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agronomy news

Irrigation Management

What are Colorado producers doing?

IRRIGATION:

Irrigation for crop production currently uses about 90% of the 1.8 trillion gallons of water diverted annually Colorado. We have a long history of irrigation innovation in Colorado, but we continually hear discussion of wasted agricultural water and questionable irrigation management, especially from urban water interests. In order to evaluate our irrigation and water management programs at CSU, we mailed a confidential written survey in 1997 to 3,281 known irrigators identified through the Colorado Agricultural Statistics. The survey asked producers about irrigation management and technology used in their operations and included questions about specific fertilizer and pesticide practices. This

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information should be helpful in documenting progress that Colorado producers are making in protecting water resources and to identify where more effort is needed.

Survey results

We found that many irrigators rely on water from both surface and ground water sources. Statewide, gravity (flood, siphon tubes, gated pipe, and other gravity) and sprinkler systems (center pivot and other sprinkler) account for nearly equal proportions of irrigated acreage, but differences among regions are great. Center pivots dominated sprinkler usage, while flood systems account for over half of the gravity-served acres in the state. On the average field, flood and siphon tube systems were installed nearly 75 and 35 years ago, respectively. The average age of all other systems falls below 20 years. In addition, we found that Colorado irrigators are highly experienced, with an average of 31 years of irrigation experience.

Each respondent was asked to identify a specific field that was representative of their farm to facilitate detailed questioning of how specific irrigation management decision are made. The average "representative field" was 67 acres with nearly one-quarter of the fields identified as rented or leased. Sixty-five percent of respondents described their water supply as highly reliable, providing adequate water ten years out of ten. Regions with higher reliance on ground water sources were found to have higher water reliability, while regions more reliant upon a ditch company, especially in the Arkansas Valley, have lower water reliability.

Nearly all center pivot users have upgraded their system in some manner, with low-pressure systems and drop nozzles widely used (Figure 1). Eighty-four percent of survey respondents reported at least one irrigation system upgrade somewhere on their farm. Among gravity systems, flood irrigation components are least frequently improved. Less than 40% of the flood systems in any of the three western regions have received an upgrade. Field leveling and lining ditches occurs frequently among flood systems in the eastern regions and for siphon tube systems across the state. Among gated pipe users, field leveling and surge valves were the most frequent upgrades. Very few producers have adopted flow meters.

Table 1. Average irrigation experience of respondents and age of system installed on respondents' "*Representative Field*".

	Center Pivot	Side Roll	Gated Pipe	Siphon Tubes	Flood	All Systems
	------------	------------	------------	Average Years	------------	------------
Irrigation experience	28	26	30	32	33	31
Age of system	14	10	11	35	74	32

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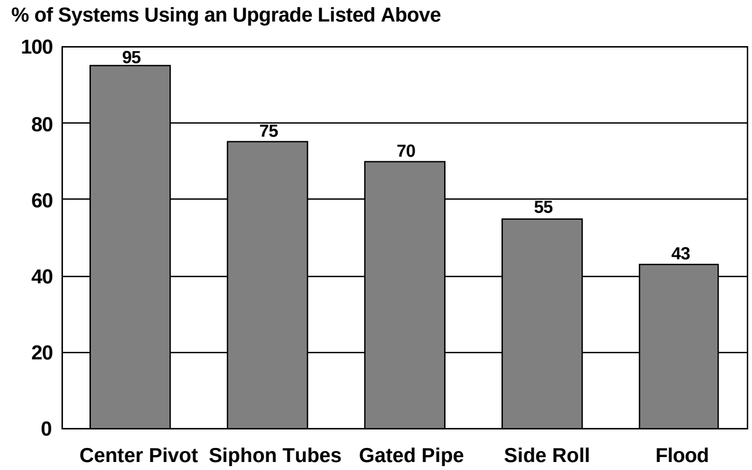
Figure 1. Results of the following question:
Check all irrigation upgrades used on the system identified for this field.

Options given in survey for selecting irrigation system upgrades:

LEPA	Corner catcher	Surge valves
Drop nozzles	Flow meters	None apply
Low pressure sprinklers	Lined ditches	Other
Computer controller	Field leveling	



Irrigation Management

When asked to estimate the field level irrigation efficiency on their representative field, the majority of respondents indicated they knew system efficiency. Estimates of application efficiency among surface irrigators, however, tended to be much higher than values commonly reported from research. Just over one-quarter of respondents indicated knowledge of the amount of water applied to their representative field. Less than one-sixth of respondents indicated keeping records of water applied to their representative field.

