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Effect of Polyacrylamide (PAM) Application under Different Flow Types on Sediment and NO_3-N Surface Transport at Furrow Irrigation

[1]Ramazan Meral, [2]Bilal Cemek, [2]Mehmet Apan, [3]Ayhan Horuz
[1]Department of Agricultural Engineering, Faculty of Agriculture,
Kahramanmaraş Sütçü İmam University, Kahramanmaraş 46060,
[2]Department of Agricultural Engineering, Faculty of Agriculture,19 May University, Samsun 55500,
[3]Department of Soil Science, Faculty of Agriculture, 19 May University, Samsun 55500, Turkey

Abstract: There is widespread concern about loss of sediment and NO_3-N into surface water from irrigated farmlands. We studied effectiveness of PAM treatment under different flow conditions on sediment and NO_3-N transport with runoff. Treatments included three different flow regimes, continuous, cutback and surge flow, which supplied either untreated or PAM-treated irrigation water. PAM was applied only in the first irrigation and 10 ppm was added to the irrigation water during the advanced period. PAM treatment reduced sediment transport by 83.7-97.5% during first irrigation and by 39.3-88.3% during the second. The PAM treatment' effect on sediment reduction was similar for all flow regimes during the first irrigation. The cutback-flow, no-PAM, treatment produced nearly the same sediment reductions as PAM treatments. A non-erosive flow rate was used after cutback, and this reduced sediment transport. The PAM treatments consistently decreased NO_3 runoff losses. In addition reducing runoff with different flow resulted in smaller NO_3-N. Finally in this study, we recommend that 10 ppm PAM should be used during advanced time to decrease the amount of sediment and NO_3-N transport in similar fields conditions. In addition, flow rate, which does not cause erosion or cutback flow, can be used with the PAM treatment. The other alternative is to use surge flow rather than the continuous flow in the first irrigation.

Key words: Polyacrylamide, sediment transport, nitrate transport, furrow irrigation

INTRODUCTION

Soil erosion is a serious problem threatening sustainability of agriculture globally and contaminating surface water. Furrow irrigation, which is widely practiced in irrigated agriculture throughout the world, is a serious cause of soil erosion and contributes significant nutrient loads to irrigation return flows and other surface waters. Nearly all nutrients in surface irrigation return flows are adsorbed by the sediments[1].

Controlling furrow-irrigation induced erosion reduces both sediment and nutrient loads in surface return flows. There are three general management approaches for controlling sediments in return flows. The first approach is to eliminate or reduce surface runoff by adopting appropriate irrigation methods. The second approach is to eliminate or reduce erosion by adopting right management practices in regard to the slope in the direction of irrigation, the furrow stream size, the run length, the irrigation frequency and duration and tillage practices. The third is to remove sediments from surface return flows by controlling the tail water and utilizing sediment retention basins[2].

Several management techniques have been developed to reduce water losses during the irrigation event. Some of these are the "cutback stream method', the "runoff recovery system" and "intermittent application of water" Cutback flow is that the flow rate is decreased after advanced period in furrow irrigation. Hence runoff rate is reduced. The intermittent application of water (surge flow) has recently received more interest than the other methods[3].

Surge flow generally has been reported to increase advance rate, reduce total irrigation time and decrease infiltration in soils which have high intake when compared continuous flow[4-7] In addition, surge flow has been reported to reduce runoff by 21 to 45% compared to continuous flow[7,8]. Decreased runoff results in less sediment transport in surge flow relative to continuous flow. Goldhamer *et al.*[9] and Önder[10] reported that

Corresponding Author: Ramazan Meral, Kahramanmaraş Sütçü İmam University, Faculty of Agriculture, Department of Agricultural Engineering, Kahramanmaras 46060, Turkey, Ph. No. 90 (344) 223 7666 / 433, Fax: 90 (344) 223 0048, E-mail: rmeral@ksu.edu.tr

suitable planning of cycle time, on and off-time period is necessary for reduce runoff and sediment transport.

Recent field studies have demonstrated that small concentrations of polymers dissolved in irrigation water appreciably reduce soil loss from irrigated furrows. Lentz *et al.*[11,12] gave the first detailed reports of PAM use in furrow irrigation for erosion control and increased infiltration, quantifying changes in sediment concentration and accumulation over time, sediment loss, infiltration, and runoff. These results have been consistent in numerous studies for different soils under a wide range of conditions, including sprinkler irrigation[13]. Because PAM stabilizes furrow soil and flocculates suspended sediment, this treatment reduce runoff, effectively prevent soil nutrient losses, increase nutrient-use efficiency, and decrease N and P loads in irrigation return flows and receiving surface waters[14].

