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Polyacrylamide for Furrow-Irrigation Erosion Control

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By Bob Sojka and Rick Lentz

What if flowing water simply didn't erode precious topsoil? That's a pretty big "what if?" — not the kind we usually deal with as agricultural scientists. We are more used to modest incremental improvements in management or understanding of natural processes. Sometimes, though, an innovation occurs that changes everything related to a core idea. Such innovations go beyond breakthroughs, because they do more than just solve one problem. In today's jargon, they are paradigm shifts — changes so radical that they force a complete rethinking of everything they rub against. The sweep cultivator was a breakthrough; 2,4-D was a paradigm shift ... airmail vs. e-mail.

The USDA's Agricultural Research Service Laboratory in Kimberly, ID, has worked since 1991 with an inexpensive polymer chemical (PAM) that nearly eliminates water's ability to erode soil from irrigation furrows. The exciting results of this field research could re-invent furrow irrigation.

Why the excitement about PAM? Polyacrylamide, usually referred to by the chemical acronym PAM (not to be confused with the kitchen fry-pan spray) is a long-chain molecule — a polymer with very high molecular weight. About one pound per acre, applied in advancing furrow irrigation water, reduced field sediment loss an average of 94 percent in the first three years of ARS tests in Idaho.

At the same time, PAM increased net infiltration 15 percent compared to untreated furrows. Because furrows didn't down-cut, lateral wetting extent also increased about 25 percent. In studies across the West, nutrient concentrations, oxygen demand and pesticides in return flows were greatly reduced. These are positive developments for riparian environments and receiving waters.

Today, PAM is one of the hottest new conservation topics in irrigated agriculture. Since 1991, more than 20 scientific papers have appeared in print worldwide documenting the effectiveness and environmental benefits of soil erosion control with PAM.

By the end of 1994, PAM products had been labeled in most U.S. western states as an irrigation-applied soil amendment for erosion control. In January 1995, the NRCS (formerly SCS) approved a western states interim conservation practice standard covering the use of PAM in irrigation water for erosion reduction and infiltration enhancement in furrow irrigation.

Reports from NRCS and PAM distributors indicate that more than 30,000 acres of Pacific Northwest farmland used PAM for erosion and infiltration control in the summer of 1995. Additional use in other states bring the total U.S. PAM-treated acreage in 1995 to around 50,000 acres. This is phenomenal first-season acceptance of a new soil- and water-conservation technology.

The NRCS PAM Practice Standard

The current NRCS standard calls for pre-dissolving PAM in the irrigation water. PAM is applied at a concentration of ten parts per million in the furrow advance water, the water that first runs down the dry furrow before runoff. PAM is halted once advance is complete (when runoff begins), usually a few hours into a typical 24-hour irrigation set. This application scenario generally translates to about one pound of PAM applied per acre.

This full rate application is recommended on the first irrigation of the season and whenever the furrow has been "disturbed," for example, after cultivation. If furrows have not been disturbed, erosion protection is reduced about in half in the next irrigation if PAM is not reapplied. The Kimberly work has seen about 1,000 pounds of erosion prevention for each ounce of PAM used, when following the NRCS standard.

How does PAM work? Water-applied PAM works by increasing soil cohesion and strengthening the soil aggregates it contacts in the furrow. It flocculates suspended sediment, causing it to settle out rather than wash away. PAM also binds soil particles together more securely on the bottom of the furrow, preventing their detachment and transport in the furrow stream.

In untreated water, the suspended fines quickly seal the soil surface, causing the infiltration rate to drop. PAM's action as a flocculent clumps together the fine dispersed particles carried in the flowing water. When settled on the furrow bottom, the PAM-clumped soil has an open pervious structure that resists sealing and doesn't block infiltration through the soil's surface pores.

It is these pores that allow water into the soil profile where it is stored for use by the crop. By keeping the surface of the furrow bottom more porous, runoff rate and amount are reduced, which also reduces stream force, carrying capacity and transport volume.

