita foetidissima HBK) is a semixerophytic cucurbit native to arid lands, prairies, and dry washes of central North America (Bailey, 1943). Its range extends from the southern Great Plains to almost as far south as Mexico City, and it has been observed at elevations of 1,000 to 7,000 feet (Scheerens, et. al., 1978). The gourd grows primarily as a weed in disturbed soils, such as abandoned fields, along roads and railroad embankments, and in low areas in open country (Hogan and Bemis, 1983). At least 25 Major Land Resource Areas in the southwestern United States may be suitable for buffalo gourd production (Draper, 1982; Icerman and Schultz, 1985). Domestication efforts at the University of Arizona have been in progress for some years (Gathman and Bemis, in press). The main products of potential interest in the cultivation of buffalo gourd in New Mexico are the seed oil and the root starch, in perennial and annual culture, respectively .

Cucurbita foetidissima HBK is capable of prodigious vegetative growth as evidenced by the large number of stems and shoots arising from the central tap root. These vines are groundcover as opposed to climbing vines, and result in a dense mat of vegetative growth (Bemis, et. a.l., 1979). The vines are frost-sensitive and cannot survive temperatures below 0°C (Bemis, et. al., 1978). The fruits (pepos) of wild buffalo gourd are 5 to 7 cm in diameter and contain 200 to 300 seeds, with 30 to 40 percent edible oil and 30 to 35 percent protein (Bemis, et. al., 1978).

MATERIALS AND METHODS

Buffalo gourd Synthetic No. 1 cultivar seeds were obtained from the University of Arizona. It was not possible to locate a field suitable for saline water irrigation. Therefore it was decided to grow the plants in tubs. Soil was obtained from the New Mexico State University Plant Science Research Center in Las Cruces from a plot adjacent to the NMERDI-funded buffalo gourd site to ensure compatability between the two projects. Thirty-two large wooden tubs (e.g., .75M x .75M) were obtained and filled with the soil. Saline water was manufactured in a 85 percent NaCl, 15 percent $CaSO_4$ mixture to obtain salinity levels of 2,000; 4,000; and 8,000 ppm TDS. The water was stored in large stock watering tanks. An irrigation system was installed to serve each of the tubs.

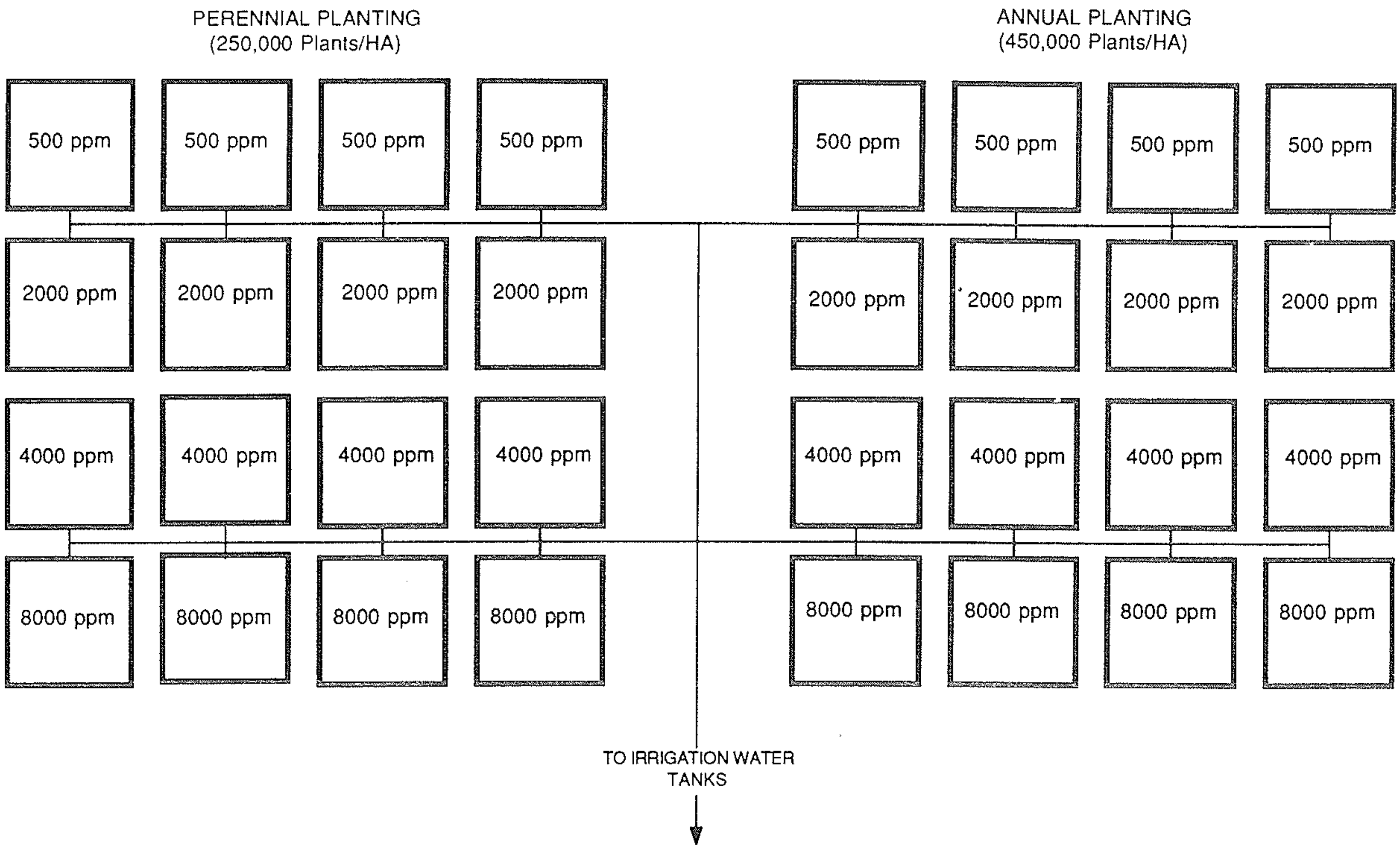
Prior to planting, laboratory tests were conducted to determine germination rates for buffalo gourd seeds at different irrigation salinity levels. The laboratory tests compared seed from the University of Arizona (e.g., Synthetic No. 1) with seed collected from native buffalo gourds in Curry County, New Mexico. Germination tests were conducted in soil free media in a controlled atmosphere growth chamber. Different water salinities were supplied to the seeds: distilled, 2,000, 4,000, and 8,000 ppm TDS.

