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Inverse effects of *Polyacrylamide* (PAM) usage in furrow irrigation on advance time and deep percolation

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Abstract: *The positive effects of Polyacrylamide (PAM), which is used as a soil conditioner in furrow irrigation, on sediment transport, erosion, and infiltration have been investigated intensively in recent years. However, the effects of PAM have not been considered enough in irrigation system planning and design. As a result of increased infiltration because of PAM, advance time may be inversely affected and deep percolation increases. However, advance time in furrow irrigation is a crucial parameter in order to get high application efficiency. In this study, inverse effects of PAM were discussed, and as an alternative solution, the applicability of surge flow was investigated. PAM application significantly increased the advance time at the rates of 41.3-56.3% in the first irrigation. The application of surge flow with PAM removed this negative effect on advance time, where there was no statistically significant difference according to normal continuous flow (without PAM). PAM applications significantly increased the deep percolation, 80.3-117.1%. Surge flow with PAM had significantly positive effect on the deep percolation compared to continuous flow with PAM but not compared to normal continuous flow. These results suggested that irrigation planning should me made based on the new soil and flow conditions because of PAM usage, and surge flow can be a solution to these problems.*

Key words: *Polyacrylamide, Advance rate, Surge flow, Water losses.*

Introduction

Furrow irrigation, which is widely practiced in irrigated agriculture thoughout the world, is significant cause of water losses and soil ersion. Recent field studies have demonstrated that small concentrations of polymers dissolved in irrigation water appreciably reduce soil loss from irrigated furrows. Lentz *et al.* (1992) and Lentz and Sojka (1994) 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 are consistent with numerous studies for different soils under a wide range of conditions, including sprinkler irrigation (Sojka and Entry, 2000).

The advance time in irrigation, which is defined as the time the water reaches the end of the furrow, is very important for reducing water waste. A longer advance time, normally, increases the water losses by deep percolation due to slow advance rates. Therefore a high inflow is recommended to obtain a rapid stream advance, thereby maximizing the uniformity of infiltration. However, this large stream size can result in excessive tailwater, especially when there is a high irrigation requirement.

Using of PAM in irrigation water increases advance time because of increased infiltration rate. Some precautions are required to get rid off disadvantages of PAM application on advance time. It is well known that surge flow in furrow irrigation shortens the advance time. Surge flow has been reported to increase advance rate, reduce total water required for irrigation. Stringham and Walker (1987) observed the advance phase with surge flow was completed very fast in a field study. This increased uniformity of water distribution in surface irrigation methods during the advance phase. In this application, cycle time was shortened after water reached the end of the furrow and runoff was reduced by decreasing the discharge.

Purkey and Wallender (1989) compared infiltration in surge flow with continuous flow using 49 neutron probes on each 240 m long furrow. Surge flows were conducted with 1.0 L/s application rate, 80 min. cycle time, and ½ cycle ratio. Infiltration was determined by neutron probe, infiltrometer, and inflow-outflow method. The difference in infiltrated water depths between surge and continuos flows was significant. Water depth was low but highly uniform in surge flow.

Most investigators agree with that the increased advance rates and reduced water application amounts are primarily due to a reduction in the infiltration rate under surge conditions (Goldhamer *et al.,* 1987).

The adoption and use of PAM have been gaining popularity since 1990s in many parts of the world, but not in Turkey. In this study, the applicability of PAM was discussed by considering planning principles and future inverse effects. In addition, the positive effects of PAM used in surge flow applications on advance time and deep percolation losses were investigated.

Materials and Methods

Field site: A field experiment was conducted on Kahramanmaras

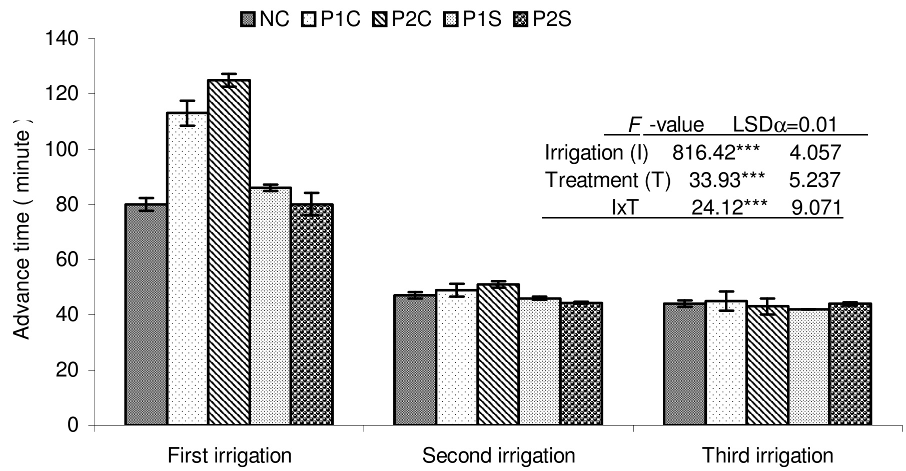

Fig 1: Advance times and the results of the LSD multiple comparison tests. Vertical bars indicate standard deviation of mean of replications at 95 % confidence level. *p<0.05, **p<0.01 and *** p<0.001.

