PRACTICAL PROSPECTS FOR HIGH SALINITY IRRIGATION

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ABSTRACT: Research activities have identified that selected crops may be successfully irrigated with high salinity water. However, irrigated agriculture is a highly competitive enterprise, and irrigators must continually strive to maximize the net profit from their operations. Where farmers have an existing right to fresh water, they will not use high salinity water unless there are economic incentives to make that switch. Where there is high salinity water available for irrigation, the economic reward for using that water must be sufficient to overcome the added cost and lowered returns associated with using poorer quality water. The problems involved in getting existing irrigators to use high salinity water in lieu of better quality water, and to have newly irrigated areas developed using poor quality water, are discussed in this paper.

INTRODUCTION

In irrigated agriculture, the economics of utilizing a piece of land is based on all aspects of the water supply for that land. Water, both its quantity and quality, and land are considered as a unit in evaluting the irrigation potential of a parcel of land. Free-draining lands can more readily grow crops with water of a higher salinity than can lands with tight, poor-draining soils. Thus, the salinity of the water applied to free-draining lands can be considerably higher than the salinity of applied water to poor draining lands and still have equivalent effects on crops. Nevertheless, for each parcel of land, economic detriments are experienced when the salinity of applied water rises above the threshhold level for the optimum crops for those lands.

Irrigated agriculture has always been a competitive business, with many producers vying for the same market place and striving to refine their operations so that they can produce at a minimum cost at all times. In the mid-1980s, this competition is at an intense level, primarily due to a reduction in overseas sales, previously depended upon to utilize a large percentage of the annual production and, as a result, prices of most crops are at depressed levels. For the next several years, there will probably continue to be intense competition in marketing crops, as production capacity generally exceeds the market demands.

In this type of economic environment, farmers must continually strive to decrease their operating costs and increase their yields.

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They have little incentive to develop new lands for irrigation unless they would be able to grow crops on those lands at a lower cost than on existing producing lands. These economic conditions must be considered in evaluating the prospects for any expansion in irrigation with high salinity water.

PRIOR STUDIES

A survey and associated research by Maas and Hoffman (12) of the U.S. Salinity Laboratory on the current assessment of salt tolerances of 76 crops in 1977, identified, for the listed crops, soil solution salinity at the point where yields initially began to decline (threshhold) and the yield decrease per unit of increase in salinity beyond the threshhold. The soil solution salinity is the concentration of soluble salts in the soil solution in the active root zone. It is a result of the salinity of the applied water, the leaching fraction, and the soil characteristics, particularly the drainage characteristics of the soil.

These data show that, in general, yields do not decrease with increasing salinity until the threshhold level of salinity for a particular crop is exceeded. As the salinity increases beyond the threshhold, yields decrease linearly. With all other factors being kept constant as the salinity of applied water increases, eventually the soil solution salinity will rise to the threshhold level, and yields will begin to decline.

Hoffman (9) relates the salinity of applied water to crop salt tolerance threshhold values for different leaching requirements. The research identifies that, as the salinity of the applied water increased, there was a corresponding increase in the leaching requirement. His report does not identify the measures that must be undertaken to obtain the required leaching, but it is in implementing those measures, which are a vital part of irrigation management, that causes farmers to incur heavy costs when the salinity of their applied water increases.

Comprehensive guidelines for evaluating the water quality suitability of an irrigation water were developed by Ayers (2), covering many aspects in addition to salinity. Table 1 is excerpted from his paper, with the conversion factor used being millimhos/cm x 640 = mg/l. This factor was used by Ayers and is also valid for water with a chemical composition similar to Colorado River water below Hoover Dam. The suitability ranges in the table assume that both the crop consumptive requirement and the leaching requirement will be applied and pass through the soil.

TABLE 1 - Salinity Criterion of Irrigation Water

Salinity Range(millimhos/cm)			Suitability for Irrigation
Low:	<0.75	(489 mg/l)	No special management problems
Moderate:	0.75 to 3.0	(480 to 1920 mg/l)	Increasing management problems
High:	> 3.0	(1920 mg/l)	Severe management problems

Ayers states that cultural practices, crop selection, and management to prevent salinity problems from developing are just as important as corrective actions taken after problems develop. In either case, direct costs increase and/or crop revenues decrease when farmers must operate with water of moderate to high salinity, as compared to water in the low salinity range.