Lentz and Sojka[12] reported that PAM treatment reduced sediment loss and improved the runoff water quality parameters ortho-P, total-P, nitrate, and biological oxygen demand. Series of studies over several years have shown that PAM treatment reduced runoff sediment losses by an average 94% and increased net infiltration 15% on silt loam soils.

Although many researchers have studied surge flow, it's effects on runoff rate and sediment and nutrient transport hasn't been fully understood. We hypotheses that; if surge flow is applied with PAM, PAM will be adsorbed by soil particles greatly amount during cutoff time. As a result PAM effectiveness will be increased. The other subject is that PAM application increase advanced time in furrow irrigation. This is unexpected situation for irrigation efficiency and uniformity. PAM may be applied with surge flow for remove this disadvantage. In addition, surge or cutback flow decrease runoff rate and deep percolation. As a result leaching of PAM will be decreased and PAM's effectiveness will be increased.

The objectives of this study were to evaluate the effectiveness of PAM application under different flow condition on sediment and NO_3-N transport with runoff. For this aim, non-treatment water and PAM adding water were applied with different flows that were continuous, cutback and surge flow.

MATERIALS AND METHODS

Field site: The field experiment conducted in 2002 on Amasya irrigation area, in the Black sea region of Turkey (40° 08'N ; 35° 15'W; altitude 412 m).

Surface soil texture was clay loam (41.68% clay, 30.73% silt, 27% sand), organic matter was 1.2 to1.5%, electrical conductivity was 2.85 to 3.14 dS m^{-1}, lime content ($CaCO_3$) was 14%, exchangeable sodium percentage was 1.6. In addition to 9.8 mg kg^{-1} NO_3^-N content of the top 0.3 m of the soil, 20 kg N da^{-1} was applied before irrigation applications

Table 1: Irrigation treatments

Water treatment	Flow treatment	Symbol
Non-treatment (normal)	Continuous	N_{con}
	Cutback	N_{cut}
	Surge	N_{surge}
Treatment (10 ppm PAM)	Continuous	P_{con}
	Cutback	P_{cut}
	Surge	P_{surge}

Tests were conducted on 70 m long and 0.7 m spaced furrows on 1.2% slope. After harvesting the corn, the field was chisel-plowed. The furrows were prepared and than cultivation was not practiced during the irrigation seasons.

Treatment P_{cut} P_{surge} and N_{cut}: Irrigations were applied at 10 day intervals when the available soil water content was depleted to nearly 60% in the 0.9 m profile. Three irrigations were applied. The same net infiltration time was taken for all applications (105 min.)

Untreated and PAM-treated water was used in the irrigations. Electrical conductivity of water was 0.51 dS m^{-1} and sodium adsorption rate was 0.65. PAM (charge density: 20%, molecular weight: 14 - 18 million mg $mole^{-1}$) was applied only in the first irrigation and 10 ppm added to the irrigation water during advanced period. Similar concentration was preferred by many researchers[14,12,15].

Flow types used were continuous, cutback and surge flow. Inflow rate was 0.36 m^3 min^{-1} on treatment of continuous flow. For the cutback flow: inflow rate was 0.36 m^3 min^{-1} during advanced time and was 0.18 m^3 min^{-1} during the remaining irrigation. For the surge flow: inflow rate was 0.36 m^3 min^{-1}, cycle ratio was 0.5, cycle time was 30 min during advanced time after then cycle time was 10 min. Treatments were identified using symbols given in Table 1.

Water was applied through gated plastic pipes connected to barrels in which a constant hydraulic head was created to obtain a fixed flow rate. We inserted perforated plugs into pipe gates and the size of the hole was adjusted to obtain the desired flow rates. Flow rates were checked by volumetric methods during the test. The tail water runoff from all irrigated furrows was measured by H-flumes installed at the end of the furrows. Water samples were collected at 15 min intervals in tail water runoff. The samples were filtered the captured sediment oven-dried at 105°C. The outflow rate at the time of sampling and the sediment content of the sample were combined to calculate an instantaneous rate of sediment discharge. Runoff samples were stored at 2°C<10d.

Distillation methods were used for NO_3-N analyses in as described by Ryan *et al.*[16].

The experimental design was a complete randomised block, with three replications. Data were subjected to analysis of variance and treatment means were compared by the Duncan Multiple Range test as described by Gomez and Gomez, (1984).

RESULTS

Water application and runoff: The applied water, advances time, tail water runoff and runoff rate are presented in Table 2. The net infiltration time was 105 min for soil water deficit, which was 55 mm 90 cm^{-1}.