1984 Season

The seeds were initially direct seeded on June 5, 1984. However, due to a series of unfortunate incidents discussed below, the crop that was ultimately harvested was not seeded until July 19. Rate of seeding exceeded 450,000 seed/ha planted at a depth of about 2.5 cm. The tubs were fertilized with 112 kg N/ha as urea and 112 kg P/ha as P_2O_5. Half of the tubs were subsequently hand thinned to achieve two plant densities of 450,000 plants/ha and 250,000 plants/ha. The 450,000 plants/ha represented the annual planting strategy and the 250,000 plants/ha represented the perennial planting strategy. An annual planting strategy was thought to be better suited for root production while a perennial planting strategy would favor root and gourd production. Although no gourds were to be grown and analyzed under this program, it was considered useful to have different planting densities to allow for comparisons between the NMERDI-funded project. Four watering strategies were established: fresh water as a control (about 500 ppm TDS), saline water at three salinity levels of 2,000; 4,000; and 8,000; ppm TDS). Four replicates of each treatment were employed; thus with the four watering and two planting strategies all of the thirty-two tubs were utilized. A plan layout of the tubs with the irrigation and planting strategies is shown in figure 1.

Buffalo gourd roots were harvested by hand from each of the annual tubs and from one-half of each of the perennial tubs after the first area frost on November 27, 1984. The roots were weighed and measured before shipping to the New Mexico State University Plant Science Research Center at Clovis, New Mexico for laboratory-scale fermentation and analysis.

Several problems were encountered during the first year of the project. The first unfortunate occurrence was that all of the seedlings were killed shortly after the first sprouts appeared. Mortality was from two causes. Due to a measuring error, salinity levels were twice as high as had been calculated for all water types except for the fresh water. For example, the 8,000 ppm TDS designated tubs were actually receiving 16,000 ppm TDS. While there was emergence at all salinity levels, growth was not vigorous. To compound the salinity problem, the irrigation spray heads in each tub discharged a 360° spray that coated the emerging leaves with water. After the water



BUFFALO GOURD TUB LAYOUT, PLANTING, AND IRRIGATION STRATEGY

FIGURE 1

had evaporated a thin film of salt was left on the leaves which caused the leaves to dessicate. Both the high salt levels and the salt-coated leaves contributed to the early loss of the plants.

The tubs were reseeded on June 30, 1984. On July 17 fertilizer was surface applied and all of the young plants were subsequently killed. The fertilizer was applied in a manner in which the leaves were coated and burned.

The entire plot, all thirty-two tubs, was again reseeded on July 19, 1984. All of the tubs were irrigated with only fresh water to ensure that the leaves would not become coated with salt. Further, the irrigation system heads were changed from 360° spray nozzles to drip nozzles rated at 7.5 liters/hour. The drip nozzles successfully kept the water off the plant leaves.

All of the plants were irrigated with fresh water and rainwater for about 1 1/2 months. On September 13 the plants appeared to be healthy and growing vigorously. The salinity irrigation strategy was again initiated. The plants received saline irrigation water for almost two months whenever the leaves showed stress.

Irrigation water delivered to each tub, after the final seeding on July 19, was about 23 cm. Rainfall for the same time period was about 21 cm which was nearly the same as the 30-year average (NMDA, 1986). However, during August when the plants were growing the fastest, the area received twice as much rain as usual. Water delivery to the tubs was more than the plants could actually utilize. It was estimated that due to leaking of the tubs perhaps only as much as 50 percent of the delivered water remained in the tub long enough to get into the soil.

The wooden tubs developed severe leaks. Both the spray and drip nozzles caused erosion patterns in the soil in the form of deep crevices that led directly to the sides of the tubs. The wooden slats were not fitted sufficiently tight to prevent water from simply draining from the tubs.

Several attempts were made to fix the tubs. Masonite sheets were cut and placed around the inside perimeter of the tubs down to a depth of several feet. This action only served to change the points where the water could flow out of the tub. Another approach was to use different caulking materials and spray foams to try to seal the tubs from the exterior. These approaches were unsuccessful. The most useful method of retaining water in the tubs was to simply push the soil around to cover the holes. This was a time-consuming task and had to be repeated for each tub on almost every watering. However, this was the best approach that was devised. In hindsight it would have been appropriate to line the tubs with plastic before putting dirt in the tubs. Plastic sheeting would have sealed the cracks and would have helped to reduce the evaporative losses on the four exposed sides of the tubs.

One other problem occurred during the growing season. In early August the cucumber beetle, Coleoptra, appeared and feasted on the young plants, particularly on the leaves and flowers. Mature plants were observed in the local area and did not appear to be infested with the cucumber beetles. Liquid Sevin was applied to the plants with high mortality rates for the cucumber beetles. The flowers suffered sufficient damage such that no gourds (pepos) were initiated. However, given the late date for the final planting it was also unlikely that any fruit would mature independent of the cucumber beetle infestation.

1985 Season

The annual group of tubs was planted with seeds at approximately 450,000 of seed/ha on May 9. The perennial group of tubs was reseeded on the side that had been harvested in 1984. Fresh water was used to germinate the seeds and was applied until June 12 when the plants were well established. The annual tubs were hand thinned to achieve a plant density of 450,000 plant/ha. The perennial tubs were hand thinned to acheive a plant density of 250,000 plant/ha. Saline water was provided when the plans showed stress until late October. By August 16 all of the vine and leaf growth in the 8,000 ppm TDS tubs both perennial and annual, had died and the plants in the 4,000 ppm TDS tubs were stunted and not growing vigorously. A total of 30 cm of saline irrigation water was delivered to each tub. Rainfall for the same period of time was about 24 cm which was about 50% above average (NMDA, 1986).

Buffalo gourd roots and pepos were harvested on November 20 following the first frost of the fall. All buffalo gourd roots were harvested. It was not possible to distinguish by appearance between roots from either the annual or the perennial planting strategy. Two-year growth was not appreciably larger than one year growth, particularly at the high salinity levels. Pepo production was greater in 1985 than 1984 but only 42 pepos were harvested from all the tubs. As in 1984, the roots were weighed and measured before laboratory-scale fermentation.

