TITLE: **Efficient Irrigation for Reduced Non-Point Source Pollution from Low Desert Vegetables**

CDFA contract number: 98-0423

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B. STATEMENT OF OBJECTIVES

The objective of this project are: (1) evaluate and develop irrigation scheduling for lettuce and melons produced in the low desert and evaluate the influence of irrigation and N fertilization on crop growth, crop N nutrition, N leaching, and salt balance, and (2) conduct an outreach program aimed at promoting and implementing efficient irrigation practices for improved on-site utilization of resources and enhancement of water quality.

C. EXECUTIVE SUMMARY

Abundant evidence from Arizona and California indicates irrigation practices are a significant factor contributing to N losses from soils used for vegetable production. There is a tendency for vegetable growers to apply generous amounts of water to produce because of anxiety about crop quality and the lack of sufficient information to do otherwise. For example, while water consumptive use for lettuce is estimated to be approximately 0.2 in, amounts applied frequently exceed 0.9 m. Additionally, concerns about salt accumulation having an adverse affect on land sustainability often prompts growers to employ a generous leaching requirement. A lack of practical technologies on irrigation scheduling is another major obstacle to progress in implementing efficient irrigation practices. It is the opinion of the authors that once efficient scheduling and on- farm water management strategies are established and demonstrated to vegetable growers in the desert, progress in efficient irrigation will be hastened. However, it is of the utmost importance to show growers that this can be achieved without compromising crop yield and

quality and long-term land sustainability. We also must provide education and training in the use of these technologies. The research and outreach activities being performed under this contract have the express objective of improving irrigation practices as a means of reducing non-point source pollution due to N leaching.

Experiments were conducted during 1999, 2000, 2001, and 2002 to evaluate "management allowable depletion" (MAD) values and crop coefficients for furrow irrigated lettuce and melons. Data from these studies suggest using a MAD of 35 to 40% depletion of available water to a 0.3 m soil depth as a basis for scheduling irrigations for lettuce. Crop evaporation (ETc) estimates from several experiments and Penman generated reference evaporation (ET°) values indicate that crop coefficients for lettuce are approximately 0.1 early in the season (six to eight-leaf stage) and increased to 0.7 during the rapid growth period (after cupping). Data for melons suggest a MAD of 40% depletion of available water to a 0.6 in soil depth. Crop coefficients for melons ranged from 0.1 after emergence, peaking at1.0 shortly before first harvest, and declining to 0.8 by the final harvest.

Studies were also conducted to evaluate irrigation regimes and the interaction between N management and irrigation management for drip irrigated lettuce and melons. Treatments were four irrigation regimes calculated as a fraction of Penman ET° values. In these studies we used constant proportions of ET° throughout the growing season because we had no basis for determining when and by how much to vary them as the season changed. For lettuce and melons, optimal yields were achieved at irrigation regimes appreciably below ET° estimates. Melons appeared to derive appreciable amounts of water from capillary movement from lower soil depths.

During 2000 to 2002, we conducted studies aimed at validating irrigation scheduling. The irrigation regimes were grower standard practice, irrigation based on frequent neutron probe measurements, and irrigations, based on weather based irrigation scheduling program (AZSCHED). In 2000-2001, lettuce yields were not affected by irrigation regime indicating that irrigation scheduling would not compromise yield compared to grower standard practices. These studies also verified the suitability of the MAD utilized. In 2001-2002, lettuce yields were improved by irrigation scheduling compared to grower standard practices

While irrigation scheduling provides information on time and required depth of irrigation, it does not provide management guidelines for efficiently and uniformly applying this required depth. Therefore, we initiated studies aimed at optimizing system variables for furrow- irrigated vegetables. This study included field and modeling components. Inputs for a surface hydraulic model were measured directly or calculated using surface irrigation parameter estimation models. The modeling component included model calibration, validation, and simulation experiments. The data generated from this experiment were used to develop guidelines that will aid growers in the implementation of efficient water management.

D. WORK DESCRIPTION (Tasks 1.1, 1.2, 1.3,1.6,1.7, 2.2, 2.3, and 2.4)

Over 99% of all lettuce produced in the desert is furrow irrigated and experiments conducted during 1999-2002 focused on developing efficient furrow irrigation practices, for lettuce. Traditionally, a significant percentage of melons are drip-irrigated and studies conducted during 1999-2002 focused on both drip and furrow irrigation for melons. Recognition of the fact that poor irrigation management is a significant contributing factor to poor irrigation performance prompted us to initiate studies aimed at developing management guidelines. It is most meaningful to interpret data collected from FREP sites with other relevant irrigation data collected during this period. Therefore, in 1999 we briefly highlighted studies with drip-irrigated lettuce that were funded by the Arizona Iceberg Lettuce Research Council (AILRC). The experiments aimed at developing management guidelines were primarily funded by the United States Bureau of Reclamation (USBOR) with partial funding from FREP. All irrigation studies conducted during this period are summarized in Table 1.