Half of all producers indicated that "crop appearance" was the primary method used to determine when to irrigate their crops (Figure 2). Nearly one-third cited a "fixed number of days" between irrigations as their method used. Rule based irrigation scheduling methods such as accumulated ET or available soil moisture were cited by about one-quarter of respondents, but most frequently by those pumping ground water and using center pivots. One in ten producers cited using crop consultants used to determine when to irrigate their crops.

Over one-quarter of all producers reported changing some aspect of management in the last five years. Among the irrigation systems, center pivot, side roll, and gated pipe users reported the most changes. Respondents with ground water sources showed the most change. Most changes involved the water application system, with improving water use efficiency the most frequent reason given for the management change.

Survey Significance

Our survey results suggest that stretching water supplies is not an incentive to change current management practices for the majority of Colorado irrigators. Irrigation

Table 2. Percent of respondents knowing and keeping records on the amount of water applied*.

	Region						
	South Platte	Eastern Plains	Arkansas Valley	San Luis Valley	Mountains	Western Slope	Statewide Average
	% Respondents per Region						
Know amount applied	36	38	25	30	17	17	28
Keep records	16	19	15	25	12	12	16

Questions read:** ***Do you know how much water was applied to the representative field in 1996?
Did you keep written or computerized records of water applied throughout the season?

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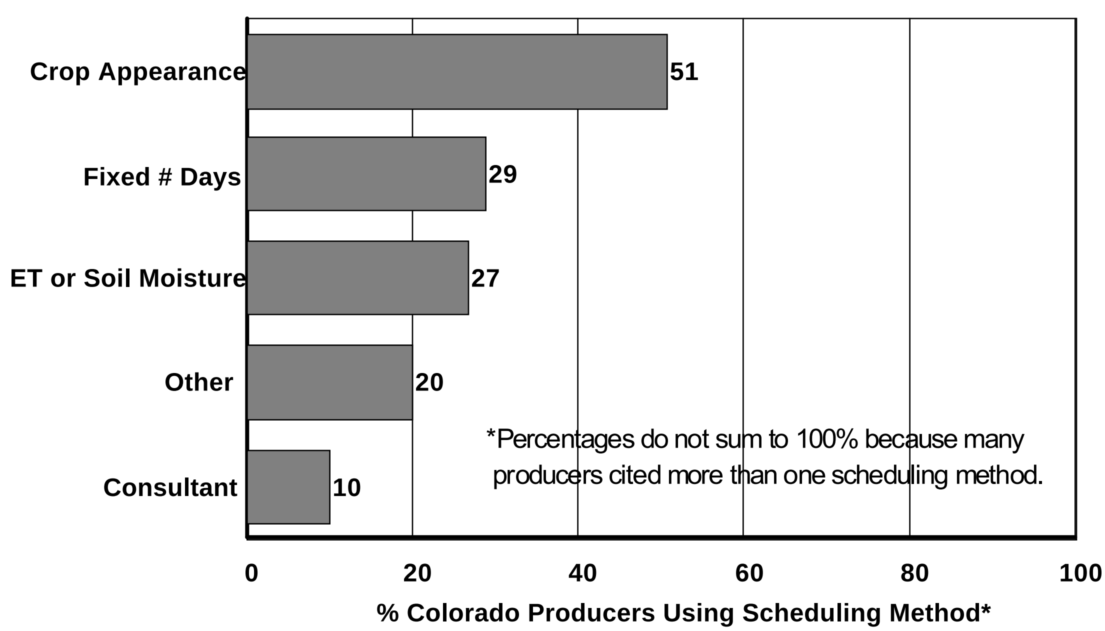
management and technology adoption in Colorado is progressing, but many producers have not incorporated improved irrigation management practices in their operations. There are many old irrigation systems in Colorado that have not been updated as technology has changed. In addition, most Colorado irrigators have many years of experience with their current systems. Research and extension programs must recognize the validity of this experience and must demonstrate a clear advantage of any new technology or management system before we can rationally expect widespread producer adoption.

Most Colorado irrigators do not keep precise records of crop water use and irrigation water applied. This may be partially explained by the fact that many irrigators feel their water supplies are adequate during most years. The management time and costs required to keep better records or implement higher levels of water management may not be justified or economically feasible for these irrigators. However, the results of this irrigation survey also show that Colorado irrigators will implement technology when it is practical, economical, or when other significant incentives exist. It may be inferred that higher levels of irrigation water management will be adopted as farmers perceive an incentive to do so. The remainder of this newsletter discusses some of the irrigation management tools that Cooperative Extension is working to disseminate.