Jury, Vaux, and Stolzy (10) conducted a lysimeter experiment using water with a chemical composition similar to power plant cooling water residual to irrigate salt-tolerant wheat and sorghum crops. Utilizing the test data, Jury et al computed a theoretical irrigation operation, under two different leaching fractions, that would utilize the output from a one million kilowatt capacity power plant operating in a California desert community. While the salinity of the water supply from the plant was not specified, it was in the range of 2865 mg/l to 5840 mg/l which is a high salinity water. The economic analysis compared the irrigation operation using saline water and, alternatively, fresh water. The researchers concluded that the saline water source would produce gross revenues of $511.50 per hectare ($207 per acre), while fresh water irrigation would produce gross revenues of $913.01 per hectare ($370 per acre). Sorghum and wheat are two crops that were identified (12) as being moderately tolerant to high salinity water, with wheat's threshhold point for declining yields at 6 millimhos/cm for soil solution salinity.

Erickson (7) discussed eight different areas in the southwest United States that had been using waters that can be classified according to Table 1 as varying, by areas, from waters causing no special management problems up to high salinity water in the range of 4,600 to 5,400 mg/l. He found that the areas that have been using high salinity water for a number of years have been able to continue in production and that their crop yields were satisfactory. Erickson concluded that the reason irrigators have been able to keep production up for many years has been due to good soil in the area, the selection of crops, and irrigation management. He points out that the irrigable lands are deep, sandy loams to loamy sand, with excellent vertical drainage qualities to considerable depth. Furthermore, these soils generally have high ratios of precipitated calcium sulfate, which chemically counter-balances to a degree sodium chloride in the water, thus reducing the sodium absorption ratio of the water in the soil solution.

The choices made by irrigators faced with the problem of increased salinity in their irrigation water was discussed in Appendix 3 of Anderson and Kleinman's report (1). They pointed out that most farmers adopt some of the several management options that may mitigate or dampen some of the major effects of using high salinity water, rather than merely accepting the effects of declining yields. However, these mitigation measures each have an associated cost of implementation which reduces the farmers' net revenues.

The studies referred to above show that, as the soil solution salinity rises above the threshhold level for a crop, those crop yields decline. When the salinity of the water available for irrigation is high, irrigators may still be able to obtain satisfactory yields by careful management to keep the soil solution below the threshhold level for his crops. However, there will be increased costs, both in capital investments and in operating costs, in these management efforts, which costs must be considered as being due to increases in the salinity of the applied water.

Any additional costs resulting from the use of more saline water must be counterbalanced by lower costs in some other parts of an irrigator's operations in order for the farmers using the poorer quality water to be able to compete. With most other costs fixed, this means that if the water available for a parcel of land is salty, the land must be available to the farmer at less cost than if good quality water was available. Irrigators must be able to compete economically or they cannot continue their operations.

POTENTIAL FOR USE OF HIGH SALINITY WATER FOR IRRIGATION

The beneficial use of high salinity water in areas where such water is available has been suggested. The potential for the economic use of saline water in three of these areas is considered in the following paragraphs. The areas reviewed are the Imperial Valley in California, the Grand Valley in Colorado, and the lower San Joaquin Valley in California.

Imperial Valley, California

Imperial Valley, located in the southeastern corner of California, relies on Colorado River water conveyed to the Valley through the All-American Canal, since the local ground water is saline and there are no surface water supplies. The imported water is distributed by the Imperial Irrigation District through a network of canals and laterals, as described by Valantine (17). The district delivers irrigation water to over 500,000 acres (202,000 ha), with approximately 50,000 acres idle in any one year. The total water charge is about $9.50 per acre-ft. During 1975, a fairly typical year, the district received 3,001,000 acre-feet (3,705 x 10^6 m^3) from the Colorado River with a flow-weighted average annual salinity of 830 mg/l (1.3 millimhos/cm). There are additional irrigable lands in the district's boundaries, but the U.S. government adopted a policy, about 20 years ago, to not increase the lands in California that would be irrigated from the Colorado River.

