REDUCTION OF NUTRIENT AND PESTICIDE LOSSES THROUGH THE APPLICATION OF POLYACRYLAMIDE IN SURFACE IRRIGATED CROPS

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Within southern Idaho furrow irrigated croplands can be impacted by irrigation induced erosion. Soil erosion T-values can be exceeded on certain types of soils and slopes *(Carter, 1990; Lentz and Sojka, 1994)*. Work conducted in southern Idaho, related to furrow irrigated erosion, has documented erosional mechanisms and processes *(Berg and Carter, 1980; Carter and Berg, 1983; Carter and Berg, 1991; Carter et al. 1993)*. Soil erosion, and nutrient and pesticide losses are concerns for producers using surface irrigation. Crop production and profitability can be negatively affected *(Carter and Berg, 1991; Carter, 1993)*. Soil lost with tailwater removes nutrients and pesticides from fields which were applied to benefit crops. Surface water quality can be impacted effecting beneficial uses of streams.

Nitrogen and phosphorus containing compounds have been well documented to leave agricultural fields finding pathways to receiving water bodies *(EPA, 1973; Brown et al. 1981; Brown, 1985b; Martin, 1983; Clark, 1985; Clark, 1994)*. Agricultural watershed evaluations in southern Idaho have focused mainly on the Middle Snake, Lower Boise, Lower Payette, and Weiser Rivers. Nutrients can enter these river systems through return flows impacting water quality and beneficial uses *(Martin, 1983; Clark, 1985; Clark, 1994)*. Sediment yields have been linked to nutrient losses in a number of Idaho river systems.

Pesticide detections in surface water bodies in various locations of North America have been determined through monitoring efforts *(Frank et al. 1982; Baker, 1985; Clark, 1985; Gilliom et al. 1985; Muir and Grift, 1987; Arruda et al. 1988; Frank and Logan, 1988; Good, 1988; Spalding and Snow, 1989; Richards and Baker, 1993; Clark, 1994)*. Muir and Grift (1987) detected pesticides including trifluralin, and bromoxynil within an agricultural watershed. Spalding and Snow (1989) detected pesticides including EPTC, and trifluralin in a tributary to the Platte River in Nebraska. Richards and Baker (1993) detected a number of compounds, terbufos and chlorpyrifos, in agricultural watersheds to Lake Erie.

Within Idaho, agricultural drains leading to the Weiser River were found to contain lindane, 2,4-D, 2,4,5-T, PCP and toxaphene during sampling events in 1983-1984 *(Clark, 1985)*. Clark (1995) reported numerous detections of pesticides in surface water and bottom sediment in the upper Snake River Basin from projects implemented from 1975-1989.

Assessments of Best Management Practices (BMPs) to reduce pesticide runoff have been conducted *(Walter et al. 1979; Baker and Johnson, 1983; Brown, 1985a, 1985b; Felsot et al. 1990; Carter et al. 1993)*. Various field experiments have been conducted to evaluate sediment and water transport of pesticides *(White et al. 1967; Hall et al. 1972; Baldwin et al. 1975; White et al. 1976)*.

Impacts of agricultural chemicals on aquatic systems are of concern. Under Section 303(d) of the Clean Water Act (CWA), the United States Environmental Protection Agency (EPA) and states must evaluate which stream segments are water quality limited. Within southern Idaho the Middle Snake, Lower Boise and Lower Payette Rivers have been determined to be water quality limited, and are classified as highly impacted. Sediment, nutrients, and pesticides have been determined to be several of the major pollutants *(IDHW-DEQ, 1994)*.

In 1991 work began at the USDA Agricultural Research Service (USDA-ARS) site in Kimberly, Idaho, to assess high molecular weight, moderately anionic Polyacrylamide (PAM) compounds to prevent soil erosion *(Trout and Lentz, 1993)*. Researchers found that an addition of 5 to 10 mg/L of PAM can reduce sediment yields by 70 to 99% *(Trout and Lentz, 1993; Lentz and Sojka, 1994)*.

Limited laboratory or field experiments have been conducted to show the effects of PAM at controlling transport of nutrients and pesticides from furrow irrigated sites. Agassi et al. (1995) created variable erosion with a high molecular weight polymer in a laboratory setting. Bromide and napropamide were evaluated for transport effects on a sandy loam soil. Agassi et al. (1995) determined that when sediment losses were reduced, pesticide losses were greatly reduced. Lentz and Sojka (1994) conducted furrow erosion PAM experiments in southern Idaho and found significant reductions of sediment, total phosphorus and nitrate when using PAM.

As the potential for rapid PAM adoption became evident, further evaluation of PAM and the effects on nutrient and pesticide yield were needed. The objectives of these field trials were to: conduct on farm PAM trials managed by growers and irrigators; evaluate PAM effectiveness for controlling soil erosion; evaluate PAM effectiveness as nutrient and pesticide Best Management Practices; and study the potential for widespread adoption of PAM technology for the protection of surface water systems.