Complete results of this survey may be obtained in the CSU Agricultural Experiment Station technical report entitled "Irrigation Management in Colorado – Survey Data and Findings" (Colo. AES TR-99-5). This report may also be accessed at http://www.colostate.edu.Depts/AES/pubs.htm.

Reagan Waskom and Troy Bauder, Extension Water Quality Specialist and Assistant Extension Water Quality Specialist, Dept. Soil and Crop Sciences, Colorado State University

Figure 2. Results of the following question:
Check the ONE primary method that you used in 1996 to decide WHEN to irrigate.



Surge Irrigation

A tool for improving irrigation efficiency and uniformity.

Surge irrigation is a surface irrigation method designed to reduce runoff and increase application uniformity. This technology became feasible for producers with the advent of the surge valve, which allows an automated intermittent application of water to furrows in a series of pulses or surges, rather than a continuous furrow stream. The process is simple; irrigation water is alternated between two sets of furrows until the irrigation is completed. Commercial surge valves have an automatic controller that is powered by an internal battery and a solar panel.

The surge valve is typically located between two sets of furrows. Through the surge valve controller, the irrigator can time irrigation sets according to the length of the field, slope, and soil texture to determine the number of hours that are needed to complete irrigating each set. This is the time required to wet and reach the end of the field. When the set time is selected, the controller will automatically determine the number of cycles or changes for each set. Typically, it takes 5 or 6 cycles, but this can be altered to reduce runoff. When the number of cycles is completed, then the soak cycles will start at constant time (i.e., 20, 30 minutes) depending on the length of initial time selected to irrigate the field. The soak cycle length also can be changed to reduce any excessive water runoff. The purpose of the soak cycle is to push the water down to the proper depth within the root zone, which depends on the crop's growth stage.

Surge valve and controller.

Gated pipe is typically used to deliver water to each of the two sets from opposite sides of the surge valve. The main line, which carries water from the well or ditch will be connected directly to the surge valve. Alternating the water between two sets of furrows seals the soil surface, decreasing the water intake rate, and causing the furrow stream to advance farther and at a faster rate to the end of the furrow. This results in a more uniform water distribution. Surge irrigation can be a very effective tool in saving water when water availability is limited. Also, surge can save irrigation time and labor costs by reducing the need to change sets as often.

Table 1. Nitrogen budget under both surge and conventional irrigation.

Field	Applied + Soil N (lb/A)		Deep Perc. (Ac-In)		N Loss (lb/Ac-In)		Cost of N Loss* ($/Acre)	
	Sur	Con	Sur	Con	Sur	Con	Sur	Con
1	311	350	2.1	9.1	6.7	8.1	6	29
2	334	257	3.6	8.9	7.2	6.6	10	23
3	393	403	3.4	12.3	10.3	7.7	14	37

*Nitrogen cost based on ammonium-nitrate price of 34% available N at $0.39/lb of available N

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Surge

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Applications

Improved water management and efficiency is a concern with surface irrigation, where over-application is the norm due to the inherent inefficiency of conventional irrigation. Over-irrigation leads to management problems such as nutrient loss, water table fluctuation, salinity problems, groundwater contamination, and yield. Water use efficiency under surge irrigation is typically higher than under conventional irrigation. In research plots, one inch of applied water produced 5.5-6.0 bu/A under surge compared with 3.8-4.7 bu/A under conventional irrigation. The higher yield performance under surge irrigation is due to the improvement in water management, reducing N loss to leaching and runoff.

Efficient nitrogen management under surface irrigation is difficult due to the leaching caused by deep percolation. In a 1996-1998 study to demonstrate the use of surge valve for water and N management in the Lower South Platte River Basin, irrigation efficiency was improved to 60-65% under surge irrigation as compared with 40-45% under conventional surface irrigation. The results also show an improvement in N savings under surge irrigation. This saving can be translated into savings of $20.00 per acre on N fertilizer costs.

Fertilizing with surge

Surge systems can be used to apply N fertilizer, commonly called "fertigation." Fertigation allows for the timely application of liquid nitrogen to maximize the plant's uptake during the crop's critical growth stages. This eliminates the need to over-fertilize to compensate for irrigation induced N loss. However, applying N through the surge valve with irrigation requires a higher level of management, otherwise, even greater N loss through water runoff and deep-water percolation can occur. Small amounts of N application are recommended (10-15 lb N/acre) during the two next-to-last soak cycles of irrigation. The last soak cycle will be used to move the fertilizer down into the crop's root zone and to flush out the pipe and valve.