What Is the Direction of Current PAM Research?

Work continues to improve application ease and efficiency. These refinements may eventually find their way into

The Kimberly, ID, USDA-ARS "Erosion Busters." Back row (L-R) summer aides Liz Whitchurch, Emily Aston and Dena Kirkpatrick, Front row (L-R) Dr. Rick Lentz, technicians Ron Peckenpaugh and Jim Foerster, Dr. Bob Sojka and visiting New Zealand soil scientist Dr. Craig Ross. Photos courtesy: Bob Sojka and Rick Lentz.

a final revision of the NRCS practice standard. Research is directed at two aspects of PAM technology that present the most serious obstacles to ease of use. One research focus has been developing ways to circumvent inconveniences associated with predissolving PAM stock solutions.

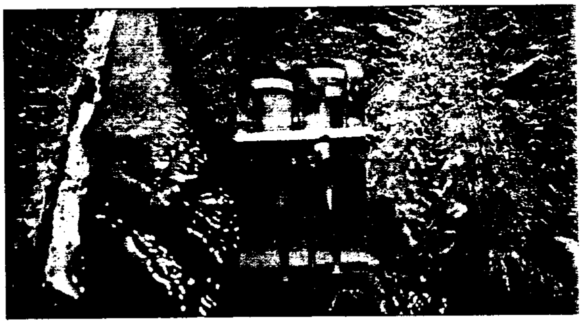
Although PAM dissolves completely in water, it requires energetic agitation. If PAM is not properly dissolved, concentrations are difficult to regulate and PAM can be either over- or under-applied, resulting in poor erosion control (under- application) or undesirable PAM losses in tail water (over-application). Extreme over-application of PAM can actually reduce PAM effectiveness by blocking soil pores.

A second research thrust aims to solve a problem resulting from PAM's incredible potency as a flocculating agent. If the irrigation water supply is high in sediment, adding PAM to the flow can silt-in head ditches and partially clog siphon tubes. In the past year, scientists and farmers have tried various ways to solve these PAM-application problems and simplify its use. Among the approaches evaluated were direct applications of dry PAM granules in the head ditch, coupled with energetic agitation of water.

Using this approach, a dry PAM applicator is placed in the head ditch in front of small dams that produce several turbulent water cascades for mixing. Compressed two-pound PAM-blocks have been used in head ditches and 1/2- to one-ounce cubes designed to dissolve rapidly early in the irrigation have been placed at the individual furrow-heads.

Scientists have experimented with delivery of stock solutions via drip lines intended to supply individual furrows, but so far delivery of consistent rates at each emitter has been difficult. The easiest approach attempted, to date, has been sprinkling the prescribed PAM amount at the head of each furrow in the dry powder form, and letting the furrow inflow slowly dissolve the PAM.

Data from Kimberly ARS and University of Idaho studies indicate these methods can provide effective erosion control, but they vary in their application efficiency and potential for PAM loss in the tail water. Preliminary results from ARS studies in 1994 and 1995 suggest that even when PAM is lost in tail water, its dissolved concentration drops rapidly in return flows. This results from its continued flocculation of encountered suspended sediments and by adsorption to soil lining the wastewater ditch. Responsible and economic use of PAM demands adherence to application methods that keep PAM from reaching receiving waters and riparian resources.



Comparison of control (untreated) furrow (left) and PAM-treated furrow (right). Note sediment load and down-cutting of the control furrow compared to the clarity and integrity of the PAM-treated furrow. Insets are water runoff samples from each furrow showing the difference in sediment load leaving the field.

Information Farmers Should Know

What is PAM? PAM is an off-the-shelf industrial flocculent. The EPA and FDA have approved it for extensive use in food processing, paper manufacturing, municipal water treatment, and many other sensitive applications. The type of PAM registered for soil erosion control under irrigation is moderately anionic, typically having about 18 percent net negative charge density. Molecular weights can be as high as 12- to 15 million grams per mole, or well over 100,000 monomer units per molecule.