Laboratory Scale-Fermentations

The buffalo gourd roots were processed and analyzed by the NMSU Plant Science Research Center at Clovis, New Mexico. Roots from all eight tubs of the same watering strategy were combined prior to laboratory anlaysis. This action, due to budgetary constraints, prevented an analysis of the potential ethanol-yield differences between the annual and perennial planting strategies. Samples of roots were selected from each grouping (e.g., 500, 2,000, 4,000, and 8,000 ppm TDS). A flow chart of the ethanol yield laboratory chemical analyses is shown in figure 2.

The roots were washed thoroughly, rinsed repeatedly, and each sample was macerated in water by using a food processor and blender. Particle distribution was determined by USA standard testing sieves. The resulting brei was used for determining moisture percent (gravimetric), carbohydrate content (dinitrosalicylic acid hydrolysis (DNS) assay in conjunction with a spectrophotometer), and soluble solids (refractometer). The total carbohydrate content is a measure of total available starches

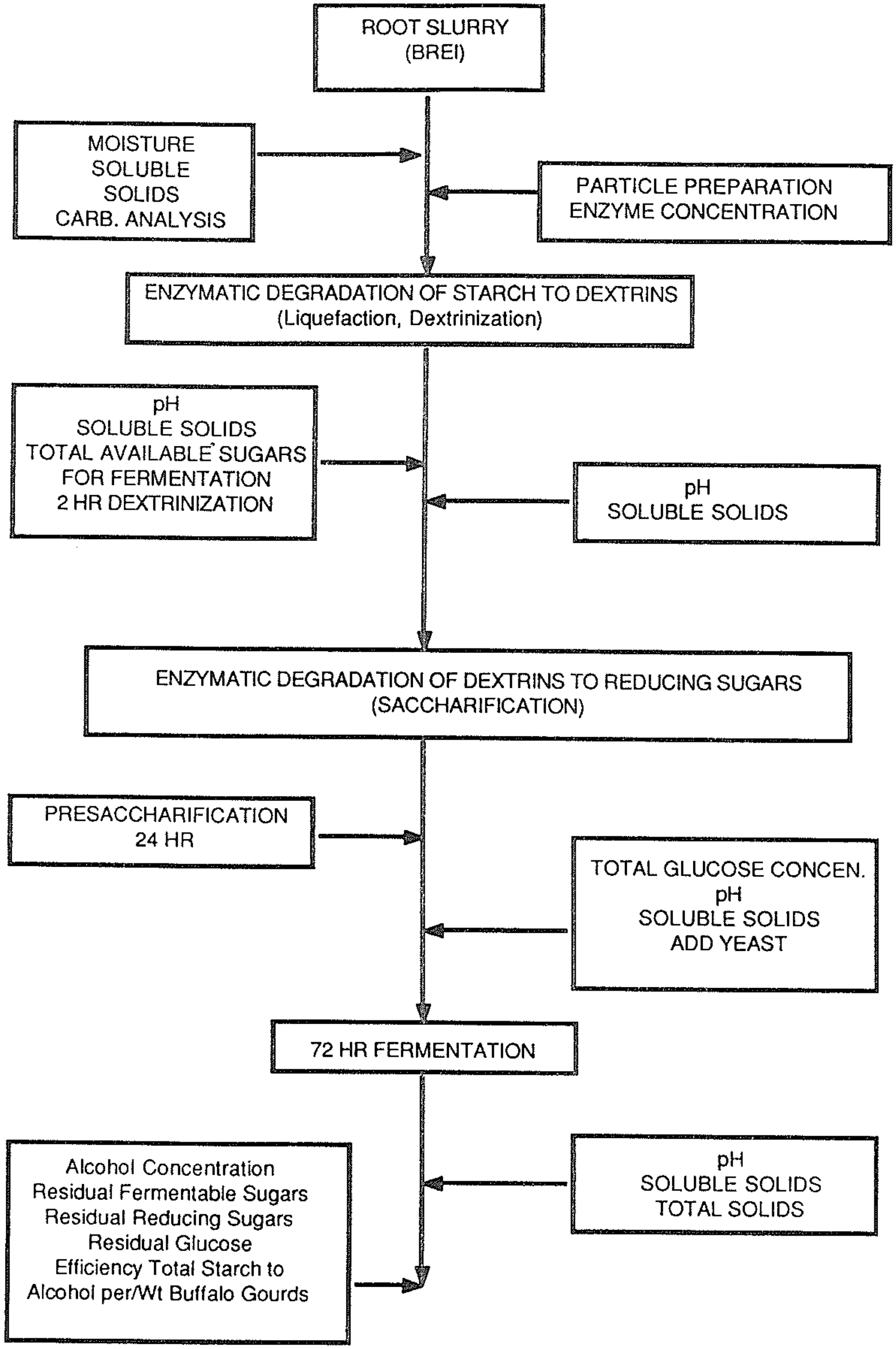


FIGURE 2 FLOW CHART OF LABORATORY ANALYSES

and sugars for fermentation, measured as glucose by the DNS method. The measurement of sugars gives a theoretical yield within each fermented sample and its appropriate alcohol producing capability (v/v), using the theory of 1 mole starch = 1.1 mole glucose = 0.511 mole alcohol. Triplicate chemical determinations were run on each sample and average values reported.

Liquefaction and dextrinization of the root slurry was accomplished utilizing a thermostable alpha amylase derived from Bacillus licheniformis with a heat stability in excess of 190°F. The alpha amylase converts starches, amylase and amylase pectin to soluble dextrins and small quantities of glucose and maltose. Prior to saccharifications, soluble solids, and total available sugar for fermentation were again determined.