Materials and methods

Two sugar beet and one onion field, in southwest Idaho, were evaluated in coordination with three separate growers (Table 1). Interested growers with similar siltloam soils and field characteristics were sought. The field trials were conducted cooperatively with the Owyhee, Payette, and Weiser River Soil and Water Conservation Districts; and American Fine Foods, Inc. The high molecular weight anionic PAM, SUPERFLOC A836, was provided by Cytec Industries, Inc.

Each field was set up to evaluate a PAM applied treatment, and a NO PAM control where conventional furrow irrigation was practiced without the PAM. Within each treatment, three furrows were selected for evaluation. Wheel row furrows and furrows influenced by possible agrichemical applicator overlap were avoided. Within the 24-hr. irrigation set for each field, each furrow was sampled at three times; 15 min, 4, and 22 hafter irrigation advance rate breakthrough.

Table 1 On-farm trial site locations and characteristics for 1995 PAM demonstrations

SITE	CROP	SOIL and SLOPE	RUN LENGTH (ft)
#1	sugar beets	Garbutt silt loam (0.75%)	1085
#2	sugar beets	Greenleaf silt loam (0.80%)	1100
#3	onions	Greenleaf silt loam (1.5%)	770

The Owyhee County site was a 40 ac sugar beet field with a Garbutt siltloam soil with a 0.75% slope, and a furrow length of 1085 ft (Table 1). The Payette County site was a 50 ac sugar beet field on a Greenleaf siltloam soil with a 0.80% slope, and a furrow length of 1100 ft (Table 1). The Washington county site was a 20 ac. onion field on a Greenleaf siltloam soil with a 1.5% slope, and a furrow length of 770 ft (Table 1).

Each site was evaluated at first irrigation following soil cultivation. Each grower preferred to maximize the number of acres under PAM treatment. Due to these requests the PAM application sites were conducted within each head ditch shortly downstream from each irrigation delivery point. An adequate border was left for the NO PAM treatment furrow to minimize edge of field influences.

The PAM product, SUPERFLOC A836, was provided by Cytec Industries, Inc. The USDA Natural Resource Conservation Service national specification was followed *(USDA, 1995)*. High molecular weight, anionic charged PAM was applied to the head ditch at 1.0 to 1.25 lb.-per-ac. rate, equivalent to 1.0 ppm.

At site one, liquid PAM solution was prepared from dry granules and was applied to the head ditch with a liquid drip applicator. For sites two and three, dry PAM was metered directly into irrigation water with a Gandy type applicator. Irrigation advance phase PAM treatment was followed once the irrigation water reached the end of the furrow.

Irrigation was applied with siphon tubes set at typical flow rates for the field. Water inflow and outflow were measured using a catch can and stop watch on three furrows per treatment for each 24-h irrigation. Irrigation advance rate was determined for each furrow. Imhoff cones were used to measure runoff sediment content. A complete water budget for each furrow and treatment.

Water and soil slurry samples were collected from tailwater runoff. Sample locations were located up gradient, within each furrow, to avoid possible influences from agrichemical buildup due to application equipment turning around at the end of each row. Soil slurry samples were collected from sediment traps located at the end of the furrows.

Water samples were analyzed for nitrate-nitrogen (NO_3-N), nitrite-nitrogen (NO_2-N), ammonia-nitrogen (NH_3-N), total nitrogen (TKN), total phosphorous and ortho phosphorus. Soil slurry samples were analyzed for soluble phosphorus, available phosphorus, and nitrogen as ammonia and ammonium. Water and soil slurry samples were analyzed for terbufos and cycloate at site one; EPTC, trifluralin and terbufos at site two; and oxyfluorfen, pendimethalin, chlorpyrifos and bromoxynil at site three. Field and laboratory work was conducted with quality assessment/ quality control (QA/QC) components integrated. All analysis were conducted at the University of Idaho, Analytical Sciences Laboratory in Moscow, Idaho.

Results

PAM application produced highly visual results at all three sites with irrigation runoff water having a transparent or clear appearance. Runoff from untreated furrows contained significant quantities of silt. Comparing the two treatments, the visual appearance of clear tailwater leaving the PAM treated field sites provided for a high degree of producer interest. Nutrient and pesticide concentrations in tailwater and sediment were also greatly reduced as the result of PAM application.

▼ **Sediment Loss.** PAM reduced sediment loss by 35 to 99%. Sediment losses were greatly reduce for the PAM treatment furrows for site one and site three (Figure 1). There was less success of controlling sediment on site two due to difficulties in maintaining proper siphon tube flow rates and PAM application rates.