The PAMs registered for irrigation use must contain no more than 0.05 percent free acrylamide monomer, which is a toxin. PAMs with these properties have been demonstrated safe for aquatic organisms at these concentrations.

Cooperative work with Idaho State University has identified no significant negative effects on soil microorganisms, and confirms that these PAMs biodegrade safely. Commercial PAMs are about 80 percent active ingredient, whereas initial research was accomplished using PAMs containing about 95 percent active ingredient. PAM concentrations should be calculated on an active-ingredient basis.

Most states require products applied as irrigation- or soil amendments to be registered for these uses. Farmers should be exceedingly cautious about buying unregistered materials not meeting these standards. If they purchase PAM from reputable chemical companies and farm chemical supply houses they are far less likely to obtain inferior or unsafe materials.

Water-soluble PAMs used for erosion control are not the same class of PAM used as super water-adsorbent soil amendments. Water-soluble PAMs are non-crosslinking molecules, and thoroughly dissolve in water if properly mixed. Super absorbent PAMs are crosslinked molecules that form gels to hold water.

Finally, PAM is only one class of an almost infinite number of "polymers" in the realm of chemistry. Polymer is a generic term, in the same sense that "building supplies" could mean anything from particle board to thermostats. Irrigators should be sure to determine that they are purchasing water-soluble PAM with the properties we have described.

Whether delivering PAM as a concentrated stock solution or dissolving dry PAM in the head ditch, it is important that care is taken to assure complete dissolving of the added PAM. If PAM is added to water too rapidly, granules and clumps of granules will form resistant gel-like globs, often called "fish-eyes" for their appearance. Such incomplete and uneven dissolution will result in poor delivery uniformity and uneven application and erosion control.

Slow uniform granule addition, accompanied by vigorous mixing, will ensure good dissolution and uniform application. In head ditches, the use of several turbulent drops after the point of granule addition and some ditch distance before the first siphon tube is advisable. PAM dissolves more easily in warm water than cold water.

When applying PAM, it is important that the furrows to be treated are dry and not exposed to PAM-free water before the PAM-treated water enters the furrow. In other words, PAM needs to beat a ten ppm concentration in the first drop of water to hit the furrow for best effectiveness. PAM does not create soil structure, but rather it stabilizes existing soil structure.

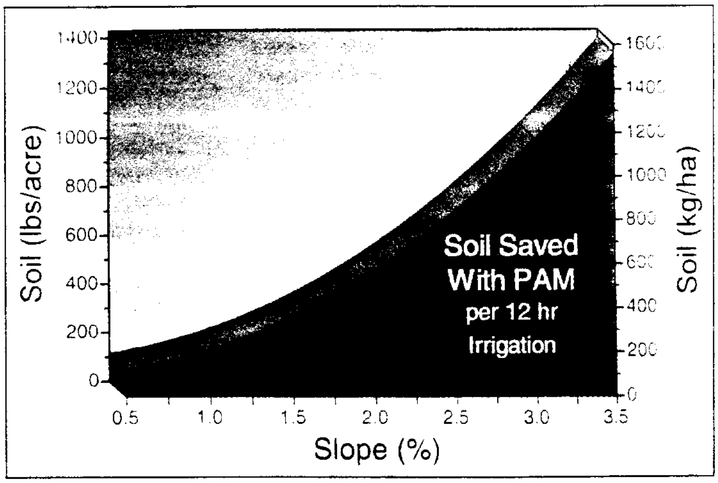
If untreated water has already passed down the furrow, the small clods and aggregates that provide structure will have been slaked away, initiating seal formation. Once this occurs, PAM's erosion controlling and infiltration stabilizing effectiveness will be greatly reduced.

continued on page 10

Erosion Control
continued from page 9

The same principle applies if the ground is wetter than usual between irrigations, for example if it has rained some but you go ahead and irrigate anyway to keep "on schedule." A thoroughly wet profile reduces water infiltration, and it is infiltrating water that carries PAM to the thin layer of soil aggregates at the soil water interface, where PAM's binding effects work. Also, even if only the surface inch or two is damp at the time of irrigation, soil erodability will already be somewhat increased, and the water films on and around aggregates will impede PAM effectiveness.