Because the soils in Imperial Valley are predominantly slow draining, irrigators have been forced to install underground drainage lines under their fields, discharging into a network of open drainage ways constructed and maintained by the district. Most of the open drains discharge into the New and Alamo Rivers, which convey surface runoff from irrigation and subsurface drainage flows to the Salton Sea. In 1975, the salinity of the drainage flows averaged about 2,600 mg/l. As the district continues its present efforts to increase the irrigation efficiency of its farmers, and to reduce spills and seepage from its facilities, the salinity of the drainage water will increase.

Several years ago, one farmer chose to irrigate an 80-acre (32 ha) parcel using drainage water but discontinued his attempts after one season that produced a very poor crop. The farmer chose drainage water because his fresh-water delivery structure collapsed and he felt that it would be less costly to divert the drain water. The cause of his poor crop as a result of using drain water appears to have been inadequate preparation of the land to receive the high salinity drain water without having the soil solution salinity rise too high.

That experience was an unplanned event, but the Imperial Irrigation District would like its drainage water to be used, thereby reducing the volume of inflow to the Salton Sea. As part of its water conservation program, the district allows any user to divert directly from its drainage ways or the New and Alamo Rivers without having to pay for the diverted water. However, in the nearly 10 years of this program, no farmer has chosen to irrigate his crops using drainage water. The University of California at Riverside, in cooperation with the U.S. Salinity Laboratory, has been conducting an experiment using drainage water for irrigation in Imperial Valley. Rhoades' paper, "New Strategy for Using Saline Waters for Irrigation", refers to that experiment and is scheduled to be presented at this conference.

Imperial Valley's experience has been that, since fresh water is available at a reasonable cost for all presently-irrigated land, and since new agricultural lands cannot be developed, there is no incentive to use drainage water even if that water is free. The increased management problems of using high salinity water rather than fresh water, coupled with reduced yields from using higher salinity water on poor-draining lands, have led farmers to conclude that they could not compete with other farmers if they used the free drain water.

Grand Valley Colorado

Irrigation in Grand Valley, located in west-central Colorado, was discussed by John W. Keyes, III (11). Approximately 71,500 acres (28,900 ha) are irrigated with about 630,000 acre-ft/yr (770 x 10^6 m^3) diverted from the Colorado and Gunnison Rivers. About 130,000 acre-ft/yr (160 x 10^6 m^3) water is consumptively used and most of the remainder returns to the Colorado and Gunnison Rivers. From 1974 through 1976, the average salinity of the irrigation water was 398 mg/l (0.67 millimhos/cm). About 40,000 acre-ft/yr (49,340 x 10^3 m^3) of field tailwaters and lateral waste waters are collected and reused for irrigation of lower lands in the valley, out of the total tailwater of about 100,000 acre-ft per year (123,350 x 10^3 m^3). The combined salinity of surface and subsurface return flow in Grand Valley averaged 1,400 mg/l (2.7 millimhos/cm) in 1976.

Under Colorado law, a person who wishes to divert water, irrespective of whether the source is a highly saline return flow or a low salinity stream flow, must have a water right for that water, with no special treatment accorded the diverter of the high salinity water. Any person or entity who wishes to make use of drainage water must obtain a permit for that diversion, which permit would have a priority predicated upon all other permits in that river system. Thus, even though there may be drainage water physically available for diversion, if the existing water rights permits total more than the river's flow, the lowest priority permit, for drainage water, would be the first one to have to cease diversions.

In these circumstances, there is no incentive for a farmer with rights to fresh water to choose to divert waste water, since, if there is any fresh water available for diversion, he can take the fresh water. While the irrigated lands in the Grand Valley have decreased over the years for a variety of reasons, the prime cause is poor financial returns from irrigating with low quality waters at the low end of the valley rather than the lack of a water supply.