Figure 1

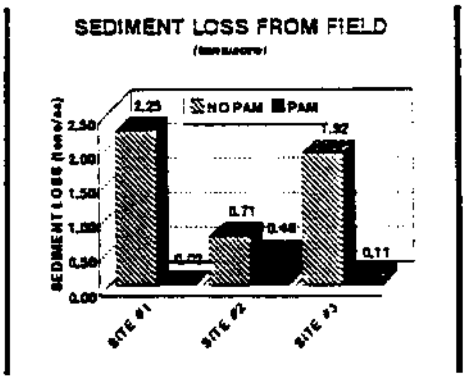

Figure 1. Sediment loss (tons/acre) from PAM trial sites in southwestern Idaho.

As displayed in Fig. 1, the NO PAM treatment for site one accounted for 2.25 tons/ac of sediment losses as compared to 0.02 tons-per-ac. for the PAM treated furrows. This accounts for an average reduction of sediment of 99% by using the PAM product. Site two had an average reduction in sediment losses of 35%. Site three had an average reduction in sediment losses of 94%.

When water is managed to keep runoff below 25% of the total applied, PAM can reduce soil losses by over 95%. The amount of PAM needed to achieve this level of erosion control cost each grower between $4-$6/ac for one irrigation.

▼ **Losses of nitrogen compounds.** Along with sediment reduction, PAM accounted for a reduction of nutrient losses in runoff water. The results for nitrogen compounds indicates PAM significantly reduces nitrogen concentration in runoff water.

Nitrate-nitrogen (NO_3-N) and total nitrogen (TKN) were significantly reduced at most all sites for tailwater and sediment. The sediment fraction, lost off field sites, generally contained a greater percentage of nitrate-nitrogen (NO_3-N), and total nitrogen (TKN). PAM treatments controlled erosion and were very effective at controlling nitrogen attached to sediment and organic particles. Over the length of each irrigation set (24 h.) the PAM treatments greatly reduced nitrogen losses. Calculations incorporating water and sediment measurements with chemical analysis indicate that PAM application reduced nitrogen loss up to 86%.

Figure 2

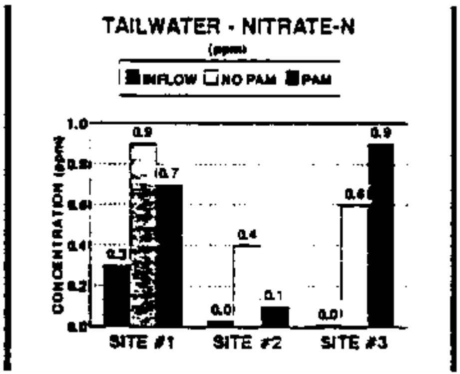

Figure 2. Tailwater concentrations (ppm) of Nitrate-N (NO_3-N) for PAM trial sites in southwestern Idaho.

The median nitrate-nitrogen (NO3-N) tailwater concentration was less for site one and two under the PAM treatment compared to the NO PAM treatment (Fig. 2). All median values for either treatment were all less than 0.9 ppm. All values are relatively low in concentration for this constituent.

Figure 3

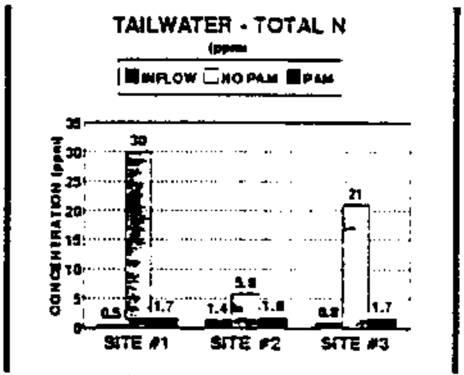

Figure 3. Tailwater concentrations (ppm) of Total Nitrogen (TKN) for PAM trials sites in southwestern Idaho.

The PAM treatments at all three sites were successful in controlling total nitrogen (TKN) concentrations. Total nitrogen was greatly reduced by PAM treatments at site one and two (Fig. 3). Under PAM treatment at site one, the median total nitrogen for all sampling time periods was reduced from 30 ppm to 1.7 ppm. Similar results were achieved at site three. The median total nitrogen concentration for all three PAM treated sites were similar. Reported results show concentrations of 1.7, 1.8 and 1.7 ppm at sites one, two and three respectively (Fig. 3). Substantial reductions in nitrogen can be achieved from PAM applications at the first irrigation set.

When assessing the losses of nitrogen compounds over the length of the irrigation set, the PAM treatments effectively controlled nitrate-nitrogen and total nitrogen. Due to the soluble nature of nitrate-nitrogen, the effect of PAM treatment at controlling the losses of this compound was not achieved until 4 h after furrow outflow began (Fig. 4). Throughout the remainder of the irrigation set, the nitrate-nitrogen concentrations remained less for the PAM treatment as compared to the No PAM treatment. The PAM treatment was very successful in controlling total nitrogen over the entire length of the irrigation set (Fig. 5). PAM proves to be effective in controlling nitrogen constituents throughout the irrigation set, especially for total nitrogen.