Example:

This example shows how to calculate the required flow rate for 32-0-0, where we want to apply 20 pounds of nitrogen per acre to a 4-acre surge set, and the soak cycle time is 30 minutes long.

Calculation:

From the table below, we find that we need about 5.6 gallons of 32-0-0 to supply one acre with 20 pounds of nitrogen. To obtain the amount required for 4 acres, multiply this value by 4, which equals to 22.4 gallons (4 acres x 5.6 gallons = 22.4 gallons) for the entire set. Since the surge valve irrigates half of the set at one time, 11.2 gallons are applied to half of the field in 30 minutes time. Therefore, the flow rate is 11.2 gallons divided by 30 minutes, or 0.40 gallon per minute. Using a marked container and a watch, set the flow rate by timing the flow and adjusting the discharge valve. If the applicator uses a commercial injector (as is available with the new P&R surge systems), the flow rate may simply be dialed in.

Table 2. Suggested nitrogen rates for surge irrigated row crops.

Desired Amount of Nitrogen Lbs./Acre	Liquid Nitrogen Fertilizer, Amounts of Solution to Apply (sources): 32-0-0	28-0-0	82-0-0
	gal/acre		
10	2.8	3.3	2.4
20	5.6	6.7	4.7
30	8.5	10.0	7.0
40	11.3	13.4	9.4
50	14.1	16.7	11.7
100	28.2	33.4	23.5

Mahdi Al-Kaisi, Extension Water Management Specialist, Colorado State University Cooperative Extension

Atmometers

A flexible tool for irrigation scheduling.

Irrigation scheduling based upon crop ET (evapotranspiration) is often perceived as too difficult or too time consuming for many producers and crop advisers. However, there are tools available that reduce the work and the complexity associated with sound ET-based irrigation scheduling. Atmometers are one of these tools. The primary purpose of these instruments is to provide actual crop ET at any field location they are installed. This information is visually displayed on a site tube mounted in front of a ruler on the instrument. Reading the site tube is as easy as reading a rain gauge. Therefore, a grower or consultant can use an atmometer to quantitatively gauge how crop water use varies with changing weather conditions.

Essentially, an atmometer acts as mini-weather station that, when properly installed, will provide reference ET (ET_r) at a reasonable cost and with little effort. One Colorado supplier sells a modified atmometer (ETgage®) for about $200. They are easy to install and require little maintenance. Studies conducted by CSU and the USDA in Fort Collins show that an atmometer will provide ET_r values that closely match ET_r calculated from weather station data (Figure 1). This ability to provide reliable ET makes atmometers especially useful for areas that do not have nearby weather stations or for people that do not have ready access to this information. A consultant or grower can install an atmometer to help schedule irrigations for many fields within a several mile radius. Also ET data from an atmometer may be more convenient and site specific than other sources.

Atmometer placed between irrigated fields.

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Atmometer

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Atmometers basically consist of a wet, porous ceramic cup mounted on top of a cylindrical water reservoir. The ceramic cup is covered with a green fabric (canvas or Gor-Tex®) that simulates the canopy of a crop. The reservoir is filled with distilled water that evaporates out of the ceramic cup and is pulled through a suction tube that extends to the bottom of the reservoir. Underneath the fabric, the ceramic cup is covered by a special membrane that keeps rain water from seeping into the ceramic cup. A rigid wire extending from the top keeps birds from perching on top of the gauge.

Atmometers are typically mounted on a wooden post near irrigated fields. A good location for placement is a border ridge in an alfalfa field. However, you may also locate the instrument alongside a dirt road if surrounded by low-growing irrigated crops. The site should represent average field conditions. Do not install near farm buildings, trees, or tall crops that may block the wind. Additionally, avoid placement near dry, fallow fields. The top of the ceramic cup should be 39 inches above the ground. The manufacturer of a modified atmometer sold in Colorado (ETgage®) provides detailed instructions on how to install and maintain their instrument.

The following is a brief description of how to use an atmometer to help schedule irrigations.

♦ The atmometer has two movable red markers on the site tube. Record height of water in the sight tube at the start of an irrigation event. The top marker can be used to record the initial height of water.

♦ Crop water use can be estimated by recording the drop in water level over a period of days. To determine the actual water use for a crop that has not fully completed its canopy, you need to multiply the drop in water level from the by a crop coefficient (multiplier) supplied in literature that comes with the atmometer (see Table 1) to estimate actual water use over a period of days. For crops at full canopy, water loss from the atmometer will be practically equal to actual crop ET.