<u>Brief Summary of work reported in 2000 and 2001</u>

Details and data for experiment-demonstrations conducted and completed through spring 2001 have been included in previous reports. Nevertheless, for continuity these studies will be briefly summarized in this report, although data tables and figures will not be shown again.

Evaluation of management allowable depletion (MAD) values and crop coefficients (kc) for furrow irrigated lettuce (Experiments 1A through 1C)

Treatments were selected such that irrigations were applied at available soil water depletion values ranging from 20 to 80%. Initially (experiments IA and IB), estimates were based on total available water (TAW) in the surface 0.6m. Based on results from experiments IA and 1B, irrigations were scheduled based on moisture measurements to 0.3m in experiment 1C. Neutron probe access tubes were installed to a depth of 1.5 in in all plots. Soil moisture measurements were made at least three times weekly. Irrigation was applied to all replications of a treatment when the mean of the treatments reached the targeted value. Growth and yield data were collected so that we could identify MAD values associated with maximum crop production. Data from the treatments receiving optimal irrigation was used to calculate kc values from ET as measured by soil water depletion and penmen ET° values.

Irrigation for drip irrigated melons and lettuce (experiments 3A through 3C and 4A and 4B)

Studies were established to evaluate irrigation scheduling approaches for drip irrigated melons and lettuce. This particular experiment focused on evaluating crop coefficients and the interaction between N management and irrigation management. Treatments were four irrigation regimes ranging from 20 to 80%, Penman ET° values. These treatments were in factorial combination with 3 nitrogen fertilizer treatments. Daily irrigations were computed from average ET° values as calculated from the previous week weather data. The influence of irrigation regimes on melon growth and yield were determined from weekly measurements of plant growth and dry matter accumulation as well as marketable yields at maturity.

Design and Management Guidelines for furrow irrigated desert vegetable production units (Experiments 7A through 7L)

We came to realize that irrigation scheduling alone would not result in efficient irrigation practices. Therefore, we initiated studies aimed at optimizing system variables for furrow-irrigated vegetables. The development of a management package for the furrow irrigated vegetable production units of the low desert area had been undertaken in four stages: (1) field studies (1998, 1999, and 2000), (2) model' calibration and validation (2000), (3) simulation experiments and development of management tools [i.e., performance charts and lookup tables (2001)], and (4) development of management guidelines that facilitate effective use of the management tools (2001). The primary objective of the field experimental study was to develop a complete database that would be used in the modeling studies (i.e., model calibration and validation).

<u>Field Experimentation</u>

The field experiments and demonstrations were performed on several sites. The locations of the sites were selected such that the range of soil textural variation. During each irrigation event, data on in-let flow rate (Qo), cutt-off time (too), depth hydrograph, cross- sectional dimensions, advance, and recession were collected on each of the test furrows. The furrows used in the experiments were of variable length depending on field location and ranged from 585 ft to 874 ft. The test furrows were used to irrigate carrot, lettuce, and broccoli. Water was applied into the individual furrows using both gated-pipes and/or siphons.

All system variables (Q°, t_{co}, L) were determined based on direct field measurements. L represents a known physical dimension of the furrow. The flow rate into the gated pipes had been measured using a flow meter fitted into the discharge end of the pump. Flow rates into the individual furrows were measured using portable flumes. Inlet flow rates into a furrow show variation during an irrigation event; however, an average value has been used in model calibration and validation. t_{co} is monitored using a stopwatch. Owing to the limited surface storage volume of furrows, adequate irrigation of furrows requires that cutoff time be set well in excess of the advance time. This has been the practice in all the experiments conducted within the framework of this study.

Among the system parameters, So and Z, are relatively easy to quantify. Bed slopes (So) were determined using standard surveyor's level along the centerline of each experimental furrow prior to the initiation of every irrigation event. Nevertheless, variations in measured elevation variations were generally low enough to assume zero bed slopes. The target amount of application, Zr, was calculated as a function of the total available water holding capacity of the soil, TAW; the MAD value; and crop root depth, Dr by Zr =TAW*(MAD/100)* D,.