Figure 4

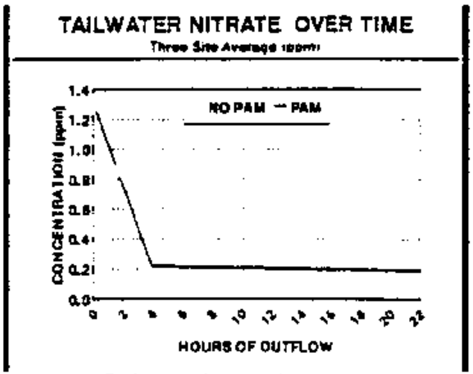

Figure 4. Tailwater Nitrate-Nitrogen (NO_3-N) concentrations (ppm) as a three site average over the length of the irrigation set.

Overall losses of nitrogen constituents from the NO PAM treated fields were significant. As calculated in lb/ac, nitrogen losses at site one for the NO PAM were significant as compared to the PAM treatment (Fig. 6). Twenty lb/ac of nitrogen constituents leaving the site one field as compared to less than 2 lb/ac for the PAM treated furrows is a substantial reduction in nutrient loading. The PAM treated furrows at site three also represent a substantial reduction in nitrogen constituents as compared to the NO PAM treated furrows (Fig. 7).

Figure 5

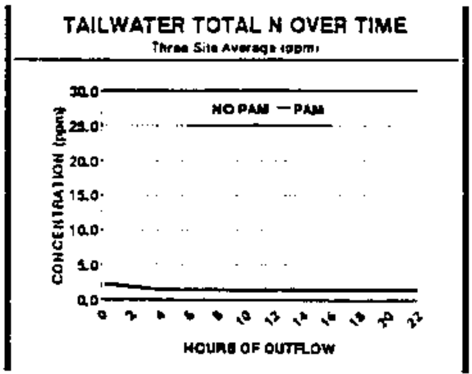

Figure 5. Tailwater concentrations (ppm) for Total Nitrogen (TKN) as a three site average over the length of the irrigation set.

Figure 6

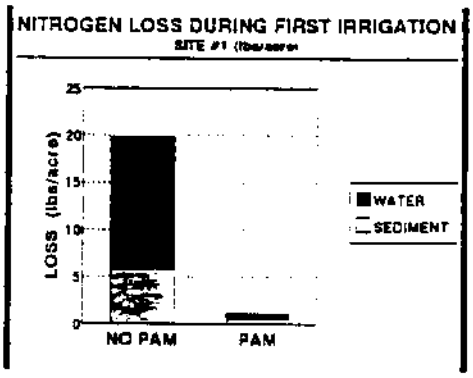

Figure 6. Nitrogen loss (lbs/acre) for tailwater and sediment for PAM and NO PAM treatments during first irrigation at PAM trial site number one.

Figure 7

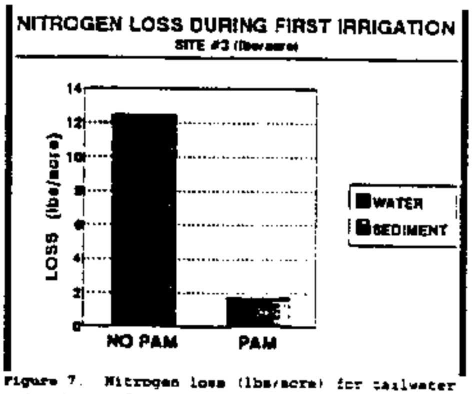

Figure 7. Nitrogen loss (lbs/acre) for tailwater and sediment for PAM and NO PAM treatments during first irrigation at PAM trial site number three.

Fractioning the sediment component from the water component as the water left each field proved to be a valuable effort. At all three sites the sediment component represented an important part of the nutrient losses off each field. At site three, the sediment fraction contained the majority of the nutrient loading leaving the furrows. Over 12 lb/ac of nitrogen compounds were lost from the field for site three (Fig.7). Over 90% of this loss was contained within the sediment fraction of the tailwater. The application of PAM greatly reduced this loss, although the sediment fraction still remained a significant portion of the losses within these PAM treated furrows.

▼ **Losses of phosphorus compounds.** As with nitrogen compounds, the PAM treatments were effective at reducing overall phosphorus losses from the three sites evaluated. Total phosphorus and ortho phosphorus were greatly reduced in tailwater. Phosphorus losses due to sediment yield were also greatly reduced. When the transport of the sediment fraction was reduced the total and ortho phosphorus were greatly reduced. During the length of each irrigation set (24 h) the PAM treatments greatly reduced phosphorus nutrient losses. Calculations incorporating water and sediment measurements with chemical analysis indicate that PAM application reduced phosphorus losses by up to 79%.