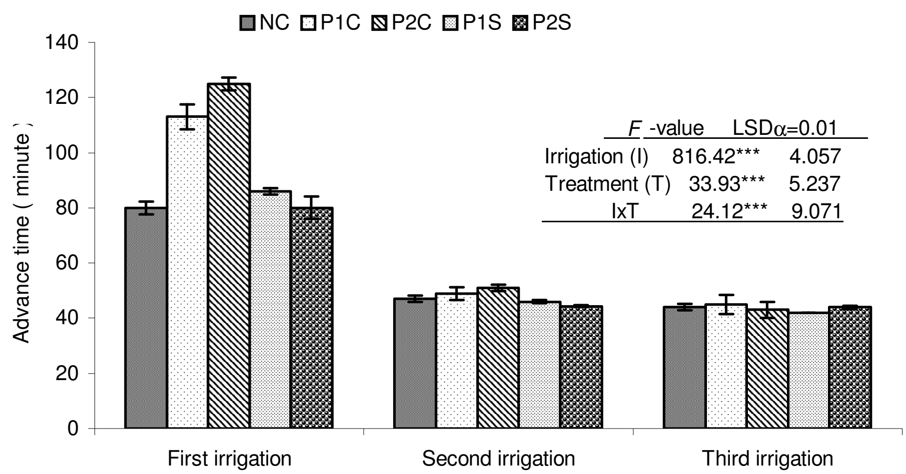

Fig 2: Deep percolation and the results of the LSD multiple comparison tests. Vertical bars indicate standard deviation of mean of replications at 95 % confidence level.

Table – 1: Some basic physical and chemical properties of the soil.

Soil depth (cm)	Texture	Field cap. Pw(%)	Wilting point Pw(%)	Total salinity (%)	Bulk density (g/cm^{-3})	pH
0-30	Clay loam	33.57	22.66	0.065	1.426	8.03
30-60	Clay	36.28	26.23	0.065	1.567	7.90
60-90	Sand loam	26.0	16.38	0.063	1.785	7.94

irrigation area, in the Mediterranean region of Turkey (37^o 35'N, 35^o 56'W, altitute 520 m). Soil properties such as texture, field capacity, permanent wilting point, and bulk density were obtained from systematically sampled soils from depths of 0-0.30, 0.30-0.60, 0.60-.0.90 m. Some basic physical and chemical properties of the soil are presented in Table 1. Tests were conducted on furrows; 120 m long, 0.7 m space, and 2.86 % slope.

Treatments: Three irrigations were applied at 10 day intervals when the available soil water content was depleted to nearly 50 % in the 0.9 m profile. The same net infiltration time was used for all applications.

Inflow rate was 0.36 $m^3.min^{-1}$ for all treatments. Treatments were continous flow (NC) continous flow with 10 ppm PAM (charge density: 20%, molecular weight: 14 - 18 million mg/mole) added water (P1C), surge flow with 10 ppm PAM added water (P1S), continous flow with 20 ppm PAM added water (P2C), and surge flow with 20 ppm PAM added water (P2S). PAM was applied only in the first irrigation during the advanced time. For the surge flow cycle ratio and time was

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

Number of irrigation	Symbol	Irrigation water amount (m^3)	Tail water runoff (m^3)	Runoff rate (%)
1	NC	13.140	5.755	43.8
	P1C	14.320	4.898	34.2
	P2C	14.760	4.613	31.3
	P1S	13.356	4.754	35.6
	P2S	13.140	4.503	34.3
2	NC	12.492	5.770	46.2
	P1C	12.564	5.927	47.2
	P2C	16.636	5.115	30.7
	P1S	12.456	5.175	41.5
	P2S	12.384	5.076	41.0
3	NC	12.924	6.844	53.0
	P1C	11.340	6.809	60.0
	P2C	12.888	6.840	53.1
	P1S	12.852	5.780	45.0
	P2S	12.924	6.145	47.5

0.5 and 30 min, respectively. Flow rates were determined by volumetric methods during the test. The tailwater runoff from all furrows was measured by H-flumes installed at the end of the furrows.