While determination of the system variables and some of the system parameters such as S. and Zr is straightforward, the estimation of such parameters as Manning's hydraulic resistance coefficient, n, and infiltration are not. In surface irrigation applications an n value of 0.04 is commonly used for situations in which flow occurs over bare soils, such as furrows. Therefore, n = 0.04 has been used in this study as well. Infiltration parameters were measured using the estimation model ModKost described in more detail in a previous report.

<u>Model Calibration</u>

In the current study, model calibration involves estimation of infiltration parameters. For each soil group two/three data sets were used in estimating infiltration parameters using ModKost. The type of infiltration function implemented in ModKost is the modified Kostiakov-Lewis infiltration function. The parameters of the modified Kostikov-Lewis infiltration function are: k, a, and f_o. ModKost employs a modified version of a simple inverse solution technique, which is commonly known as the two-point method. Once the basic intake rate, f_o, is determined, there remain two infiltration parameters (k and a) to estimate. At least two equations are needed to estimate the two unknown infiltration parameters. The two equations can be formulated by applying the principle of mass balance to two instants of time during the advance phase. Mathematically any two points will do in practice, however, some pairs will give better results than others. Elliott and Walker (1982) used the mid-distance and downstream points. Although the question of how to locate the two points for minimal parameter estimation error is still an issue that merits further investigation, in the current study the approach proposed by Elliott and Walker has been used in this study.

<u>Simulation Experiments</u>

In the low desert reconfiguring (redesigning) most existing systems may entail significant capital expenditure, hence improvements in furrow performance can best be realized through improved management practices. Management tools (performance charts and lookup tables) are central to the management package developed for this area. A prime consideration in developing the management tools was that they should be simple enough to be understood and used by growers without the aid of trained irrigation technicians or experts. This practical constraint requires a direct and simplified graphical and tabular presentation of the relationships between performance indicators and system variables. In the management tools developed in this study, irrigation performance indicators are expressed as direct functions of the two management variables: unit inlet flow rate, Q0, and cut off time, tip. In the lower Colorado River area, a standard irrigation block constitutes a tract of land that is 0.5 mile wide and about 660 ft long. After making allowances for canals and access roads, the average length of a furrow is about 600. ft. Therefore, 600 ft has been taken as the typical length of a furrow throughout the simulation experiment. For each soil textural group a spatially and temporally averaged infiltration parameters have been used in the simulation experiment. This implies that temporal and spatial variation in infiltration are insignificant within a textural group. The fact that (1) soil textural variation within a group is relatively minimal, (2) more or less similar cultural practices and land grading methods/tools are used in the area, and (3) the management tools are developed for a narrow range of crop types (lettuce, broccoli, and carrot), make the forgoing assumption plausible. Although the effective crop root depth generally varies between 0-1.64 ft (0.5 m) during the life cycle of the crop, given the simplifications that have already been made, the development of management tools for different target application depths is unwarranted.

<u>Research only partially reported previously or reported for first time</u>

Evaluation of management allowable depletion (MAD) values and crop coefficients (kc) for furrow irrigated melons (2A through 2E)

Seven experiments (2A through 2G) were conducted to develop crop coefficients and MAD values for melons. Treatments were selected such that irrigations were applied at available soil water depletion values ranging from 20 to 80%. These estimates were based on measurements in the surface 0.3m in experiment 2A. However, we quickly realized we had to monitor soils moisture to greater depths for melons and modified our protocol such that irrigations were performed based on estimates to 0.6m in subsequent experiments. Neutron probe access tubes were installed to a depth of 1.5 in in all plots. Soil moisture measurements were made at least three times weekly. Irrigation was applied to all replications of a treatment when the mean depletion of available water of the treatments reached the targeted value. Growth and yield data were collected so that we could identify MAD values associated with maximum crop production. Data from the treatments receiving optimal irrigation was used to calculate kc values from ET as measured by soil water depletion and penmen ET° values.

Evaluation and demonstration of irrigation scheduling for lettuce (Experiments 5A, 5B, and 5C)

Three studies were conducted in 2000 through 2002 to evaluate and validate irrigation scheduling for lettuce. The first (5A) and third (5C) experiments evaluated three irrigation regimes and five N rates. The irrigation regimes were grower standard practice, irrigation based on frequent neutron probe measurements, and irrigations based on weather based irrigation scheduling program (AZSCHED). The N rates ranged from 0 to 250 kg/ha. Information for MAD and kc values utilized in AZSCHED were determined or validated in studies reported previously. The second experiment (5B) evaluated the three irrigation regimes but did not include N rates. The irrigation regimes were AZSCHED scheduled irrigation at 50% MAD, AZSCHED scheduled irrigation at 35% MAD, and TDR scheduled irrigation at 50% MAD.