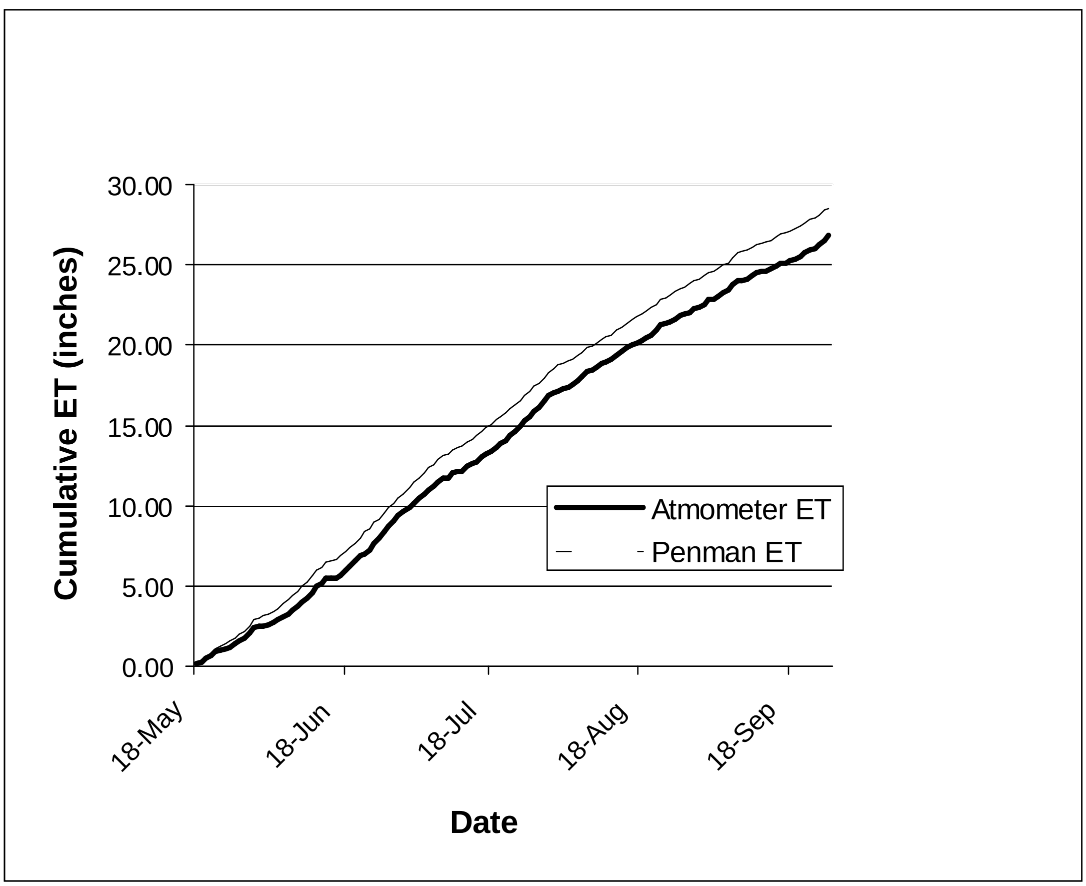

Figure 1: Comparison of Atmometer ET to Penman ET. **Source: Bausch and Altenhofen.**

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Atmometer

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♦ Irrigation is needed when the accumulated ET_r x crop multiplier equals the allowable depletion for that soil type and growth stage (see Table 1).

Example #1:

- The crop corn is 6-leaf and the ETgage drops 1.45" over an 8-day period from the last irrigation.
- The crop coefficient is 0.55 so the crop used about 0.66" during this time. This value is close to the 0.7" depletion for this growth stage.
- Irrigation water should be applied to refill the soil profile (~0.7") in time to avoid crop stress.

♦ Another way to estimate the next irrigation event with an atmometer is to move the 2nd marker on the sight tube below the marker set at the last irrigation to the amount of allowable depletion for the crop growth stage. However if the crop has not covered canopy, you have to divide the allowable depletion by the crop coefficient to determine actual depletion. When the water in the sight tube reaches the bottom marker, irrigation is required if no rain is received.

Example #2:

- The corn is 8-leaf, the multiplier is 0.65", and the allowable depletion is about 1.25". 1.25 ÷ 0.65 = 1.9"
- If you set the 2nd marker 1.9 inches below the initial water level, you should irrigate in time to refill the profile before the water level approaches the 2nd marker.