The resulting product is a mixture of various chain length dextrins and these are degraded by amyloglucosidase to glucose (i.e., saccarification). This degradation occurs at 140-150°F under the action of Asperigillus niger amyloglucosidase. The glucoamylase hydrolyzed both the α-D-1, 4 glucosidic branch point and the predominating α-D-1, 4 glucosidic linkages of starch. Prior to adding yeast (Saccharomyces cerevisae), a 24-hour saccharification period with glucomylase was used. After the 24-hour period, the mash was tested for total glucose concentration, utilizing an immobilized enzyme within a membrane (i.e., Yellow Springs Instruments Analyzer Model 27 (YSI)). The conversion of glucose to ethanol can be monitored by this instrument. The pH and soluble solids were again tested. Yeast was then added and allowed to ferment for 72 hours. Yeast addition is within 12 million cells/g mash and fermented at 70-80°F during the entire operation of 72 hours. After 72 hours, samples were taken and tested for pH, soluble solids, and total solids. The conversion efficiency of the complete hydolysis from starch to ethanol was determined as follows:

- Measure of ethanol concentration was determined by utilizing immobilized enzyme. Alcohol oxidase is immobilized in a thin microporous membrane (measured by YSI).

- Hydrolysis of total fermented mash measures the total unknown forms of sugar still capable of fermentation (DNS acid hydrolysis assay measured by spectrophotometer).
- Residual reducing sugars were detected by DNS assay without acid hydrolysis (measured by spectrophotometer).
- Residual glucose concentration was measured by the YSI glucose membrane.

RESULTS

Seed Germination

Two series of experiments were performed to evaluate the effect of salinity of the irrigation water on seed germination. In the first series of experiments, the germination rate of wild seed from Curry County, New Mexico was compared to the germination rate of University of Arizona Synthetic No. 1 seeds in soil free media at four salinity levels (e.g. distilled water, saline water at 2,000; 4,000; and 8,000 ppm TDS) at constant temperature and light. As can be seen in figure 3, there was a uniform, high rate of germination of Synthetic No. 1 seeds regardless of water salinity. The Curry County seed, however, demonstrated an inverse relationship of water salinity and germination rate. This result might be expected because Synthetic No. 1 contains seven hybrid lines; it is certainly possible that the observed "hybrid vigor" could manifest itself in this situation as improved salt tolerance. Further, there may have been an unintentional selection for salt tolerance in the Synthetic No. 1 seeds since present hybrid lines were selected for positive response to initial cultivation which includes irrigation. Irrigated fields often show salt buildup in the soil. Thus, Synthetic seed parent lines may be selected to some extent for salt tolerance whereas wild Curry County seed is adapted to make maximum use of rainwater, which has low salt content.

Figure 3

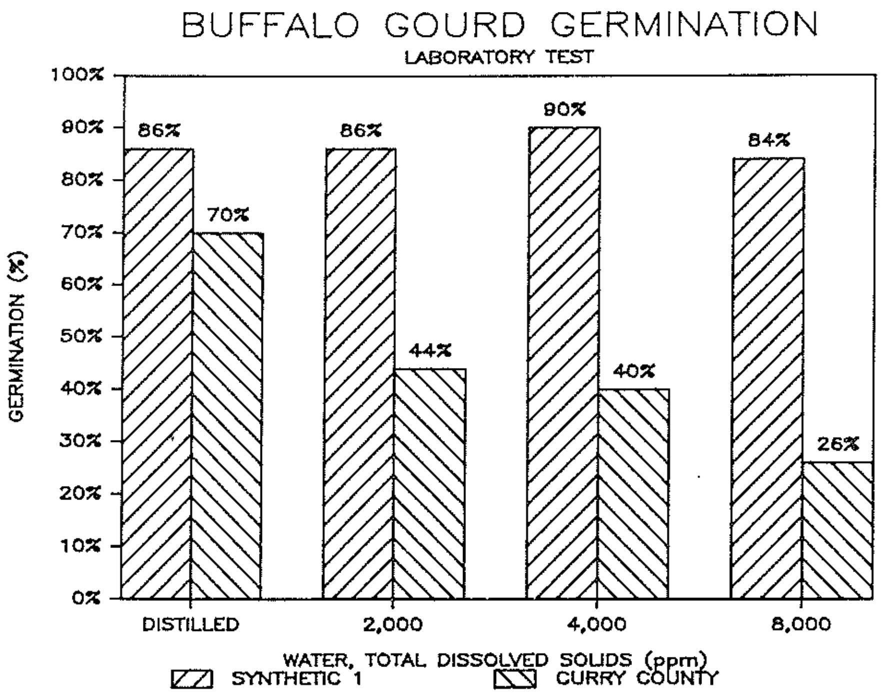
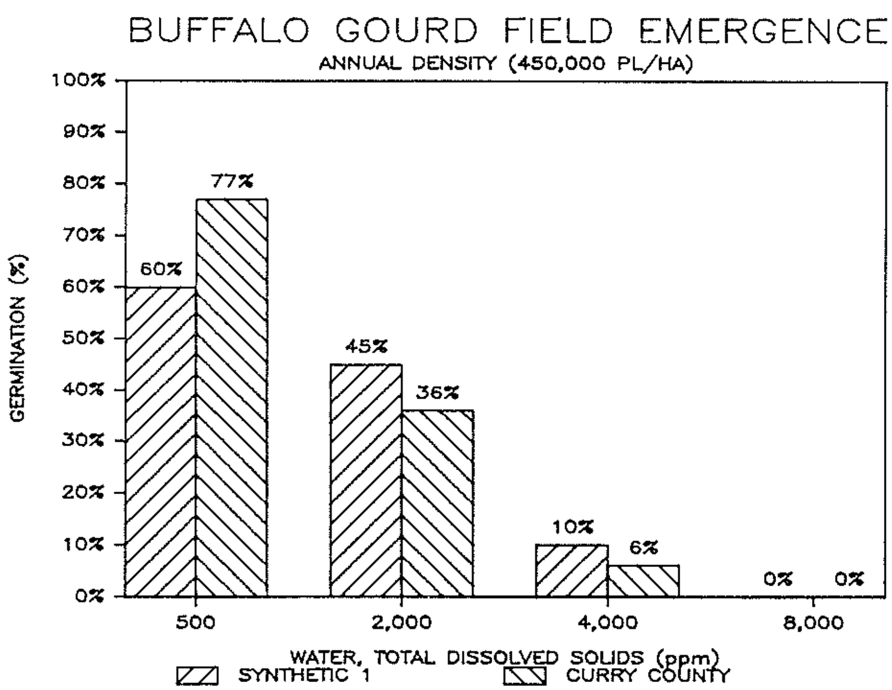


Figure 4



In a second test, Curry County and Synthetic No. 1 seeds planted in both the annual (higher density) and the perennial mode (lower density) in field trials demonstrated an inverse relationship of emergence rate and the salinity of irrigation waters. In figure 4 the emergence of Synthetic No. 1 seeds and Curry County seeds are compared for tubs planted in the annual mode. There was greater emergence for Curry County seeds than Synthetic No. 1 seeds at the lowest salinity irrigation level, of 500 ppm TDS, but for other levels of irrigation water the Synthetic No. 1 had an emergence rate better or equal to Curry County. Seeds planted in the perennial mode exhibited similar patterns for emergence.