E. RESULTS AND DISCUSSION

<u>Brief Summary of work reported in 1999-2000 and 2000-2001</u>

Evaluation of management allowable depletion (MAD) values and crop coefficients (kc) for furrow irrigated lettuce

These data were presented and discussed in more detail in the 1999-2000 report and those tables were not reproduced in this report. Summarizing the results briefly, the relationship between depletion of available moisture to 0.3 and 0.6m soil depths and the relative yield of iceberg lettuce across all experiments show yields decline rapidly as available soil moisture is depleted below 40%. Lettuce is a shallow rooted crop and the data show that there is no advantage to monitoring available water to 0.6 in instead of 0.3 in. We propose using a MAD of 35% to 40% depletion of available water as a basis for scheduling irrigation of iceberg lettuce. Data suggest crop coefficients (kc values) for lettuce are approximately 0.1 and increase to 0.7 during the rapid growth phase. Interestingly, these data agree closely with lysimeter estimates determined previously.

Irrigation for drip irrigated melons and lettuce

These data were summarized in detail in the 1999-2000 and 2000-2001 report and the tables and figures are not reproduced in this report. Only a brief summary is provided in this report. The irrigation regimes applied ranged from 0.35 to 0.8 ET° in experiment 3A, 0.17 to 0.66 ET° in experiment 3B, and 0.17 to 0.43 ET° in experiment 3C. In experiment 3A, it seemed that the high irrigation regime delayed maturity because they produced significantly less yield at the first harvest date and significantly more yield at the last harvest date. Based on results of experiment 3A, we made the decision to lower all irrigation regimes in experiment 3B and 3C. In experiments, 3B, and 3C, there was no significant yield response to irrigation regime. We suspect sub-surface flow from neighboring irrigations compromised irrigation treatments on this clay loam soil. Early yields appeared reduced for both high and low irrigation regimes. Overall, melons appeared to derive appreciable amounts of water from capillary movement from lower soil depths in fine textured soils.

Design and management guidelines for furrow irrigated vegetable production units

An extensive body of tables and figures pertaining to these experiments were presented in the 2000-2001 report. These tables and figures will not be reproduced in this report where we will only briefly summarize results.

Infiltration parameter estimates were obtained using ModKost, for each soil textural group (i.e. moderately coarse textured soils, medium textured soils, moderately fine textured soils, and fine textured soils). For each soil textural group, with the exception of moderately coarse textured soils, temporally and spatially averaged infiltration parameters have been calculated by taking the arithmetic mean of the parameter estimates obtained using ModKost. However, for moderately coarse textured soils, the average infiltration parameter have been adjusted such that advance predicted by SRFR matches reasonably well with field observed advance. The capability of the SRFR model to simulate dyked-end level furrow irrigation processes with an acceptable level of accuracy had been evaluated by comparing its output with field data. Seventeen data sets, which are not used in model calibration, were used in the model verification exercise.

Comparison of model predicted and field observed advance for made for 17 independent data sets. The mean absolute error in the advance predicted by SRFR is 4.7 minute with a confidence interval of ± 1.2 min at the 5 % confidence level. Excluding only eight outliers, the mean absolute residual drops to 3.1 min with a confidence interval of ±0.5 minute at the 5% level. The results of model verification clearly demonstrate that SRFR is capable of simulating the furrow irrigation processes in the low desert with acceptable accuracy. In addition, it shows that the spatially and temporally averaged parameter estimates resulted in consistent and reasonably accurate estimates of advance, even when used to analyze irrigation events that occurred in different temporal and spatial coordinates than the ones used in their estimation. This result, to a degree, validates the assumption that has been made earlier about the relative homogeneity of infiltration properties in a textural group.

Simulation experiments were performed to generate the database required to develop the management tools. Systematic variation of furrow inlet flow rate and cutoff time combinations were used to evaluate several management possibilities. From these simulations, charts and look-up tables were both derived (presented in 2000-2001 report). In general, the lookup tables are more comprehensive than the charts in terms of the type of information they provide. They contain information on application efficiency, low quarter distribution uniformity, water requirement efficiency, maximum, average, as well as applied depths, and maximum surface depth. The performance charts have to be used in conjunction with the lookup tables in making management decisions. We have developed a guideline on how to make effective use of these management tools and these guidelines are available for use by irrigators. The USBOR is funding follow-up work aimed at training irrigators in the use of these technologies.