In the absence of any changes in Colorado water law, irrigators would probably not choose to use saline waters; accordingly, Grand Valley return flows, a major contributor of salt load to the Colorado River system, probably will not be economically utilized for an irrigation water supply.

Southern San Joaquin Valley, California

There have been many studies of the water supply problems of the southern San Joaquin Valley, California, comprising the counties of Kern, Kings, and Tulare. In 1977, there were about 2,243,000 acres (907,700 ha) (5) irrigated by a combination of surface and ground water supplies, with a groundwater overdraft of about 955,000 acre-ft/yr (1,178 x 10^6 m^3) (6). Surface water is available to the area both as streamflow from the southern Sierra Nevada mountains and as imported water through the California State Water Project and the Bureau of Reclamation's Friant-Kern Canal. The naturally-occurring streamflows have been fully developed, and the imported supplies are fully committed by contract. Thus, any future increases in irrigation will depend upon future importation projects or on increasing ground water pumping. The present overdraft, however, is already too high to permit any significant increases in ground water pumping and has caused severe land subsidence at several locations throughout the area.

In addition to problems resulting from overdrafting of the southern San Joaquin Valley groundwater basin, the area has been experiencing an increase in lands with drainage problems (3) to the extent that there have been numerous studies made of the problems and alternative measures to alleviate the problem. A few of the more recent studies are cited herein (4, 5, 13, 14, 15, and 16). Because there is no natural outlet for the southern San Joaquin Valley, irrigators have not been able to install the needed buried drainage lines, for there is no place that they can dispose of the drainage effluent. The San Joaquin Interagency Drainage Program was organized in 1975 by California and the U.S. Bureau of Reclamation to plan for agricultural drainage and salt management covering the northern and southern San Joaquin Valleys. The final report on the program was issued in 1979 and presented five basic alternatives and a recommended plan that combines the maximum feasible reuse of drainage water with the export of the unusable water by canal to the San Francisco Bay.

One possible means of maximizing the reuse of the saline drainage water would be the desalting of a portion of the water. Smith and Brice (14) reported on studies of reverse osmosis desalting procedures for the drainage water. Because of the need for water in the Southern San Joaquin Valley, the study concluded that desalting, with a cost of about $300/acre-feet, would provide a potentially cost-effective alternative water supply to the valley agricultural areas.

The possible conveyance of treated urban waste water from the San Francisco Bay area to the Southern San Joaquin Valley for reuse was reported on by Harnett and Hall (8), who concluded that with a dependable delivery of about 340,000 acre-ft/yr, the waste water could be delivered for about $275/acre-ft. They reported that market surveys indicate an interest in using the reclaimed water in the Southern San Joaquin Valley, even at that cost.

While these studies indicate that the southern San Joaquin Valley may be willing to pay very high prices for the desalted and treated water supplies, the unique conditions in this area should be recognized as creating a special marketplace for the water. First, the additional water would only be a supplement to other significantly lower-priced water supplies available to the area farmers and would thus only represent a portion of a farmer's total annual water costs. Second, the areas requiring supplemental water have only recently been developed, and are growing high-income crops close to major domestic markets and export centers, in a very favorable climatic regime, with highly-efficient irrigation systems aand farm managements. Third, prior to being developed for irrigation, the land commanded very low values and, in many cases, was owned by large corporations primarily for the underlying mineral rights; thus, there was a very small component of the land-water valuation represented by the value of the land and there was a large increment in that valuation, after irrigation commenced, to pay for supplemental water supplies.

SUMMARY AND CONCLUSIONS

Of the areas that have been considered as potential users of saline water, it appears that the southern San Joaquin Valley is the most likely candidate for such water. Because of conditions peculiar to that area, the additional management costs of using drainage water, coupled with reduced market returns from growing lower valued but higher salt tolerant crops, apparently can be tolerated by the Valley growers. In most irrigated areas of the United States, though, the significant problems encountered in the use of saline water will tend to discourage its use in lieu of fresh water wherever there are sufficient supplies of fresh water. However, where fresh water supplies are scarce and the cost of additional fresh water is high, as in the southern San Joaquin Valley, then there appears to be incentives to use saline water, provided that it can be made available at a price to enable farmers to economically compete in the market place.