Figure 8

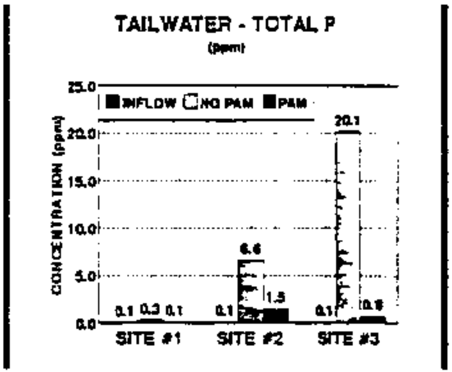

Figure 8. Tailwater concentrations (ppm) of Total Phosphorus for PAM trial sites in southwestern Idaho.

For tailwater, median total phosphorus concentrations for all sampling time periods was greatly reduced at site two and three (Fig. 8). Total phosphorus at site three was reduced from a median value of 20.1 ppm for the NO PAM treatment to 0.8 ppm for the PAM treatment. The site three onion field fertilization practices may have had an impact on the median total phosphorus concentration for the NO PAM treatment.

Figure 9

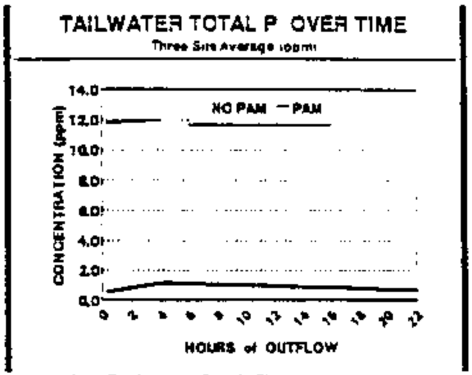

Figure 9. Tailwater Total Phosphorus concentrations (ppm) as a three site average over the entire irrigation set.

PAM treatments, as a three site average, were very successful in controlling total and ortho phosphorus containing compounds for the entire irrigation set (Fig. 9 and 10). Three site average concentration differences for total phosphorus were significantly reduced throughout the irrigation set by using PAM (Fig. 9).

Figure 10

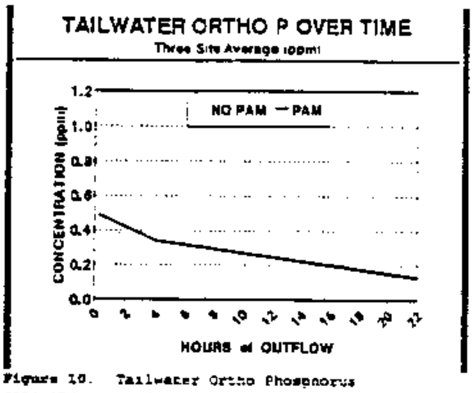

Figure 10. Tailwater Ortho Phosphorus concentrations (ppm) as a three site average for the entire irrigation set.

Figure 11

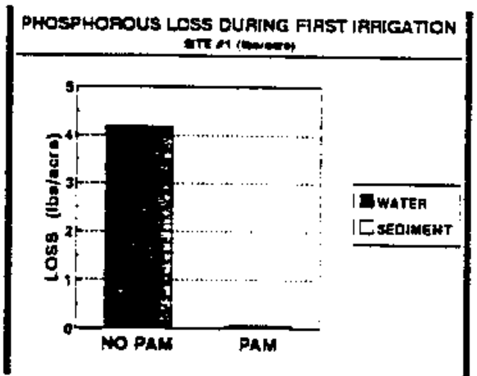

Figure 11. Phosphorus losses (lbs/acre) for tailwater and sediment for PAM and NO PAM treatments during the first irrigation at PAM trial site one.

For phosphorus, the overall losses from the NO PAM treated fields were significant. As calculated in lb/ac, phosphorus losses at site one and three for the NO PAM were substantial as compared to the PAM treatment (Fig. 11 and 12). Phosphorus reductions were found to occur at site one with the application of PAM treatments (Fig. 11). From NO PAM treatment of site three, over 7 lb/ac of phosphorus constituents were determined to leave the end of the furrows as compared to less than 2 lb/ac for the PAM treated furrows (Fig. 12).

Figure 12

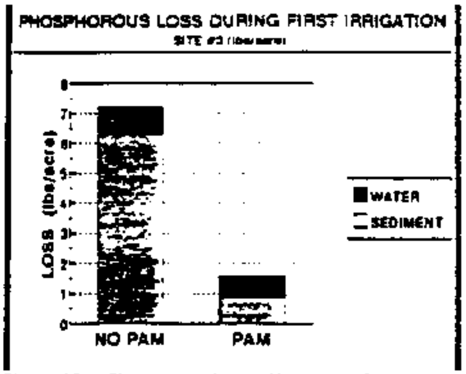

Figure 12. Phosphorus loss (lbs/acre) for tailwater and sediment for PAM and NO PAM treatments during first irrigation at PAM trial site number three.

For the NO PAM treatments the sediment component contained a significant quantity of phosphorus leaving each field. At site one, the PAM treatment significantly reduced phosphorus leaving the field with sediment (Fig. 11). The sediment portion of the tailwater at site one and three contained significant quantities of phosphorus (Fig. 11 and 12). The PAM applications were successful in greatly reducing the phosphorus loading, especially from the sediment portion.