Research only partially reported previously but complete reporting here

Evaluation of management allowable depletion (MAD) values and crop coefficients (kc) for furrow irrigated melons

Results for experiments 2A and 2C have been reported in earlier reports and are not reproduced in this report. Briefly, in experiment 2A, melons yields in the first harvest were significantly reduced for the wetter (20% depletion of available water) irrigation regime. However, higher yields for this treatment during the second harvest resulted in no significant differences in overall total yield. Although not statistically significant it seems optimal yields were obtained when irrigation were made at 40% depletion of available water. We suspect capillary movement of water from lower soil depths minimized growth and yield responses to irrigation regime.

As noted previously, we made the decision that in subsequent experiments irrigation decisions would be based on measurements to a minimum of 0.6 in. Unfortunately, we lost experiment 2B to disease and experiment 2C to insects. The results for experiments 2D through 2G are summarized in Tables 2 through 4. As shown for data from experiment 2E, crop coefficients ranged from 0.1 to 0.8 and are a little less than what we previously estimated for melons. Our worked aimed at validating crop coefficients for melons is on-going with funding from another source.

The MAD for melons is estimated to be 40% to a 0.6 m depth (Figure 2 and Tables 2, 3, and 4). There seemed to be subtle differences depending on soil type. In experiments 2A and 2D, melons were produced on clay loam soils. In these experiments melons seemed to be able to obtain water from lower soil depths. For experiments 2F and 2G, the melons were produced on loamy sand. In these experiments melons were not as successful at obtaining water at lower soil depths and were more susceptible to soil moisture deficits.

Evaluation and demonstration of irrigation scheduling for lettuce

Data for experiment 5A were presented in a previous report and are not presented here. In experiment 5A, yields were not affected by irrigation regime, indicating that irrigation scheduling would not compromise yield compared to grower standard practices. Yields and crop N uptake were not affected by N fertilization, suggesting that residual N was high on the site used for this experiment. Lettuce midrib nitrate-N values varied by N rate but were near or exceeded critical concentrations at all N rates. Residual soil nitrate- N after harvest increased with N rate. In addition, the amount of N recovered in resins set below the root zone suggests increased leaching at high N rates. In experiment %B, lettuce irrigated by AZSCHED using a MAD of 35%

produced higher yields than that irrigated by AZSCHED or soil moisture measurements using 50% MAD (Table 5). This is further validation of the suitability of MAD values determined in previous experiments. In experiment 5C, lettuce irrigation at 35% MAD based on AZSCED scheduling or soil moisture measurement produced higher lettuce yields compared to the grower standard practice (Table 6). Lettuce midrib nitrate-N levels increased by N rate but were not affected by irrigation level
(Table 9). Data for nitrate-N leaching as determined from resins was high variable and not significantly affected by treatment (Table 10). Residual soil nitrate-N in the soil after harvest increased by N rate but was not affected by irrigation (Table 11).

Subtasks 1.4, 1.7, 2.5, and 2.7 (Reporting)

With the submission of this final report we have submitted four interpretive summaries, three interim reports, and three annual reports. This completes our written reporting responsibilities. However, we have secured funding from other sources to continue this research and we are receptive to additional oral reporting at the FREP annual conference.

Subtasks 1.5, 2.1, 2.6

Gave presentation at Extension Irrigation meeting May 20, 1999 at Holtville in Imperial Valley California.

Gave demonstration of irrigation management experiment during field tour in fall, 1999.
Gave presentation at field day June 2, 1999 in Yuma, Arizona.

Gave presentation on N Management and Irrigation TMDL meetings on September 13, 2000, at Holtville in Imperial Valley California.

Gave presentation on Irrigation and Salt Management during lettuce field day on November 16, 2000 in Yuma, Arizona.

Gave presentation at salinity and irrigation meetings November 28, 2000 in Yuma Arizona.

Gave presentation on Irrigation and Salinity Management on May 2, 2001 at Desert Agriculture Conference in Phoenix, Arizona.

Gave presentation on Irrigation and N Management in Tucson, Arizona on May 14, 2001.

Gave presentation on Salinity and Irrigation Management at workshop in Yuma on August 21, 2001.

Gave report at FREP conference in Tulare, California on November 14, 2001.

Gave presentation on Salinity and Irrigation Management at workshop in Yuma on August 20, 2002.