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HIGH PRODUCTIVITY FROM HALOPHYTIC CROPS USING HIGHLY SALINE IRRIGATION WATER

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ABSTRACT: Several halophytes (plants with tolerance of extremely high salinity) have been screened for their potential use as crop plants. Many have been found to have high protein contents in both foliage and seeds, and some have high seed oil content as well. Some of them have been grown under field conditions and irrigated with water at several salinities, from mildly saline to hypersaline (greater than seawater salinity). Yields have been achieved at the highest salinities that exceed the average yield of crops such as alfalfa, irrigated with fresh water. Digestibility, nutritional value, and acceptance by animals is excellent.

INTRODUCTION

For all of the obvious reasons enumerated so many times in the past, it is inevitable that an increased percentage of our crops will have to be grown in the future with water considered too brackish or saline by today's agricultural standards. Recognition of this fact is attested to by the high level of attention given to research designed to improve soil and water management practices and to increasing crop tolerance to salinity. The soil and water management practices that will be required in the future scenario involving use of increasingly brackish or saline water for irrigation are relatively independent of the types and sources of plants used as crops. However, the development of crops with the required level of salinity tolerance can be accomplished in two rather diverse ways. One is to use selection and genetic improvement to increase the salinity tolerance of our present crops. This is an approach that has been, now is, and will continue to be an effective way of making incremental gains in increasing salinity tolerance. However, an alternative approach with equal, or even greater, probability of success is to search among the wild plants that already possess extremely high salinity tolerance for those that have the appropriate characteristics that might make them desirable crop plants.

A large percentage of the world's plants grow in environments with inherently high salinities and have been naturally selected for their ability to grow and thrive under those highly saline conditions. These plants are called halophytes (literally, salt plants). Even though most plants selected for domestication over the past 10,000

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years or so have come from environments that are not especially saline, there is no good reason to believe, or even suspect, that there would not also be representatives among the halophytes of the world with foliage having forage values as good as alfalfa or seeds equally as nutritious as wheat or soybeans. Nor is there any good reason to believe that the same selection and breeding successes that resulted in improving the desirable characteristics of the wild progenitors of our present-day crops would not also be successful when applied to those wild halophytes that have potentially useful crop characteristics. Taking advantage of the knowledge gained during the domestication of our present crops, coupled with the new genetic techniques that soon will be available for making specific improvements, significant accomplishments should accrue within decades rather than taking thousands of years. We have been collecting halophytes from around the world for the past five years and have assembled a germplasm collection of well over 1000 accessions so far and continue to add to it. Using plants from this source, we have begun the accelerated domestication process, and the results so far are extremely encouraging.

The plants fall into two categories. Some of them can be found growing under saline conditions, but they actually grow much better on fresh water, and there is a steady decline in growth with increasing salinity. These are called miohalophytes. Very few of these will tolerate salinities approaching that of seawater. On the other hand, there are those that actually require a reasonably high salinity for best growth, showing increased growth up to about 5 to 10 parts per thousand (ppt) total dissolved solids (TDS) and then a gradually declining growth with increasing salinity. These are called euhalophytes, and they tolerate salinities up to and even exceeding that of seawater.

PRODUCTIVITY

Several of these have been grown under cultivation and irrigated solely with seawater (2). The most productive halophytes yielded the equivalent of 8-17 tonnes of dry matter per hectare (Table 1). This compares favorably with a conventional forage crop such as alfalfa grown on fresh water, which yields 5 to 20 tonnes of dry matter per hectare annually (8).

Table 1. Annual productivity of selected halophytes irrigated with 40 ppt seawater at Puerto Peñasco, Sonora, Mexico.