Figure 13

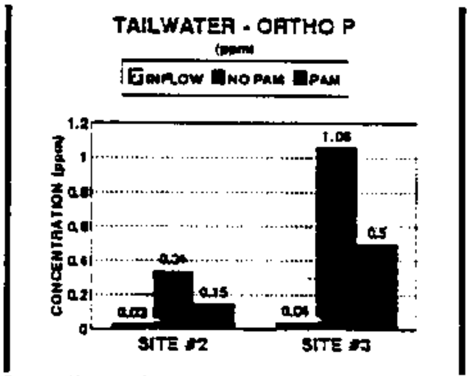

Figure 13. Tailwater concentrations (ppm) for Ortho Phosphorus for PAM trial sites two and three.

Ortho phosphorus was evaluated for sites two and three. For these two sites, the PAM treatments were successful in controlling ortho phosphorus (Fig. 13). The trends were similar as compared to total phosphorus. Site three had a higher concentration (1.06 ppm) of ortho phosphorus for the No PAM treatment as compared to site two (0.34 ppm).

Evaluation of pesticide transport. For the trial sites all pesticides utilized by growers, except cycloate, were detected in sediment samples. The majority of pesticides utilized were detected in tailwater samples, with the exception of cycloate and terbufos. Sites two and three accounted for the majority of detections. For the majority of compounds the sediment detections were the highest in concentration.

Of the herbicides, EPTC and pendimethalin were detected in 100% of the samples analyzed for these compounds. At site one there were no detections of the herbicide cycloate in water or sediment. The majority of detections of oxyfluorfen were in the sediment fraction of site three. In the following order, the herbicides EPTC, pendimethalin, trifluralin, bromoxynil and oxyfluorfen were most frequently detected.

There were no detections of the insecticide terbufos in the water fraction sampled at site one or two. Terbufos was found in sediment at site one for both PAM and NO PAM treatments but not at site two. There were an equal number of detections of terbufos in sediment samples from the PAM and NO PAM treatments. Chlorpyrifos detections were found in 100% of sediment samples collected and 82% of tailwater samples collected.

Figure 14

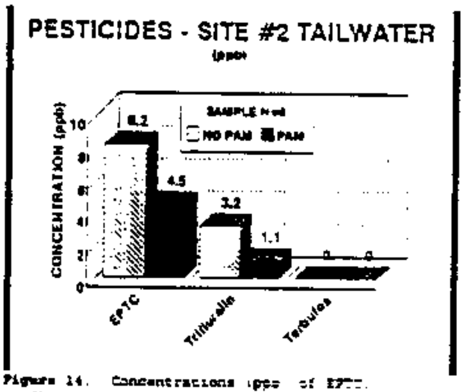

Figure 14. Concentrations (ppb) of EPTC, trifluralin, and terbufos in tailwater from PAM and NO PAM treatments at site number two.

EPTC and trifluralin were detected in tailwater at site two (Fig. 14). There were no detections of terbufos in tailwater (Fig.14). The median detections of EPTC and trifluralin, for all times from the PAM treated furrows, were less than the NO PAM furrow detections (Fig. 14). The concentration range and median value was less for the PAM treated furrows for EPTC and trifluralin (Fig. 15). Over the length of the irrigation set, the concentrations of EPTC and trifluralin within the PAM treated furrows were significantly less (Fig. 16). With PAM treatment trifluralin losses were reduced over the irrigation set.

Figure 15

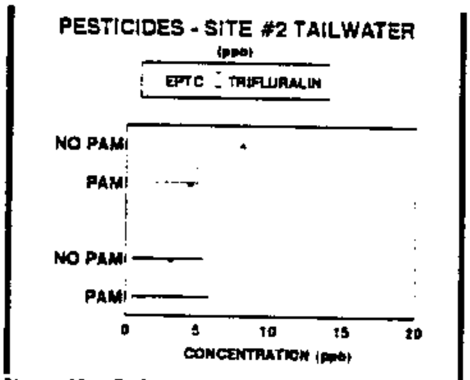

Figure 15. Tailwater median concentrations (ppb) and ranges of EPTC and trifluralin detected for PAM and NO PAM treatments at site number one.

Figure 16

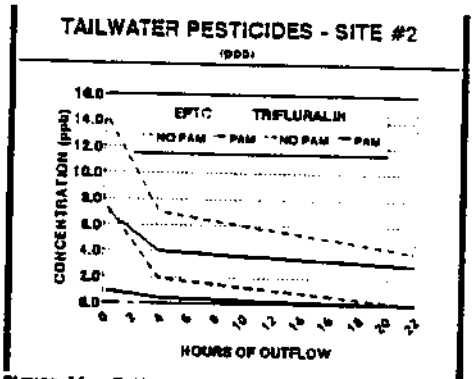

Figure 16. Tailwater concentrations (ppb) of EPTC and trifluralin for PAM and NO PAM treatments for the entire irrigation set at PAM trial site number two.