Gave presentation on Nutrient Management (including the effects of irrigation management) at meeting in Mexicali, Mexico on October 24, 2002.

Gave presentation on efficient irrigation of desert vegetables at workshop in Yuma on December 4, 2002

REFERENCES

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Strelkoff, T. S., Clemmens, A.J., and Schmidt, B.V. (1998). *SRFR v 3.31. Computer Program For Simulating Flow in Surface Irrigation, Furrows-Basins and Borders.* US Water Conservation Laboratory, 4331 E. Broadway, Phoenix, AZ. 85040.

Table 1. Summary of irrigation studies.

Experiment Number	Experiment Type	Crop	Funding Source	Planting Date	Harvest Date
1A	MAD/kc	Lettuce	FREP	Dec. 9, 1998	April 9, 1999
1B	MAD/kc	Lettuce	FREP	Dec. 18, 1998	Mar. 31, 1999
1C	MAD/kc	Lettuce	FREP	Dec. 14, 1999	Mar. 30, 2000
2A	MAD/kc	Melon	FREP	Mar. 8, 2000	Jun. 16, 2000
2B	MAD/kc	Melon	FREP	Aug. 14, 2000	lost
2C	kc	Melon	FREP	Aug. 21, 2000	lost
2D	MAD/kc	Melon	FREP	Mar. 23, 2000	June 27, 2001
2E	kc	Melon	FREP	Mar 21, 2001	June 29, 2001
2F	MAD/kc	Melon	FREP	Aug. 14, 2001	Oct. 24, 2001
2G	MAD/kc	Melon	FREP	Feb. 15, 2002	June 17, 2002
3A	Drip	Melon	FREP	Mar. 4, 1999	Jun. 28, 1999
3B	Drip	Melon	FREP	Aug. 25, 1999	Nov. 17, 1999
3C	Drip	Melon	FREP	Mar. 8, 2000	Jun. 16, 2000
4A	Drip	Lettuce	AILRC	Nov. 29, 1995	Mar. 18, 1996
4B	Drip	Lettuce	AILRC	Sep. 20, 1996	Dec. 11, 1996
5A	Irrigation Schedule validation	Lettuce	FREP	Oct. 17, 2000	Jan. 25, 2001
5B	Irrigation Schedule validation	Lettuce	FREP	Jan 26, 2001	Apr 30 2001
5C	Irrigation Schedule validation	Lettuce	FREP	Oct 8, 2001	Jan. 22, 2002
7A	Management-Model Calibration	Lettuce	USBOR & FREP	Oct. 9 1998	Jan. 2 1999
7B	Management- Model Calibration	Lettuce	USBOR & FREP	Oct. 12 1998	Jan. 26 1999
7C	Management- Model Calibration	Lettuce	USBOR & FREP	Oct. 16 1998	Jan. 25 1999
7D	Management- Model Calibration	Lettuce	USBOR & FREP	Dec. 16 1998	Mar. 26 1999
7E	Management-Calibration/Validation	Lettuce	USBOR & FREP	Sep. 5, 1999	Dec. 8, 1999
7F	Management-Calibration/Validation	Broccoli	USBOR & FREP	Sep. 5, 1999	Dec. 12, 1999
7G	Management-	Carrots	USBOR	Sept. 22, 1999	Feb. 15, 2000
	Calibration/Validation		& FREP		
7H	Management-	Carrots	USBOR	Sept. 22, 1999	Feb. 15, 2000
	Calibration/Validation		& FREP		
7I*	Management	Lettuce	USBOR	Oct. 17, 2000	Jan. 25, 2001
	ModelValidation		& FREP		

*Experiments 71 through 7L were validation performed on various field sites in December 2000.

Table 2. Yield response of cantaloupe to depletion of soil moisture in experiment 2D.

Marketable yield (Mg/ha) Date				
Depletion	**06/19/01**	**06/22/01**	**06/27/01**	**Totals**
20%	5.34	12.42	29.43	47.19
40%	3.45	12.39	13.91	29.75
60%	6.43	9.68	16.05	32.16
80%	5.49	7.42	12.20	25.11
Stat.	NS	NS	NS	*

* ,** ,*** Significant at the 5%; 1% and 0.1% levels. NS=Not Significant.

Table 3. Yield response of cantaloupe to depletion of soil moisture in experiment 2F.