Both seed types showed a decline in emergence relative to increasing salinity. Both seed types also demonstrated markedly lower emergence versus laboratory germination at the two highest salinity levels. For instance, Synthetic No. 1 showed 90% germination in the laboratory at a salinity level of 4,000 ppm TDS and only 10% emergence in the field at the same irrigation water type.

In the laboratory tests the differences between the germination rates for the two seed types was striking. The Synthetic No. 1 seeds demonstrated higher germination rates than the Curry County seeds at all salinity levels. In some cases, well over twice as many Synthetic No.1 seeds germinated relative to the Curry County seeds. In the field, however, the emergence rates for the two seed types were more similar at each salinity level. Synthetic No. 1 has the genetic potential to demonstrate high seed germination rates as demonstrated by laboratory experiments. The expression of the genetic potential (phenotype) is mitigated by the environment. That is, suboptimal growth conditions prevented the full expression of the genetic potential of the Synthetic No. 1 as demonstrated in field trials.

It should be emphasized that the initial comparison of germination rates between Synthetic No. 1 and wild seed was conducted in a plant growth chamber at a constant temperature in a soil free medium. Thus performance under these conditions represents the optimum potential germination rate of the seed. Even under these optimal conditions, once germination had occurred, there was significantly greater cotyledon growth in the less saline waters indicating some negative salinity effects. In field trials, the added stress of fluctuating temperatures (often less than optimal), imperfect delivery of moisture to the seed and the necessity of pushing through the soil could readily account for the poorer emergence rate in field trials, especially at the higher salinities evaluated.

Root Yield

Two-year results on root yield present conflicting data. Summary data on total root yield by irrigation water quality is shown in figure 5. For each water quality level the reported data represent the total yield for all eight tubs. No effort was made to distinguish between the yields from different tubs at similar water quality levels. Thus, only average values are reported for weights and yields with no statistical analysis. As a reminder, it is not useful to compare absolute yields between the two years because of the difference in growing conditions. Due to the proceedural errors in 1984, a small harvest was recorded relative to 1985. The data for 1985 should be considered more representative of realistic growing conditions.

For the 1984 season, the relationship between irrigation water salinity and root yield was not linear (figure 5). It is indicated by the data that irrigation water with a salinity of 2,000 ppm TDS is optimum for the production of buffalo gourd roots. Higher salinities caused greatly reduced root yields. Roots from the 2,000 ppm treatment also had a higher moisture content than roots from any other treatment (figure 6). It would be expected that there would be an inverse relationship of root moisture content and irrigation water salinity because the roots of plants irrigated with a saline solution would have to retain moisture against an osmotic gradient; the higher the irrigation water salinity, the greater would be this gradient. Fowler et al. (1985) report similar

Figure 5

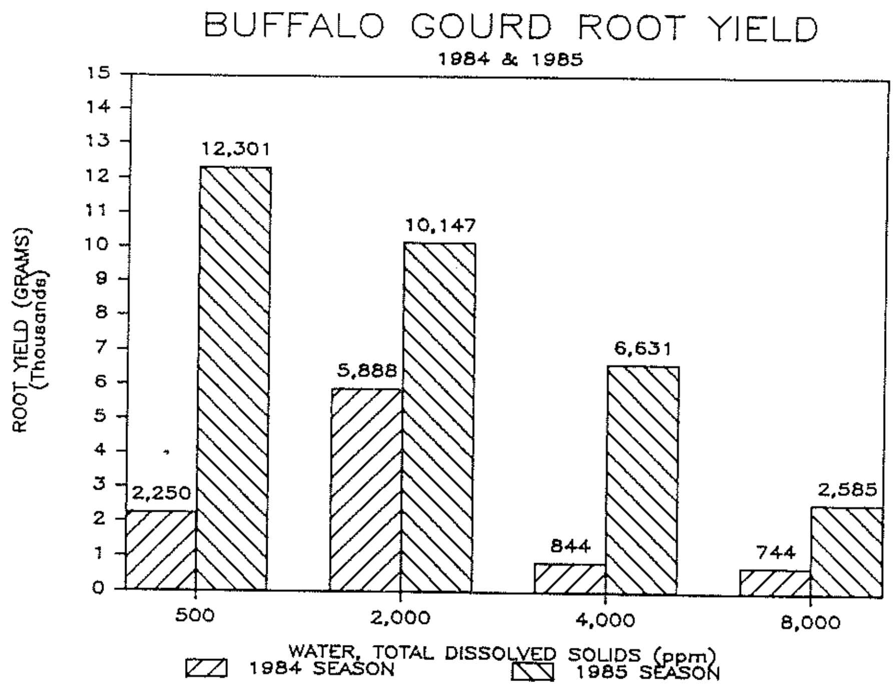
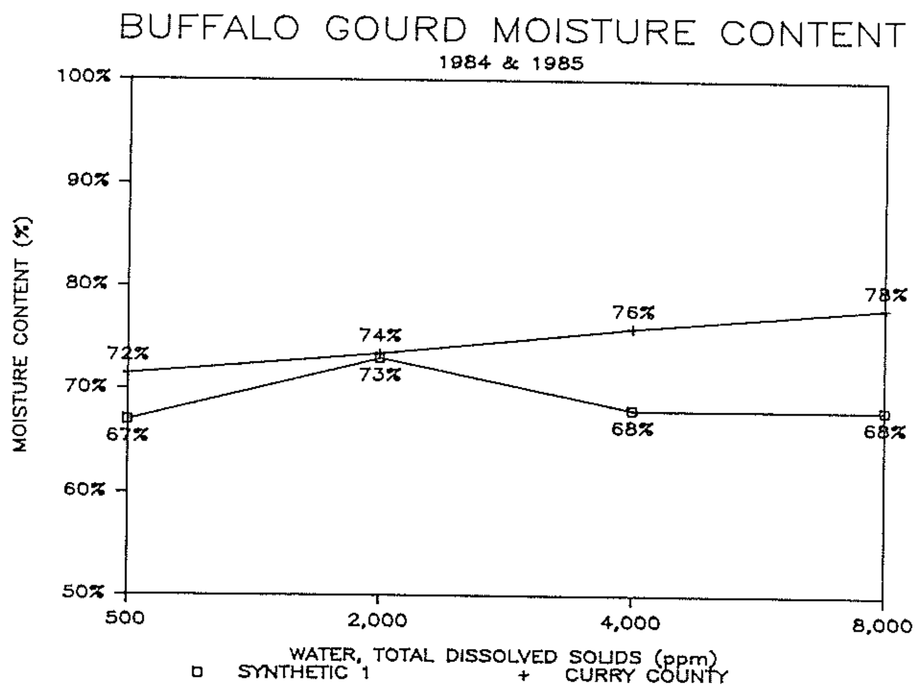