Site three tailwater contained detections of bromoxynil, chlorpyrifos, oxyfluorfen, and pendimethalin in order of frequency of detections. Concentrations of detections from the PAM treated furrows were either lower or equal to the detections under the NO PAM control (Fig.17). PAM treatment provided for a significant reduction of bromoxynil leaving the field through tailwater transport (Fig.17 and 18). Average concentrations of the other compounds were quite low (Fig.17). PAM treatment appeared to have no effect on tailwater transport of chlorpyrifos and oxyfluorfen. Average concentrations of bromoxynil over the span of the irrigation set were much less for PAM as compared to NO PAM treatment (Fig.19). Initial transport of pendimethalin for the NO PAM control appeared to occur in the first few hours of the first irrigation set (Fig.19). However, concentrations of this compound within the first few hours are somewhat low (Fig.19). After 4 h from furrow breakthrough the average concentrations of pendimethalin for PAM and NO PAM treatments were similar throughout the set (Fig.19). Transport of these compounds through tailwater was determined to be minimal.

Figure 17

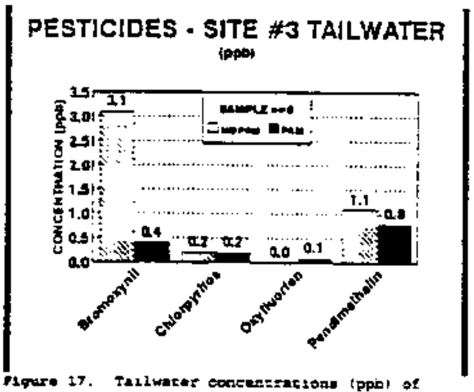

Figure 17. Tailwater concentrations (ppb) of bromoxynil, chlorpyrifos, oxyfluorfen, and pendimethalin for PAM and NO PAM treatments at PAM trial site number three.

Figure 18

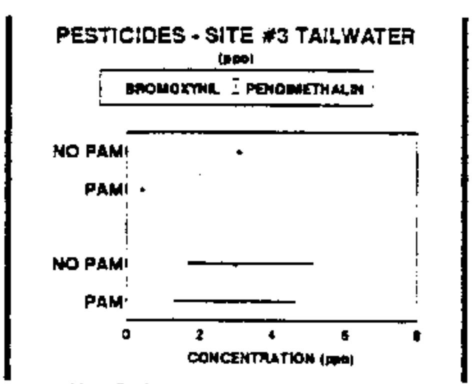

Figure 18. Tailwater concentration (ppb) median and concentration range values for bromoxynil, and pendimethalin for PAM and NO PAM treatments at PAM trial site number three.

These four compounds exhibited a potential for transport off field site through sediment yield. Pendimethalin, oxyfluorfen, chlorpyrifos and bromoxynil, in that order, showed an affinity for attachment and transport with sediment. PAM treatment did reduce average concentrations of these compounds leaving the furrow (Fig.20). The average concentration of pendimethalin for sediment was 654 ppb for NO PAM treatment as compared to 275 ppb for PAM treatment. PAM treatment also reduced concentrations of the other compounds in sediment especially for oxyfluorfen.

Figure 19

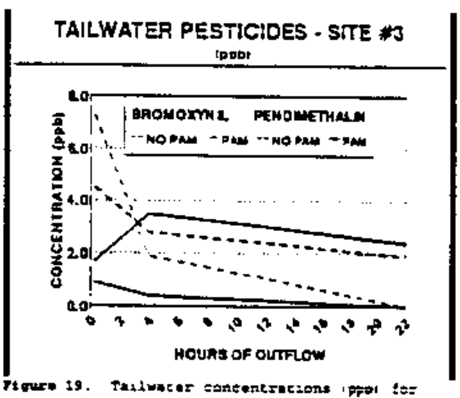

Figure 19. Tailwater concentrations (ppb) for bromoxynil, and pendimethalin for the entire irrigation set for PAM and NO PAM treatments at PAM trial site number three.

Figure 20

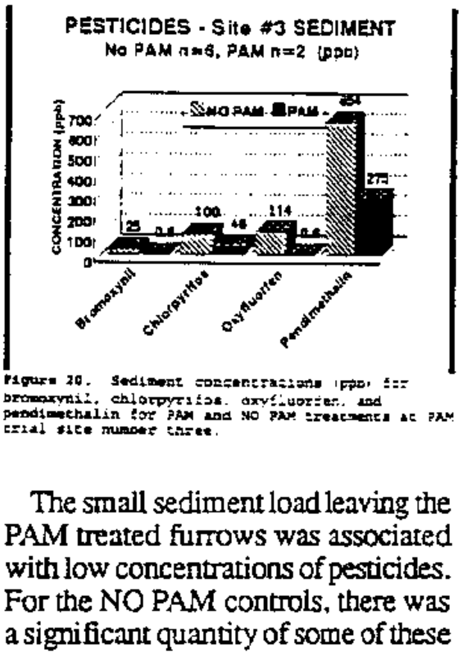

Figure 20. Sediment concentrations (ppb) for bromoxynil, chlorpyrifos, oxyfluorfen, and pendimethalin for PAM and NO PAM treatments at PAM trial site number three.