Marketable yield (Mg/ha) Date			
Depletion	**10/24/01**	**10/29/01**	**Totals**
20%	15.12	20.95	36.07
40%	14.46	10.44	24.90
60%	3.08	2.78	5.86
80%	0	0	0
Stat.	**	**	***

*, **, *** Significant at the 5%; 1% and 0.1% levels. NS=Not Significant.

Table 4. Yield response of cantaloupe depletion of soil moisture in experiment 2G.

Marketable Yield **(Mg/ha)** Date					
Depletion	**06/07**/**02**	**06**/**10/02**	**06/13/02**	**06**/17/02	Totals
20%	4.15	7.72	10.99	18.08	40.94
40%	3.45	11.38	16.85	10.24	41.92
60%	1.55	9.13	3.30	7.26	21.24
80%	1.96	4.33	4.33	8.91	19.53
Stat.	NS	NS	NS		

*, **, *** Significant at the 5%; 1% and 0.1% levels. NS=Not Significant.

Table 5. Yield of lettuce to irrigation regime in experiment 5.

Treatment	**Marketable Yield (Mg/ha)**
AZSCHED 50	34.1
AZSCHED35	39.0
TDR50	33.8
LSD	5.0

LSD = Least Significant Difference at the 5% level.

Table 6. Yield of lettuce as affected by irrigation practice and N fertilization in experiment 5C.

Marketable Yield (Mg/ha)	
Irrigation	
Grower Practice	38.73
Neutron Probe	42.94
AZSCED	45.18
Stat.	
Irrigation (I)	
I*N rate (NR)	NS
N Treatment	
0	34.46
50	43.55
100	41.89
150	45.94
200	44.14
250	43.72
Stat.	L*Q*

NS= Not significant; I=Irrigation ; NR= N Rate.
Significant linear (L) or quadratic (Q) trend at the 5% level.

Table 7. Irrigation and Fertigation performance study for lettuce dry matter in experiment 5C.

Dry Matter (g plant-)	
Irrigation	
Grower Practice	57.37
Neutron Probe	58.78
AZSCED	58.54
Stat.	
Irrigation (I)	NS
I*N rate (NR)	NS
N Treatment	
0	53.13
50	58.02
100	59.60
150	63.67
200	54.65
250	60.32
Stat.	NS

NS = Not significant; I=Irrigation; NR=N Rate.

Table 8. Above-ground N accumulation of lettuce as affected by irrigation practice and N fertilization in experiment 5C.

N uptake (kg/ha)	
Irri_ation	
Grower Practice	117.45
Neutron Probe	126.63
AZSCED	123.33
Stat.	
Irrigation (I)	NS
I*N rate (NR)	NS
N Treatment	
0	118.03
50	112.41
100	113.45
150	141.60
200	121.80
250	127.54
Stat.	NS

NS = Not significant; I=Irrigation; NR=N Rate.

Table 9. Midrib-nitrate-N of lettuce as affected by irrigation practice and Nfertilization in experiment 5C.

Midrib N03-N (mg/kg)	
Irrigation	
Grower Practice	7111
Neutron Probe	7222
AZSCED	7056
Stat.	
Irrigation (I)	NS
I*N rate (NR)	NS
N Treatment	
0	4556
50	5889
100	7556
150	8444
200	8222
250	8111
Stat.	L*Q*

NS= Not significant; I=Irrigation; NR=N Rate.
Significant linear (L) or quadratic (Q) trend at the 5% level.

Table 10. Nitrate-N recovered in resin capsules buried at 0.5 m below soil surface as affected by irrigation practice and N fertilization in experiment 5C.

N03-N k /ha		
	Date	
	11/30/01	01/02/02
Irrigation		
Grower Practice	27.35	54.46
Neutron Probe	29.85	17.67
AZSCED	4.38	9.38
Stat.		
Irrigation (I)	NS	NS
I*N rate (NR)	NS	NS
N Treatment		
0	17.88	31.98
100	11.84	13.56
200	31.86	35.96
Stat.	NS	NS

NS= Not significant; I=Irrigation; NR=N Rate.

Table 11. Residual ammonium-N and nitrate-N after harvest as affected by irrigation practice and N fertilization in experiment 5C.

	NH4-N m k	N03-N m /k
Irrigation		
Grower Practice	4.76	20.75
Neutron Probe	5.37	21.65
AZSCED	6.16	23.25
Stat.		
Irrigation (I)	*	NS
I*Nrate (NR)	NS	NS
N Treatment		
0	4.46	5.86
50	5.15	9.31
100	6.08	12.19
150	5.59	21.66
200	5.83	37.19
250	5.47	45.07
Stat.	NS	L*Q*

NS= Not significant; I=Irrigation; NR=N Rate.
Significant linear (L) or quadratic (Q) trend at the 5% level.