Figure 6



findings for the relationship between moisture content and irrigation water salinity for Russian Thistle.

In 1985 a different pattern of root yield was observed than in 1984. The lower salinity levels produced greater yields of roots relative to the higher salinity levels. Additionally, moisture content was directly related to salinity. At higher salinity levels, the roots had higher moisture levels. For all root samples, the 1985 moisture content was higher than in 1984.

The root yields for only 1985 are shown in table 1. The yields have been converted to illustrate the yield that may have been obtainable from a one hectare plot. The highest yield, from the 500 ppm TDS irrigation water, was 26,489 kg/ha. Nelson et. al., (1983) report the highest yield achieved at 34,550 kg/ha. The yield achieved in the 1984 portion of the NMERDI-sponsored project in Las Cruces ranged from 19,264-23,005 kg/ha (Goldstein, 1985). Thus the same Synthetic No. 1 seeds grown in tubs and irrigated with 500 ppm TDS water achieved higher yields than the concurrent field trial. Indeed, the yield from the slightly saline water, 2,000 ppm TDS, was within the range of the Las Cruces field trial.

It is difficult to make a definitive statement concerning root yield, moisture content, and irrigation salinity levels. Perhaps buffalo gourd could be termed salt tolerant. Buffalo gourd yields at moderate salinity levels (e.g., $\leq$2,000 ppm TDS) appear to produce root yields that are consistent with field tests using irrigation water with low salinity levels. While the buffalo gourd survives and grows at higher salinities, there is a reduction in root yield with increasing salinity.

Table 1

Buffalo Gourd Root Yields
1985

Irrigation Water Salinity (ppm TDS)	Avg. Yield/Tub* (g)	Yield (kg/ha)
500	1,538	26,489
2,000	1,268	21,839
4,000	829	14,278
8,000	323	5,563

*each tub was about .58 m^2.

Starch and Sugar Content

Table 2 summarizes ethanol production-related characteristics of the 1984 and 1985 buffalo gourd root. The percentage of sugar in the 1985 sample of roots tends to decrease with the increasing salinity levels. Sugar data for 1984 were not collected. Similarly, the percentage of starch either decreases (1985) or remains stable (1984) with increasing salinity levels. Figure 7 graphically illustrates the relationship between starch, sugar, and the salinity of the irrigation water.

Total sugars available for fermentation (TASSF), an important index of the utility of a potential feedstock for ethanol production, remain fairly constant in the roots of plants irrigated with waters of different salinities in 1984 (figure 8). This may be explained by the unnaturally high rainfall that year, which mediated the effect of irrigation water salinity. In 1985 there is a decided decrease in TASFF with increasing salinity of the irrigation waters (figure 8). Also in 1985, the TASFF levels were more than twice as high for the 500 and 2,000 ppm TDS samples as in 1984. For all samples, the 1985 TSAFF values were higher than the 1984 TSAFF values. The difference in TASFF between 1984 and 1985 may be attributable to the longer growing season in 1985 which allowed for greater production of sugar.

It is illustrative to compare the saline water starch and sugar content results with similar tests on buffalo gourds grown in the field. Table 3 presents the results from the NMERDI-sponsored research for both Las Cruces, 1984, and Clovis, 1985. The percent moisture averages about 70% for the field crops with a small range. The saline water irrigated buffalo gourds have a higher moisture content, particularly in 1985. Conversely, percent sugar is higher for the field crops, even when compared with the lowest salinity irrigation level. For percent starch, there is a marked difference between Clovis and Las Cruces crops but a general similarity with the saline irrigated crops in 1984. In 1985 the saline irrigated percent starch figures are low compared

TABLE 2

Laboratory Results From Buffalo Gourd Roots
Fermented for Ethanol Processing Efficiency
at Different Irrigation Salinity Levels

	500 ppm TDS		2,000 ppm TDS		4,000 ppm TDS		8,000 ppm TDS	
	1984	1985	1984	1985	1984	1985	1984	1985
% Moisture	67.0	71.5	73.0	73.5	68.0	76.0	68.0	78.0
% Sugar	n/a	1.3	n/a	1.3	n/a	0.7	n/a	0.2
% Starch	18.8	15.4	15.1	16.4	17.3	10.2	17.5	8.5
% Starch DWB*	57.0	54.0	56.0	62.0	54.0	43.0	55.0	39.0
TASFF(g)**	9.3	18.2	7.9	19.3	10.3	11.9	7.1	9.6

*% starch dry weight basis.
**Total available sugars for fermentation in g/slurry.