The cutback flow applications successfully reduced runoff at all irrigations. Those values were ranged 0.37-0.54 m^3. The surge flow applications affected at only first irrigation for runoff and decreased from 1.49 to 1.17 m^3 and from 1.32 to 1.01 m^3

Runoff amount with PAM added irrigation water was especially smaller at the first irrigation than the other application. Because PAM increased soil infiltration rate. As a result runoff rate was reduced too. Similar results were reported by Zhang and Miller[18]; Francisco and Ricard[15]. Because of this affect, advances times increased with PAM.

Sediment: The N_{con} produced the greatest runoff sediment losses during the first irrigation, while N_{cut}, P_{cut}, P_{con} and P_{surge} treatments produced the smallest sediment losses. The N_{surge} treatment was found significantly different from the N_{con} treatment and it reduced soil loss by 63.5% (Table 3). Miller *et al.*[19] were reported that surge flow increased sediment transport but Goldhamer et al (1987) were reported that surge flow reduced sediment transport. As a conclusion, the reduction of sediment transport in the surge flow might be possible by decreasing the runoff through an appropriate cycle time and ratio.

The PAM treatments reduced sediment transport in the first and second irrigations, but not in the third. The Cutback-flow, no-PAM, treatment produced nearly the same sediment reductions as PAM treatments. A non-erosive flow rate was used after cutback, and this reduced sediment transport. PAM treatment reduced sediment transport by 83.7-97.9% during first irrigation and by 39.3-88.3% during the second. The PAM applications' effect on sediment reduction was similar for all flow regimes during the first irrigation.

Lentz *et al.*[11] were reported that PAM treatment with surge flow on silt loam soils notably reduced sediment transport, relative to untreated furrows. On the clay loam soils in this study, the surge flow with PAM treatment has some effect on sediment transport but the difference between the surge flow with PAM and continuous flow with PAM was not statistically significant. This situation can be explained with cycle duration or soil types.

Influence of treatments continued for the second irrigation even though PAM was not reapplied; however, efficacies were not as great as in the first irrigation. The P_{cut} and N_{cut} treatments reduced soil loss by 82.9-88.3%. The P_{con} and P_{surge} treatments were 39.3-51.1%. The N_{surge} treatment was found significantly different than the N_{con} treatment at the second irrigation too with reducing soil loss by 28.6%. At the third irrigation, the differences were

Table 2: Irrigation water amount, advances time, tail water runoff and runoff rates for irrigations

Number of irrigation	Symbol	Irrigation water amount (m^3)	Advances time (min)	Tail water trunoff (m^3)	Runoff rate (%)
1	N_{con}	5.87	58	1.49	25.40
	N_{cut}	3.91	56	0.40	10.30
	N_{surge}	5.51	48	1.17	21.20
	P_{con}	6.34	71	1.32	20.80
	P_{cut}	4.37	69	0.37	8.60
	P_{surge}	5.83	57	1.01	17.40
2	N_{con}	5.00	34	1.67	33.40
	N_{cut}	3.04	32	0.51	16.90
	N_{surge}	4.86	30	1.65	33.90
	P_{con}	4.93	32	1.63	33.00
	P_{cut}	3.08	33	0.53	17.30
	P_{surge}	4.93	32	1.64	33.20
3	N_{con}	4.61	23	1.70	36.90
	N_{cut}	2.93	29	0.54	18.40
	N_{surge}	4.86	30	1.74	35.70
	P_{con}	4.82	29	1.69	35.00
	P_{cut}	2.97	30	0.53	17.90
	P_{surge}	4.82	29	1.69	35.10

Table 3: Sediment loss data and results of statistical analyses

Number of irrigation	Symbol	Sediment consatration g L^{-1}	Sediment (g m^{-2} min^{-1})	Sediment reduction rate (%)
1	N_{con}	4.72	1.48c*	-
	N_{cut}	1.82	0.15a	89.9
	N_{surge}	2.26	0.54b	63.5
	P_{con}	0.73	0.24a	83.7
	P_{cut}	0.26	0.03a	97.5
	P_{surge}	0.40	0.12a	91.8
2	N_{con}	2.69	0.94d	-
	N_{cut}	1.44	0.16a	82.9
	N_{surge}	2.07	0.69c	26.6
	P_{con}	1.92	0.57bc	39.3
	P_{cut}	1.01	0.11a	88.3
	P_{surge}	1.10	0.46b	51.1
3	N_{con}	3.35	0.84bc	-
	N_{cut}	1.30	0.16a	80.9
	N_{surge}	2.10	0.74b	11.9
	P_{con}	2.90	0.98c	-16.6
	P_{cut}	1.24	0.12a	85.7
	P_{surge}	2.43	0.84bc	0