♦ If a significant rainfall occurs (>0.1") you can move the markers down on the site tube to factor in the additional moisture.

As these examples illustrate, once an allowable depletion is determined, using the atmometer to help schedule irrigations is as simple as reading a rain gauge. It is especially useful for center-pivot users or surface irrigators that know their applications amounts. In these cases, you should irrigate when the site gauge drops to the same amount as the typical irrigation application.

When using any ET-based irrigation scheduling, field verification of soil moisture status is a good idea. Field probing can confirm needed irrigation and provide confidence in using ET-based scheduling. An atmometer can also be used in conjunction with computer scheduling software such as Cropflex, especially if users do not have internet access. This tool can also help growers deal with salinity problems by providing ET over a period of time to determine leaching rations. A Colorado-based company that manufactures atmometers can be reached at (970) 667-9821. Growers interested in trying an atmometer for a season should contact your regional CSU Cooperative Extension water specialist.

Troy Bauder, Assistant Water Quality Specialist, Soil and Crop Sciences, Colorado State University

Table 1. Examples of allowable depletion for corn for typical Colorado sandy loam soil.

Corn leaf stage	Rooting depth (inches)	Crop coefficient	Total rootzone available H_2O (inches)	Allowable rootzone depletion (inches)
4	9	0.35	0.9	0.54
6	15	0.55	1.6	0.8
8	21	0.65	2.3	1.25
10	30	0.90	3.4	1.7
12 & up	36+	1.0	4.1	2.0

Cropflex

A water and fertilizer management program.

Many irrigation scheduling programs that use the water balance approaches were developed during the last two decades. The acceptance of these programs by users such as farmers and ranchers was very slow. Recently a new approach to developing irrigation management programs, based on expert systems, was developed at Colorado State University. This approach also calls for integrating water and nitrogen management. The result is a flexible crop management computer program called "Cropflex," developed at the Department of Chemical and Bioresource Engineering and Cooperative Extension at CSU. This easy to use tool provides irrigation scheduling and fertility management advice to help producers maintain or increase yields while minimizing the potential of leaching nitrates into the ground water. Studies have shown that fertilizer and water applications can be substantially reduced without reducing yield by proper timing of irrigation and nitrogen applications. Cropflex is a decision support system designed to help the producer apply water and fertilizer more accurately.

Cropflex handles a variety of Colorado crops. Basic crop information has been developed for corn, alfalfa, sorghum, onions, potatoes and barley. Entering new or additional crops to the database is simple and straightforward. As a matter of fact, all the databases of the program can be accessed by the user, and crop, soil, and weather station information can be edited or new information can be entered. The program was developed for use by a producer with minimal computer experience and has self-explanatory and easy to understand pull down menus. The new version of Cropflex runs in Windows 95 and is user friendly.

Cropflex has some unique features that are not available in other programs such as: Irrigation scheduling based on growing degree days and growth stages, yield prediction capability to refine fertilizer recommendations; full year weather data, which can span years; calculations of water and nitrogen balance will continue after harvest; a daily display of nitrogen balance and nitrogen deep percolation; and a daily soil moisture override is available. The program can be downloaded from our Web site: http://ulysses.atmos.colostate.edu/~crop/. Weather information for different sites in Colorado can be downloaded from our COAGMET site: http://ulysses.atmos.colostate.edu/cgi-bin//coag_raw_form.pl. The weather information should be saved as file with the location name and it then can be imported into CROPFLEX. For help in implementing or running CROPFLEX contact Israel Broner at (970) 491-7872 or email at: israel@engr.colostate.edu.

Israel Broner, Dept. Chemical and Bioresource Engineering, Colorado State University

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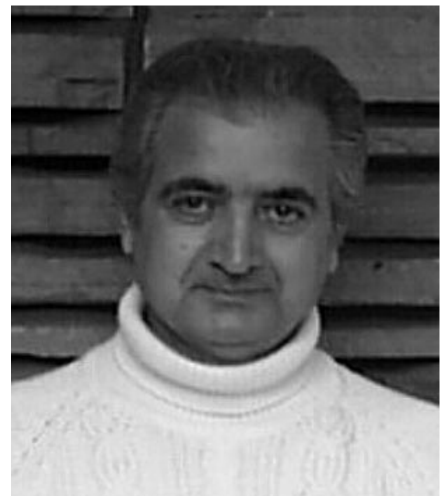

Dr. Parviz Soltanpour

conducts research in the areas of salinity, soil testing, fertilizer recommendations, and availability of heavy metals to plants. He directs graduate student programs and teaches graduate courses in soil-plant nutrient relationships, tropical soils, and crops and farming systems.