Figure 7

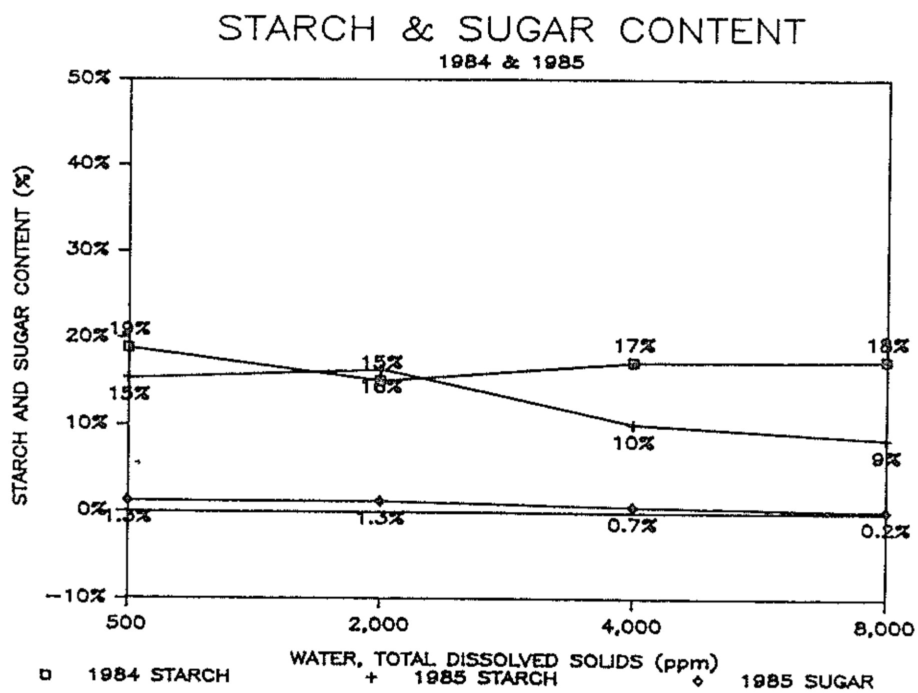


Figure 8

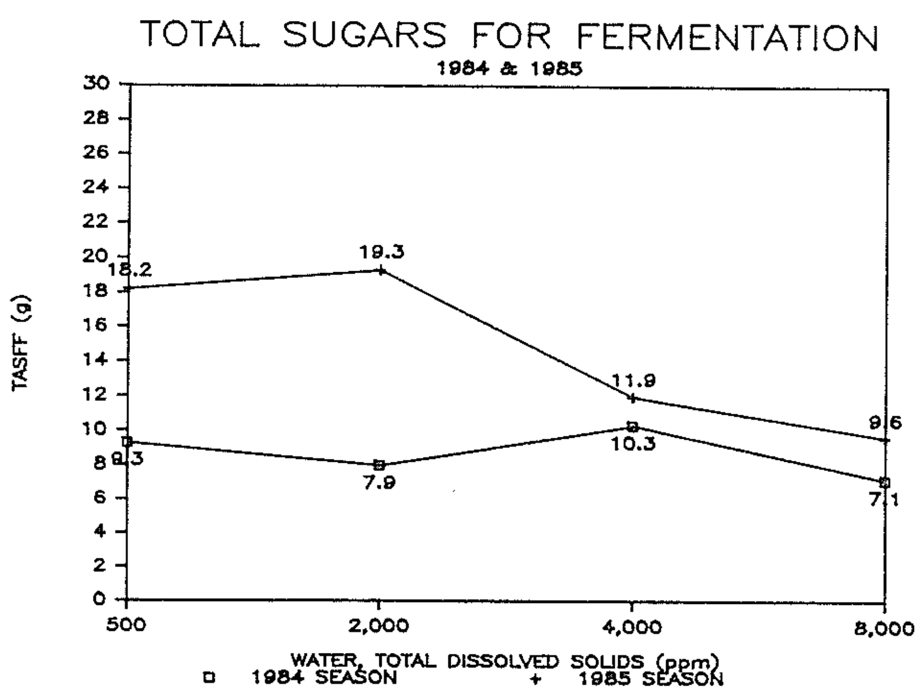


Table 3

Laboratory Results from Buffalo Gourds
Fermented for Ethanol Processing Efficiency
Las Cruces and Clovis, NM Field Tests

	Las Cruces, 1984		Clovis, 1985	
	Annual	Perennial	Annual	Perennial
% Moisture	72.1	72.2	70.5	70.0
% Sugar	n/a	n/a	1.9	1.6
% Starch	19.6	19.1	14.2	15.3
% Starch DWB*	70.0	69.0	48.0	51.0
TASFF (g)**	9.4	9.5	17.5	18.4

*%Starch dry weight basis.
**Total available sugars for fermentation in g/slurry.

with the field crops, especially at the highest salinity levels. On a percent starch dry weight basis, the Las Cruces field crops have a higher starch content than all of saline irrigated buffalo gourds while the Clovis crops are comparable with the saline water irrigated crops. TASSF is very different for the field crops with the Clovis group showing values almost twice those of the Las Cruces crop. The 1984 saline water buffalo gourd TASSF values are similar to the Las Cruces field TASSF values while the 1985 saline TASSF values more nearly resemble the Clovis values, particularly at the lower salinity levels.

When total starch produced per treatment is calculated (table 4), it can be seen that maximum starch production was achieved by those plants receiving 2,000 ppm TDS water in 1984 and plants receiving 500 ppm TDS water in 1985. Because of the problems encountered during the 1984 growing season, it is likely that the 1985 results may be more representative.

It thus appears, at least in the more representative year of 1985, that there is a definite decrease in overall yield with increasing salinity of the irrigation waters. This decrease in yield is reflected in a decrease in overall root yield (an organ for storage of photosynthate), in percentage of starch (the major storage form of photosynthate), and in total sugars available for fermentation. It would appear that buffalo gourd production is not optimal with irrigation water with a salinity above 2,000 ppm TDS.

Alcohol Yield

Alcohol yield data for 1984 and 1985 present a confusing picture. In 1984 alcohol yield, measured in gallons of alcohol produced per hundredweight of roots, decreased with increasing salinity levels (figure 9). However in 1985, overall alcohol yield was lower than in 1984 and alcohol yield showed a generally increasing trend

TABLE 4

Total Starch Produced Per Salinity Level

Salinity	Starch %		Yield (g)		Total Starch (g)	
(ppm TDS)	1984	1985	1884	1985	1984	1985
500	18.82	15.39	2,250	12,301	423	1,893
2,000	15.07	16.39	5,887	10,147	887	1,663
4,000	17.32	10.22	844	6,631	146	678
8,000	17.51	8.51	744	2,585	130	220

with increasing salinity. Both the total yield data and the trend data are more perplexing because the 1985 root samples had considerably higher total sugars available for fermentation than 1984 root samples, at all salinity levels. It is apparent that the conversion efficiency of sugar to alcohol was lower in 1985 than in 1984. However, it is not apparent as to whether or not there is any statistical significance to this observed condition because of the absence of statistical tests.