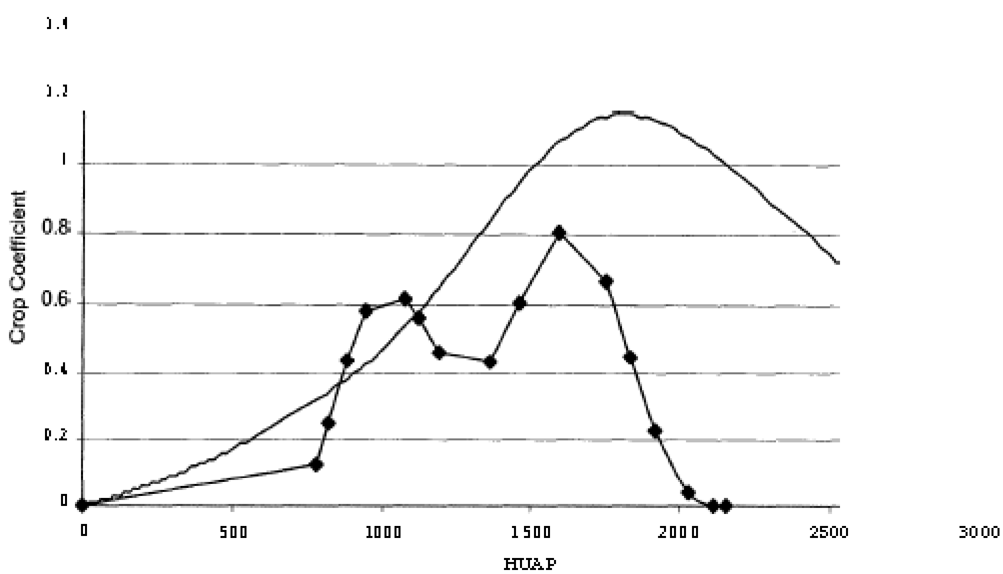

Figure 1. Crop coefficient data for cantaloupes grown in experiment 2E.

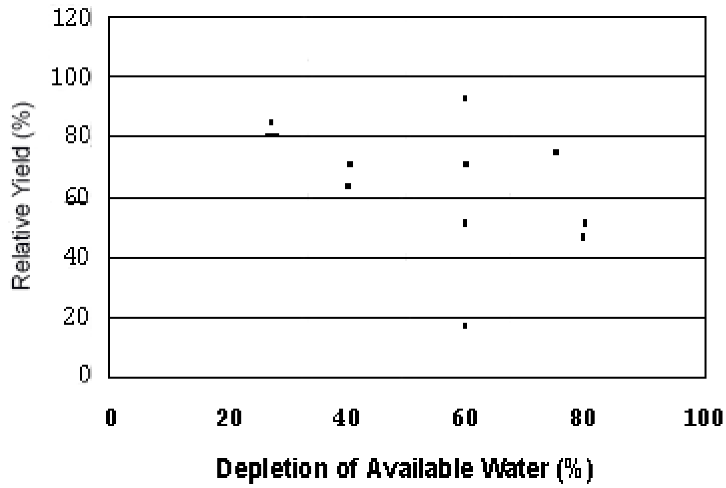

Figure 2. Relationship between melon yield and depletion of available water to 0.6 m in four field experiments.

F. Project Evaluation

The costs of the technologies proposed in this project are very minimal. The irrigation scheduling software is free. The design and management recommendations are based on decisions by the irrigator and require little additional infrastructure other than perhaps flow measuring equipment. Although growers are adapting some of the technologies proposed in this project, barriers to development remain.

The low cost of irrigation water in the region remains an obstacle to widespread implementation of improved irrigation practices. However, as water restrictions are implemented, or water-marketing opportunities arise, incentives to manage water more efficiently will hasten the adaptation of more of the technologies developed.

Another major obstacle is the communication between those that conduct outreach activities (ourselves), those that make major decisions (farm management), and those that conduct irrigations. Most outreach activities are conducted in the English language aimed at the farmer or farm manager. It is my observation that most of those actually conducting the irrigation speak primarily Spanish as their first language. Future outreach programs should include a component that involves the irrigator and similar outreach materials provided to the farm management in English could be made available in Spanish to non-English speaking personnel. The efficacy of the outreach activities could improve appreciably if the irrigators are involved in the training.