The stations along the furrows were located at 20 m intervals for obtaining the advance time. The tailwater runoff for each treatment was determined from the outflow hydrograph. The outflow hydrograph of the furrows was then obtained by plotting the runoff versus time (Hart *et al.,* 1980). Infiltration equations were obtained by inflow-outflow method for each treatment. The infiltration depth at each station was calculated by substituting the corresponding infiltration opportunity time into the infiltration equations. Deep percolation at each station and for each treatment was estimated from the difference between the infiltrated depth for the infiltration opportunity time and the required depth (Walker, 1989).

Analysis of variance (ANOVA) was performed on different applications to compare the means of advance time and deep percolations. Differences between individual means were tested using the LSD test (Gomez and Gomez, 1984).

Results and Discussion

The applied water, infiltration parameters, tail water runoff and runoff rate are presented in Table 2. The net infiltration time calculated based on the soil water deficit was 285, 300 and 315 min for irrigations, respectively.

Even though infiltration times were the same for all irrigations, the applied water was different, at the range of 11.340-14.760 m^3, because of the difference in advance times. While PAM applications caused an increase in the amount of applied water in the first irrigations, a decrease in runoff was observed. Runoff from PAM added irrigation was especially smaller at the first irrigation than the other applications. Similar results were reported by Zhang and Miller (1996), Francisco and Ricard (2000). Surge flow increased runoff because of the adverse effect on infiltration rate.

Table – 3: According to continuous flow application, advance time reduction rates of the applications (%).

Application	First irrigation		Second irrigation		Third irrigation	
	Advance time (min)	Reduction rates (%)	Advance time (min)	Reduction rates (%)	Advance time (min)	Reduction rates (%)
NC	80	-	47	-	44	-
P1C	113	-41.3	49	-4.2	45	-2.3
P2C	125	-56.3	51	-8.5	43	2.3
P1S	86	-7.5	46	2.1	42	4.5
P2S	80	0.0	44	6.4	44	0.0

(-) indicates the increase in the advanced time.

Table – 4: According to continuous flow application, deep percolation reduction rates of the applications (%).

Application	First irrigation		Second irrigation		Third irrigation	
	Deep percolation (m^3)	Reduction rates (%)	Deep percolation (m^3)	Reduction rates (%)	Deep percolation (m^3)	Reduction rates (%)
NC	0.987	-	0.780	-	0.897	-
P1C	1.780	-80.3	0.737	5.5	0.917	-2.2
P2C	2.143	-117.1	0.973	-24.7	0.870	3.0
P1S	1.170	-18.5	0.687	11.9	0.920	-2.6
P2S	1.353	-37.1	0.723	7.3	0.917	-2.2

(-) indicates the increase in the deep percolation.

Advance time: The advance time at the end of the furrow and LSD test results are presented in Fig. 1. Advance time reduction rates of the applications compared to NC are given in Table 3. PAM application significantly increased the advance time at the rates of 41.3-56.3% in the first irrigation. This might be the result of the change in infiltration rate. Similarly, Lentz and Sojka (1994), and Sojka and Entry (2000) reported that PAM applications significantly increased infiltration rate.

In the second and third irrigations, the effect of PAM on the advance time was statistically not significant. This is the result of the application of PAM in only the first irrigations. Similarly, in the sediment transport study, Lentz *et al.* (1992) investigated that the effect of PAM decreased in later irrigations. However, advance time in furrow irrigation is more important especially in the first irrigations in which soil is recently tilled and loose. In later irrigations, the advance times have already diminished significantly because of firming.

Surge flow with PAM had significant effect on the advance time and similar results were obtained in the P2S and NC applications. The advance time in the P1S application increased at 7.5 %, but this increase was statistically not significant. A number of studies reported that surge flow increased advance rate (Goldhamer *et al.,* 1987; Kemper *et al.,* 1988; McCornick *et al.,* 1987; Kanber *et al.,* 2001).

Deep percolation: Deep percolation and LSD test results are presented in Fig. 2. Deep percolation reduction rates of the applications compared to NC are given in Table 4. PAM applications significantly increased the deep percolation, 80.3 % and 117.1 % for P1C and P2C, respectively. Surge flow with PAM had significantly positive effect on the deep percolation compared to the P1C and P2C applications. However, P1S application increased the deep percolation at 18.8 % compared to the NC application. These results show that this inverse effect can be partially reduced when PAM concentration and the other irrigation planning criteria are considered.

Recent studies have shown that PAM applications have positive effect on sediment transport especially in erosion-sensitive soils. The further increase in currently high infiltration rate results in the increase in advance times and deep percolation in respect to water management. Application of surge flow, a furrow irrigation type, which reduces infiltration and increases flow, can be a solution to these problems. In addition, new furrow inflow rate, width, and length should be determined based on the new soil and flow conditions. Such a maximum furrow inflow rate should be chosen so that erosion does not occur. Furrow inflow rate can be increased based on the fact that PAM reduces runoff and erosion. Therefore, deep percolation can be reduced by shortening advance time.

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