Normally, erosivity of a fixed streamflow increases drastically in furrows with slope. PAM combats this effect, as shown by the increased relative soil savings with identical PAM treatment on increasing slopes.



If irrigation water is high in sediments, farmers may need to consider several options to prevent sedimentation problems that will be caused by PAM. One approach is to introduce PAM to the water via a small settling pond at the upper end of the field. Another is to deliver PAM directly at the head of each furrow, rather than in the head ditch.

If gated pipe is used, sediment is usually less of a problem if the PAM is introduced in the pipe, where the confined flow sustains velocities well enough to push sediment along pipes and out the individual gates. When using gated pipe, turn the gates a little more downward than usual. This will wash out flocculated sediment more effectively. Also, when irrigating multiple sets with one pipeline, irrigate the set closest to the treated water inlet first and the farthest set last. This further decreases sedimentation near the inlet, and reduces the chance for accumulated PAM-caused sediment to set up and resist subsequent flushing.

PAM Spearheads Changes in Furrow Irrigation

Because PAM both increases infiltration and substantially halts erosion, much about how soil and water are managed under furrow irrigation can be changed, while still accomplishing important conservation goals. PAM use allows much higher inflow rates while still greatly reducing soil loss. This results in greatly reduced advance times. Since infiltration opportunity time can be more nearly equal from top to bottom of the field, irrigation uniformity can be greatly improved. PAM's properties might facilitate development of improved surge-flow technology without the risk of accelerated erosion.

Improved infiltration can reduce water costs and shorten set times, particularly early in the season, when PAM's greater lateral wetting can more efficiently deliver the small amount of water needed to germinate seed or water seedlings. Improved infiltration is also particularly advantageous on steep field portions that otherwise severely down-cut and fail to soak up enough water for profitable yields. Since most farmers furrow irrigate to avoid stress at the lower end of the field, upper ends are typically over-irrigated, causing leaching of nitrates and other soluble chemicals.

If irrigation uniformity is improved, groundwater can be more easily protected. Harvest yield and quality can be improved because of more near-optimal water and nutrient availability along the furrow. If soil isn't transported down the furrow, furrows need not be as deep, and fields might be longer without risk of erosion.

Cultivation for furrow reshaping can be eliminated or reduced, as might field-sediment-retention ponds, along with their attendant operational costs and loss of production acreage. Fewer field operations also reduces fuel and labor costs while conserving fuel and reducing emissions.

Halting surface erosion reduces loss of soil inputs, and prevents exposure of untreated weed seeds in furrows. Reduced sediments in return flows will reduce ditch-cleaning costs and improve the health of receiving waters and riparian areas. Perhaps most importantly, PAM has not shown any adverse environmental impacts with proper use.

PAM provides yet another highly effective tool in a balanced conservation plan. It offers a soil conservation alternative to furrow irrigators for whom other conservation practices are precluded by some aspect of the farming operation, such as lack of adequate surface residues. Work in Idaho has even shown that early-season PAM use can improve performance of mechanically placed straw mulches by preventing straw migration down furrow.

Until recently, the number of agricultural scientists investigating PAM use in irrigation has been limited to a handful of scientists worldwide. The widespread successful on-farm experiences of the 1995 growing season have prompted numerous new research efforts. PAM use has gone from a laboratory curiosity in 1991, greeted by the uninformed with the skepticism usually reserved for "snake-oil" compounds, to one of the most promising irrigation management- and soil-conservation opportunities in recent decades. We think this exciting new technology is definitely one worth keeping an eye on ... and trying. ❑

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