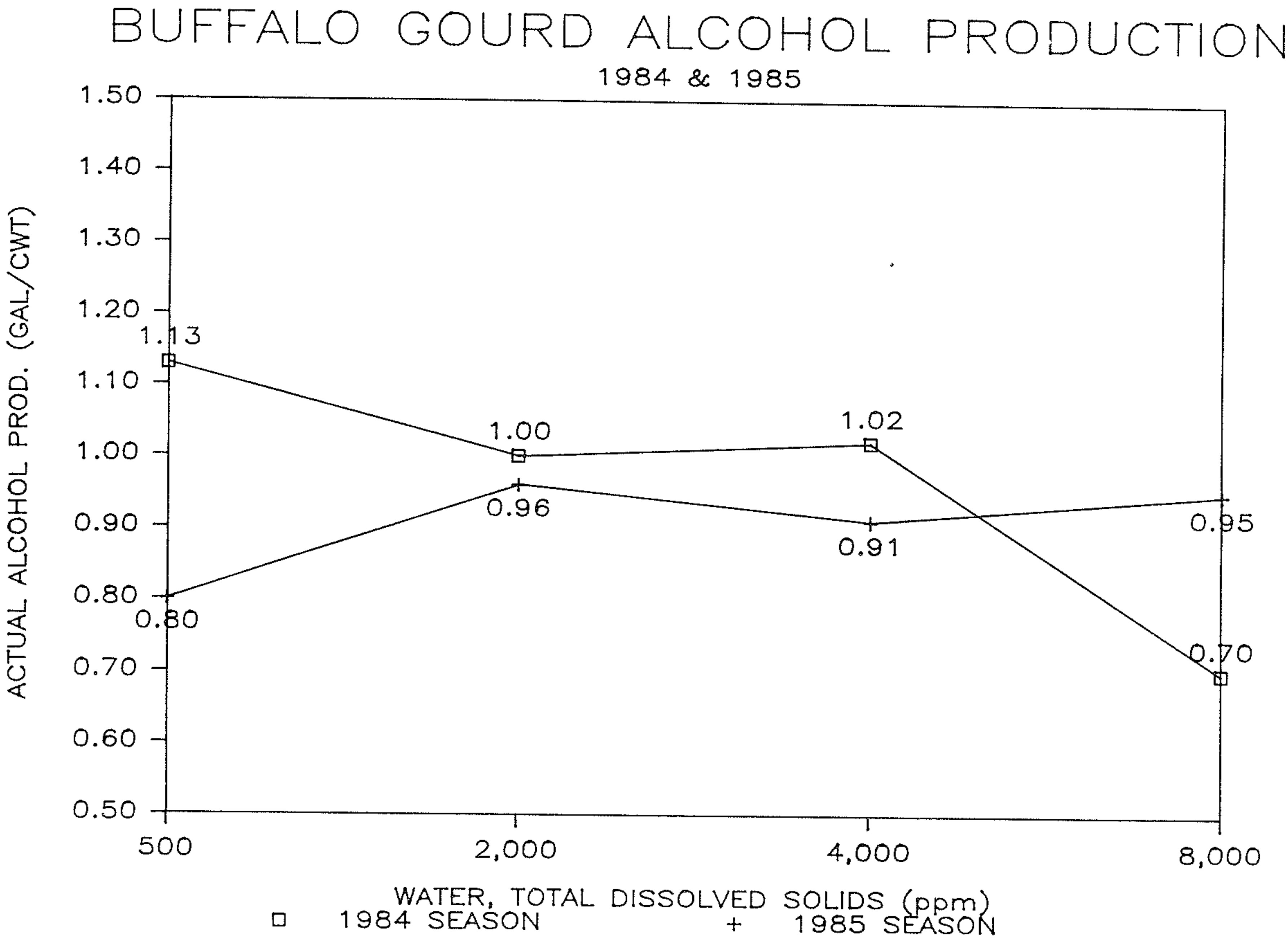
As with the comparisons between starch and sugar content, alcohol production data comparisons between field crops of buffalo gourds and saline water irrigated buffalo gourds are inconclusive. The 1984 Las Cruces field crop laboratory results indicate that about 1.25 gallons of alcohol would be produced per hundredweight (gal/cwt) of roots. However, the 1985 Clovis data are .74 gal/cwt or about 40% lower than the Las Cruces data. The saline water results fit in between the field results.

SUMMARY AND CONCLUSIONS

The highest values for root production, percentage starch and alcohol yield were observed from buffalo gourd plants which were irrigated with 2,000 ppm TDS water in 1984. In 1985, the highest values for root production were observed in the tubs irrigated with 500 ppm TDS water. The percentage of starch in the roots was similar between both the 500 and 2,000 ppm TDS tests. For both years, there was a decrease in root and starch yield for the higher salinity levels. It is not possible to make a definitive observation concerning alcohol yields because of conflicting data. In general, alcohol yields tend to decrease or remain constant with increasing salinity of irrigation water. It appears as though the buffalo gourd is tolerant of moderate irrigation salinity levels, up to 2,000 ppm TDS, and is non-tolerant of irrigation water salinity levels above 2,000 ppm TDS.

It has been demonstrated that water that is generally too saline for potable water use and most agricultural activities may be successfully used to irrigate fields of

Figure 9



BUFFALO GOURD ALCOHOL PRODUCTION
1984 & 1985
ACTUAL ALCOHOL PROD. (GAL/CWT)
1.50
1.40
1.30
1.20
1.10
1.00
0.90
0.80
0.70
0.60
0.50
1.13
1.00
1.02
0.70
0.80
0.96
0.91
0.95
500
2,000
4,000
8,000
WATER, TOTAL DISSOLVED SOLIDS (ppm)
1984 SEASON
1985 SEASON

buffalo gourd. Thus, a novel energy crop that may be profitable for farmers in eastern New Mexico (Schultz and Icerman, 1985) may be grown with slightly saline water; this would spare scarce freshwater in the region.

While no salt build-up effects were apparent over the course of the two-year project, it is likely that over several growing seasons salt build-up in the field would be a potential problem. For areas where it is possible, an irrigation strategy of alternating fresh water with saline water may be appropriate for buffalo gourd production.

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