* Similar lower case letters indicate no difference between treatment means ($P<0.01$)

Table 4: NO_3-N loss data in runoff and results of statistical analyses

Number of irrigation	Symbol	NO_3-N concentration mg.L^{-1}	NO_3-N kg ha^{-1}	NO_3-N reduction rate (%)
1	N_{con}	5.4	1.62c*	
	N_{cut}	5.6	0.46a	71.6
	N_{surge}	5.2	1.24b	23.5
	P_{con}	4.4	1.19b	26.5
	P_{cut}	4.9	0.43a	73.5
	P_{surge}	3.9	0.63a	61.1
2	N_{con}	3.3	1.32c	-
	N_{cut}	3.3	0.35a	73.5
	N_{surge}	3.3	1.12bc	15.2
	P_{con}	2.8	0.93b	29.5
	P_{cut}	2.6	0.27a	79.5
	P_{surge}	2.8	0.93b	29.5
3	N_{con}	2.6	0.91dc	-
	N_{cut}	2.3	0.25a	72.5
	N_{surge}	2.8	1.02d	-12.1
	P_{con}	2.2	0.75b	17.6
	P_{cut}	2.5	0.25a	72.5
	P_{surge}	2.2	0.85bc	6.6

* Similar lower case letters indicate no difference between treatment means ($P<0.01$)

not statistically significant any treatment apart from N_{cut} and P_{cut} treatments

The N_{cut} treatment reduced soil loss by 89.9% compared to the N_{con} treatment. This may be a consequence of the flow-rate cutback, which reduced the post-advance stream flow rates to levels, which were nearly non-erosive.

Nitrate: In the first irrigation, the P_{cut},P_{surge} and N_{cut} treatments significantly reduced NO_3-N losses compared with the N_{con} treatment which amount to 61.1-73.5%. The N_{surge} and P_{con} treatments also significantly reduced NO_3-N losses, (26.5 and 23.5%), but were not as effective as P_{cut}, P_{surge}, and N_{cut} treatments. N_{cut} treatment greatly reduced NO_3–N losses by decreasing runoff and found similarly with P_{cut}, P_{surge} treatments. In the second irrigation, cutback flow treatments (P_{cut} and N_{cut}) produced the greatest NO_3–N losses reductions (73.5 and 79.5%). PAM application effects were continued at this irrigation reduced nitrate loss by 29.5% and found significantly different than the N_{con} treatment. The PAM application reduced NO_3-N loss in the third irrigation too, but to a lesser extent than the first and second irrigations (Table 4).

Nitrate losses are a function of nitrate concentration in runoff water, which, in turn, was related to runoff sediment concentration. The cutback treatment reduced NO_3-N losses primarily by decreasing runoff, since stream NO_3-N concentrations did not differ than continuous flow. Spalting et al (2001) reported that, because of the smaller amount of irrigation water used during surge flow, the amount of NO_3-N transport was smaller.

The PAM treatments consistently decreased NO_3-N runoff losses. There were two reasons for this. First, PAM reduced runoff rate and volume and second, PAM reduced runoff NO_3-N concentrations by decreasing erosion and the load of sediment mixed into the furrow stream. Reducing runoff sediment transport resulted in smaller runoff NO_3-N concentrations. Lentz *et al.*[21] reported that cumulative NO_3-N losses from PAM treatments were half that of controls, the differences were not statistically significant. This situation may be result of applying cutback flow to all treatments by researchers. Similar results were found this study among cutback flow treatment.

In this study, for decreasing of sediment and NO_3-N transport; PAM was added to irrigation water and continuous, cutback and surge flow were applied. In addition the flow types were applied with normal (non-tread) irrigation water for comparing application's effect.

PAM treatment substantially reduced sediment and NO_3-N transport during first and second irrigation. The PAM treatments' effect on sediment reduction was similar for all flow regimes during the fist irrigation. As a conclusion, PAM had significant effect on the sediment transport under chosen soil type and inflow rate. However, flow types would increase the effectiveness of the PAM in different soil types and high flow rates.

NO_3-N losses were reduced with PAM treatments. In addition reducing runoff with different flow resulted in smaller NO_3-N. At this study runoff rate was decreased significantly with surge flow. Short cycle duration was chosen in reaching to goal.

Finally we recommend that 10 ppm PAM should be used during advanced time to decrease the amount of sediment and NO_3-N transport in similar fields conditions. However, this may not be valid for all situations such as when runoff is relatively significant. Irrigators may decide to increase inflow rates to shorten furrow advance times, which might, in turn, increase runoff and surface sediment and nutrient mass losses. That is why different flow types (cutback or surge) should be chosen.