At Colorado since 1966, Dr. Soltanpour has served at the CSU research station in Center, Colorado, then at the CSU Soil Testing Lab and presently as a Professor of Soil Science. Parviz has had an extension appointment in the past and can be a resource for information on salinity management, soil testing, and soil fertility.

PAM

A cost-effective tool for improving irrigation and protecting soil and water resources.

The use of PAM in furrow irrigation is probably the fastest growing soil and water conservation technology in irrigated agriculture today. PAM is an acronym for a linear-linked polyacrylamide being used in agriculture to reduce erosion in furrow irrigation. In trials and demonstrations throughout the western U.S., PAM has significantly reduced erosion, up to 99%. The proper use of PAM not only reduces erosion, it also increases infiltration as much as 50% when compared to untreated areas. PAM also helps in high residue furrow irrigation. Because the PAM treated water has a low sediment load and the sediment does not accumulate against the residue, water can flow by the residue. On untreated furrows, sediment stacks up against the residue which can cause the rows to break over.

How PAM works

PAM is an environmentally safe flocculent that is widely used in municipal water treatment, paper manufacturing, food processing, and other industrial applications. Agricultural PAM is available commercially as a dry granular, tablet or liquid product. It works because the large molecule carries a negative charge that acts as a bridge between water molecules and soil particles. This bridge causes increased soil cohesion and strengthens soil aggregation in the irrigation furrows, resulting in greatly reduced detachment and transport of soil sediments. From a surface water quality point of view, the reduction in transported nutrients and particles attached to soil sediments is a significant benefit of PAM.

PAM treated (right) and untreated (left) irrigation runoff.

Because PAM only treats the wetted perimeter of furrows, and since PAM penetrates the soil only a few millimeters, very small application rates are effective. Several suppliers are marketing PAM in Colorado. Typically, granular PAM costs about $5 per acre for 1 application at a rate of 1 lb/acre or 10 ppm in irrigation water. Liquid PAM runs $8 - 10 per application for the same rate. Usually, the supplier can also provide low cost automated head-ditch applicators and technical assistance to get started. Producers should plan on at least two applications for best results. An application during the initial irrigation and another after the final cultivation pass works well for some farmers. Erosion reduction seems to be more effective on medium textured, silty soils than on sandy soils. The economic benefits of saving topsoil are hard to quantify, but we know that sustaining soil quality is essential for long term profitability. In the initial crop season, many producers are seeing a direct economic benefit from increased yields and labor savings.

When applying PAM, it is important that no untreated water wet the furrows ahead of the PAM-treated flow because the untreated water will destroy soil structure before PAM can stabilize it, reducing PAM's effect. If there is a significant amount of suspended sediment in the ditch water, PAM will cause it to settle out almost immediately. Increasing flow rate with PAM treated furrows is often necessary to offset greater infiltration rates. Research in Idaho showed that you can double inflow rates with PAM and achieve greater overall field uniformity while still reducing sediment loss.

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PAM

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Once treated water has reached the end of the furrow, addition of PAM at the head ditch is stopped. Untreated water is used for the remainder of the irrigation and flow rates should be reduced to sustain minimal runoff. Erosion protection declines on the ensuing irrigations, but still is significantly better than non-treated furrows. Furrows disturbed by traffic or cultivation must be retreated. The number of PAM treatments per year will vary with crop and producer objectives but it is common in Colorado to make 2 to 3 applications at 1 lb/acre during a typical growing season.

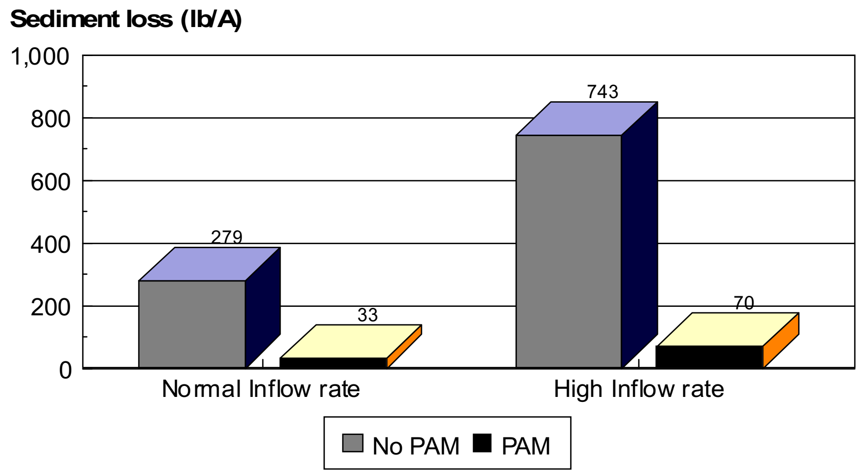

Figure 1. Sediment losses in PAM vs. untreated irrigation water return flows at two inflow rates. **From Sojka and Lenz, 1997.**