The small sediment load leaving the PAM treated furrows was associated with low concentrations of pesticides. For the NO PAM controls, there was a significant quantity of some of these compounds, especially pendimethalin, leaving the field site. When assessing the tailwater concentrations of pendimethalin and bromoxynil, within the first few hours of the set (Fig. 20), it is likely that the majority of losses of these compounds is through sediment yield which occurs within the first few hours of irrigation. It is apparent that if sediment yield is controlled by PAM, that specific compounds could be controlled from moving off site. Pesticide losses for the compounds evaluated in this study appear to be greater in overall loading and concentrations when transported by sediment yield versus tailwater.

Compounds such as bromoxynil and oxyfluorfen can be prevented from leaving the site through sediment transport under PAM treatment. The characteristics of these compounds and application parameters can influence the transport mechanisms. Pendimethalin has a very low solubility (0.50 mg/L) but has a very high Koc of 104 *(Honeycutt and Schabacker, 1994)*. This compound is prone to transport due to the high adsorption coefficient and possibly application parameters. Chlorpyrifos has a very low solubility (0.4 mg/L) and also has a high Koc of 6000 *(Honeycutt and Schabacker, 1994)*. Chemical characteristics and application techniques probably contribute to transport of this compound. Oxyfluorfen also has a low solubility (0.1 mg/L) and a very high Koc of 105 *(Honeycutt and Schabacker, 1994)*, contributing to its transport in sediment. With a lower Koc (200) and a solubility of 130 mg/L *(Honeycutt and Schabacker, 1994)*, bromoxynil would have a potential for both sediment and tailwater transport. Site three data indicates bromoxynil is present in both tailwater and sediment. Application parameters may also influence this result. Timing of application, application method, tillage factors, application placement and irrigation water management can have an influence on transport potential.

The PAM treatments consistently provided successes at sites two and three at controlling the losses of pesticides applied to the growing sites. At site one there were no detections of applied pesticides in the water or sediment fractions sampled. With this result, there was no treatment effect for controlling terbufos, and cycloate pesticides that may leave the growing site, by applying PAM.

Summary

The three PAM trials were a success in many ways. Project objectives were met. PAM applications resulted in greater retainment of sediment, nutrients, and pesticides on field sites as compared to NO PAM controls. The on-farm trials were a success for both growers and agency personnel. The application of high molecular weight, anionic PAM to these sites proved to be a successful best management practice.

PAM reduced sediment loss by 35 to 99%. Calculations incorporating water and sediment measurements with chemical analysis indicate PAM application reduced nitrogen loss up to 86%. Calculations incorporating water and sediment measurements with chemical analysis indicate that PAM application reduced phosphorus losses by up to 79%. Reduction in pesticide losses with the use of PAM was confirmed with these trials. Pesticide losses were greater with the sediment fraction for the NO PAM furrows as compared with the PAM furrows. Pesticide losses are also dependant on pesticide management parameters, and chemical and physical properties of compounds.

Application of PAM at recommended rates during irrigation advance can significantly reduce soil erosion, and nutrient and pesticide losses from farm fields. Widespread adoption of PAM technology can assist in economically protecting surface waters from sedimentation and nutrient loading. This practice must be implemented as recommended within the NRCS standard and specification *(USDA, 1995)* and be incorporated with other practices such as irrigation water management. PAM treatment should be customized for fields of varying erosion potential, water management and agrichemical management. With the use of PAM there may be potential for agrichemical management to be to adjusted. The results for the NO PAM controls indicate management changes are needed if PAM is not used.

Water quality in agricultural watersheds could benefit from the adoption of the PAM on furrow irrigated fields. The results indicate a substantial reduction of sediment, nutrients and pesticides losses off growing sites. Economic benefits could be gained with the retention of soil, and agrichemicals on the growing sites benefiting agriculture and water quality.

Table 2 Average nutrient content of irrigation runoff averaged over 3 sites, 1995

Water Analyzed	Ortho Phosphorus (ppm)	Total Phosphorus (ppm)	Nitrate Nitrogen (ppm)	Total Nitrogen (ppm)
Inflow Water	0.03	0.08	0.11	0.9
Runoff NO PAM	0.70	9.01	0.63	18.9
Runoff PAM	0.32	0.78	0.57	1.7

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White, A.W., A.P. Barnett, B.G. Wright, and J.H. Holladay. 1967. Atrazine losses from fallow land caused by runoff and erosion. Environ. Sc. Technol. 1:740-744.Table 1. On-farm trial site locations and characteristics for PAM demonstrations in 1995.

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