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REFERENCES

1. Carter, L.D., 1990. Soil Erosion on Irrigated Lands. In: Irrigation of Agricultural Crops. Agronomy Monograph no: 30, Madison, USA.

2. Carter, L.D. and J.A. Bondurant, 1972. Management Guidelines for Controlling sediments, Nutrients and Adsorbed Biocides in Irrigation Return Flows. National Conference on Irrigation Return Flow Quality Management, Colorado.
3. Walker, W.R. and G.V. Skogerboe, 1987. Surge flow surface irrigation. In: surface irrigation. Prentice Hall, Inc, Englewood Cliffs, New Jersey.
4. Musick, J.T., J.D. Walker, A.D. Schneider and F.B. Pringle, 1987. Seasonal evaluation of surge flow irrigation for corn. Appl. Eng., 2: 247-251.
5. Testezlaf, R., R.L. Elliot and J.E. Garton, 1987. Furrow infiltration under surge flow irrigation. Trans. ASAE. 30: 196-197.
6. Sirjacobs, D., I. Shainberg, I. Rapp and G.J. Levy, 2000. Polyacrylamide, sediment, and interrupted flow effects on rill erosion and intake rate. Soil Sci. Soc. Am. J., 64: 1487-1495.
7. Kanber, R., H. Köksal, S. Önder, S. Kapur and S. Sahan, 2001. Comparison of surge and continuous furrow methods for cotton in the Harran plain. Agric. Water Manage., 47: 119-135.
8. Boldt, A.L., D.E. Eisenhauer, D.L. Martin and G.J. Wilmes, 1999. Water conservation practices for a river valley irrigated with groundwater. Agric. Water Manage., 38: 235-256.
9. Goldhamer, D.A., M.H. Alemi and R.C. Phene, 1987. Comparison of surge and continuous flow irrigation in California. irrigation systems for the 21st century proceedings of a conference, Oregon, ASCE.
10. Onder, S., 1994. Comparison of surge and continuous furrow methods in Cukurova plain. Cukurova Universty, Irrigation and Agricultural Structures Department, Ph.D thesis, Adana. Turkey.
11. Lentz, R.D., I. Shainberg, R.E. Sojka and L.D. Carter, 1992. Preventing irrigation furrow erosion with small applications of polymers. Soil Sci. Soc. Am. J., 56: 1926-1932.
12. Lentz, R.D. and R.E. Sojka, 1994. Field results using polyacrylamide to manage furrow erosion and infiltration. Soil Sci., 158: 274-282.
13. Sojka, R.E. and J.A. Entry, 2000. Influence of polyacrylamide application to soil on movement of microorganisms in runoff water. Environ. Poll., 108: 405-412.
14. Lentz, R.D., R.E. Sojka, C.W. Robbins, D.C. Kincaid and D.T. Westermann, 2001. Polyacrylamide for surface irrigation to increase nutrient-use efficiency and protect water quality. Com. Soil Sci. Plant Anal., 32 : 1203-1220.
15. Francisco, L.S. and P.S. Ricard, 2000. Improving infiltration of irrigated Mediterranean soils with polyacrylamide. J. Agric. Eng. Res., 76: 83-90.
16. Ryan, J., G. Estefan and A. Rashid, 2001. Soil and plant analysis laboratory manual. International Center for Agricultuiral Research in the Dry Areas (ICARDA), pp: 67-75.
17. Gomez, K.A. and A.A. Gomez, 1984. Statistical procedures for agricultural research, 2nd Edn., John Willey and Sons Ltd., Singapure.
18. Zhang, X.C. and W.P. Miller, 1996. Polyacrylamide effect on infiltration and erosion in furrows. Soil Sci. Soc. Am. J., 60: 866-872.
19. Miller, D.E., J.S. Aarstad and R.G. Evans, 1987. Control of furrow erosion with crop residues and surge flow irrigation. Soil Sci. Soc. Am. J., 41: 421-425.
20. Spalding, R.J., D.G. Watts, J.S. Schepers, M.E. Burbach, M.E. Exner, R.J. Poreda and G.E. Martin, 2001. Controlling nitrate leaching in irrigated agriculture. J. Environ. Qual., 30: 1184-1194.
21. Lentz, R.D., R.E. Sojka and C.W. Robbins, 1998. Reducing phosphorus losses from surface-irrigated fields: Emerging polyacrylamide technology. J. Environ. Qual. , 27: 305-312.