Colorado Research with PAM

The improvement in irrigation uniformity and stand establishment achieved with PAM has been shown to improve crop yields in some cases. Jim Valliant, Extension Irrigation Specialist in the Arkansas Valley has shown alfalfa, onions, pepper and tomato yield increases in PAM treated fields as compared to non-treated control fields. Jim has seen particularly good results combining surge irrigation with PAM treatments. Using a combination of PAM and surge irrigation, erosion was reduced an average of 64% while using 25% less irrigation water and producing equal yields of 179 bushels per acre of grain corn when compared to untreated conventional irrigated corn in 1996-7.

In trials at the Arkansas Valley Research Center conducted by Mike Bartolo, soil loss was reduced 47% when using PAM on 6 of 11 irrigations and still produced similar total market weight on onions of 370 cwt/ac compared to 357 cwt/ac on the untreated check in the 1996 trials. In 1997, soil loss was reduced 22% when PAM was applied on only 3 of 10 irrigations and total yield was significantly increased from 377 cwt/ac on the untreated control as compared to 425 cwt/ac on the PAM treated plots.

PAM has also been used to reduce seepage in dirt ditches. Work done by Dan Crabtree of the Bureau of Reclamation on the west slope with models indicated that seepage was reduced as much as 60% by adding PAM and a soil mix to the model troughs. Field work done by Jim Valliant, Colorado State University Cooperative Extension, on a Bureau of Reclamation grant demonstration indicated that adding PAM to water in a dirt lateral ditch carrying 6,000 to 7,000 gallons per minute substantially reduced water levels in two wells located approximately 125 feet from the lateral as compared to the well in the untreated area, also located 125 feet from the lateral. Five (5) pounds of PAM were applied to the flowing ditch water at the rate of one pound per minute. One hour later, another 5 pounds of PAM was applied at the same rate. Since PAM also acts as a flocculent, the sediment load was reduced as much as 67%, from 10,146 to 3,334 pounds per acre-foot. This sediment coated the bottom of the ditch in the 450 foot stretch and reduced seepage to the observation wells below the PAM treated area.

So far, no negative impacts have been documented with PAM usage and producers are rapidly adopting this new technology. The environmental benefits of reduced erosion and contamination transport have been phenomenal in test studies. Improved infiltration and lateral wetting rates seen with PAM can also help producers do a better job irrigating and conserve soil and water resources.

Jim Valliant, Colorado State University Cooperative Extension

web sites

World Wide Web Virtual Library for Irrigation
http://www.wiz.uni-kassel.de/kww/irrig_i.html#index
Multiple links to irrigation topics from around the world

WETTING FRONT The Water Management Research Unit Newsletter
http://www.cprl.ars.usda.gov/wmru/wfront.htm
Newsletters on line from the Conservation & Production Research Laboratory in Bushland, Texas

Irrigation Engineering Publications
http://www.ianr.unl.edu/pubs/irrigation/
Irrigation publications online from the University of Nebraska

Irrigation Publications
http://www.ColoState.EDU/Depts/CoopExt/PUBS/CROPS/pubcrop.html#irr
Irrigation publications online from Colorado State University Cooperative Extension

Irrigation and drainage directory
http://www.ars.usda.gov/id/
Index to USDA/ARS irrigation topics and expertise

PAM Research homepage
http://kimberly.ars.usda.gov/pampage.ssi
Multiple links to research and practical applications of using polyacrylamides in irrigation

Irrigation & Agronomy Page of Southeast Colorado
http://www.ColoState.EDU/Depts/CoopExt/SEA/agro.htm
Area homepage for extension irrigation in Southeast Colorado

USDA Irrigation Information
http://www.wmuinfo.usda.gov
Homepage for the USDA irrigation unit in Ft. Collins.

Irrigation & Agronomy Page of Northeast Colorado
www.Colostate.EDU/depts/CoopExt/GPA
Area homepage for the Golden Plains Area Extension unit.

Cropflex download site:
http//ulysses.atmos.colostate.edu/~crop/.

COOPERATIVE EXTENSION
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