Species	Productivity ($gDW\ m^{-2}\ y^{-1}$)
Atriplex lentiformis	1794
Batis maritima	1738
Atriplex canescens subsp. *linearis*	1723
Salicornia europaea	1539
Atriplex barclayana	863
Atriplex nummularia	801

Since forage or fodder crops such as alfalfa usually are harvested several times per year, it was of interest to investigate the ability of these potential halophyte crops to tolerate multiple cuttings per year and to see what effect this had on annual yield. Four species of *Atriplex* were planted in October, 1980, irrigated solely with seawater, and clipped to a height of 30 cm three times during the first 16 months after planting (Table 2). There was significant mortality in *A. lentiformis* and *A. canescens* subsp. *linearis*, and the annual productivity was reduced substantially as a result. On the other hand, there was little or no mortality in *A. barclayana* and *A. nummularia*, and the annual productivity was increased considerably, by 170% and 160%, respectively, which puts them right at the upper level of the annual yield range of alfalfa grown on fresh water.

Table 2. Annual productivity and mortality of *Atriplex* spp. planted in April 1980 and clipped to a height of 30 cm the succeeding October, January, and August.

Species	Productivity ($gDW\ m^{-2}\ y^{-1}$)	Percent Mortality
A. barclayana	2,336	3
A. nummularia	2,080	0
A. lentiformis	1,456	20
A. canescens subsp. *linearis*	1,104	40

There is potential for even higher yields when grown with water of lower salinity. Plants have to expend a significant amount of their available energy in processes associated with tolerating the high salinity in their environment (5). The higher the salinity, the greater the energy expenditure required. Thus, if halophytes that are tolerant of very high salinity are grown on water of lower salinity, much less energy is required to handle the salinity problem. Theoretically, assuming the total amount of energy available to the plant remains the same, more energy (i.e., substrate) can be allocated to growth. Thus, if plants that can tolerate and grow well on seawater are grown on water that is far less saline, such as 10 ppt, they should be receiving a considerable energy subsidy which could be translated into significantly higher dry matter production. We tested this hypothesis by growing several halophytes at salinity levels ranging from fresh water to 40 ppt (well beyond seawater) (3). Using 10 ppt as representative of a "worst-case" scenario for use of highly saline water in irrigated agriculture (problems associated with soil and water management assumed to be the real limitation to the maximum salinity that will be tolerable), we found that there is an approximate doubling of growth rate in 10 widely differing halophytes when irrigated with water of 10 ppt salinity versus growth rate when irrigated with water of seawater-level salinity. *Atriplex lentiformis*, e.g., had 1.7 times greater growth rate at 10 ppt. In other work, we found that *Atriplex barclayana* had four times the dry matter yield at 10 ppt as it did at 30 ppt (6).

NUTRITIONAL VALUE

Depending on the age of the plant tissue at harvest and the salinity on which the plant has been grown, we have found that the protein content of most halophytes examined so far ranges from 10 to 20% of the dry weight (6). Atriplex lentiformis and Atriplex barclayana, e.g., grown on seawater, had 16.7% and 11.6% protein content, respectively (2). For comparison, alfalfa ranges from 12% to 22%, with an average of 16.9% (1). Fat and fiber contents compare favorably also (2). The negative aspect of using halophytes as forage or fodder is the high ash or salt content of the foliage. This can be as high as 40% of the dry weight (6). Atriplex lentiformis and A. barclayana grown on seawater had ash content of 27% and 33%, respectively. This reduces the yield values significantly if ash-free dry matter is the basis for comparison, but nevertheless, because of the high total yield and the relatively high percentage of protein, the most productive halophytes (Table 1) yielded the equivalent of 0.6 to 2.6 tonnes of protein per hectare when grown on seawater (2), compared to typical alfalfa yields of 0.5 to 3.0 tonnes of protein per hectare when grown on fresh water (8).

The high salt content of the foliage also is a constraint to consumption by animals. Thus, use of such materials probably will be limited to use as a component in a feed mix rather than as a sole source. Salt content of the tissue is not a problem with seeds, however. Even though the vegetative tissues of a plant may contain extremely high salt content, the seeds of those same plants normally have low salt levels, even when irrigated with highly saline water (Table 3).

Table 3. Ash, protein, and oil content of some halophyte seeds, as percentage of dry weight.

Species	Protein	Oil	Ash
Atriplex triangularis	16.4	9.4	3.5
Cakile edentula	28.6	51.2	5.2
Cakile maritima	21.5	47.1	5.0
Crithmum maritimum	21.5	41.4	8.0
Kosteletzkya virginica	23.8	18.1	5.0
Salicornia europaea	30.2	28.0	7.5

Furthermore, the protein and oil contents of the seeds are high. The oil contents compare favorably with conventional oilseed crops such as soybean and safflower, which have 21% and 30% oil contents, respectively (7). Investigation of halophytes as potential seed crops has not been pursued as vigorously as has been the case for use as forage and fodder crops, but it certainly seems that this would be profitable (6).

DIGESTIBILITY AND ACCEPTABILITY BY ANIMALS

In order to survey as many species as possible in the shortest possible time as a prelude to conducting large-scale animal feeding trials, we have conducted in vitro organic matter digestibility studies of 45 different halophytes (4). Foliage samples were incubated for 48 hr in a rumen fluid-buffer inoculum followed by 48-hr digestion in acid pepsin. At the end of this time, the amount of in vitro organic matter disappearance (IVOMD) was measured. The IVOMD for the 45 plants ranged from 50.1 to 87.2%. Standard alfalfa samples, included as a reference sample, had IVOMD of 64.3%. Thirty-five of the halophytes had values in excess of the alfalfa value. When samples from plants grown on fresh water were compared with those grown on water with salt content up to 20 ppt, there was no detrimental effect of the salinity apparent. In fact, in some cases, the IVOMD was actually higher at the higher salinities.

Limited feeding trials have been conducted with goats using Atriplex lentiformis and A. barclayana grown with seawater irrigation (9). When the halophytes were included as 25% of the total diet, acceptability and digestion were high. The A. lentiformis seemed to be definitely superior to A. barclayana in acceptability and digestibility.

CONCLUSIONS

The biological limitations to use of highly saline water for irrigation do not seem to be great. Even if the incremental increases in salt tolerance of present crop plants do not come rapidly enough or if there is a threshold beyond which salt tolerance of conventional crops cannot be advanced, there is great promise in finding suitable crop plants among the halophytes of the world. This approach has not been intensively pursued for very long yet, but the results so far lead to the conclusion that the use of highly saline water for irrigation will be constrained more by the problems associated with soil and water management than by plant tolerance of the high salinity.

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Recommended Irrigation Schedule Terminology

By the On-Farm Irrigation Committee of the Irrigation and Drainage Division

It is axiomatic that to optimize crop production and irrigation efficiency, that the water supply must be flexible in: (1) frequency to supply water to various crops on different soils when it is needed; (2) rate to match the field size, irrigation method, and soil intake rate, and should be modifiable during a set as conditions change; and (3) duration so that flow can be cut off when an adequate depth has been applied.

To facilitate communications concerning the various combinations of restraints on the three factors, a standardization of terminology is needed. The following Table 1 is proposed by this committee. It is based on a similar table presented in an American Society of Agricultural Engineers Proceedings paper (3) the terminology of which was reviewed and informally discussed and accepted as modified in a committee. It has been thoroughly discussed in this committee and its use is recommended for basic terminology. Variations and elaborations have been developed (4) and additional adjectives can be employed, but the basic terminology should be retained for simplicity. Predecessor descriptions were developed in references (1) and (2).

The schedules are broken into three groups. The flexible DEMAND schedules are user controlled and require no communication between user and supplier. The ARRANGED schedule require communications to agree on the arranged conditions. The rigid ROTATION schedules are supplier determined. They require no communication system, and while they could be, they are infrequently modified during an irrigation season.

Frequency restrictions affect on-farm cropping patterns, reduce crop production per unit of area and unit of water, many often cause over-irrigation and consequently drainage, fertility, and labor problems. They have indifferent affects on system capacity and cost.

Rate restrictions affect the selection of the irrigation method and its effective use, have a major affect on labor requirements unless an on-farm reservoir is constructed, and inhibit obtaining satisfactory irrigation efficiency values