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Potential for Irrigation Water Saving Using Polymers in Kingdom of Saudi Arabia†

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Saudi Arabia consumes about 18 billion cubic meters of water per year for irrigation, most of which comes from non-renewable groundwater. Therefore there is an urgent need for agricultural practices aimed at reducing the water use. Since there is an estimated 25 % irrigation loss, the use of commercial polymers that improve the soil structure and moisture-holding capacity are recommended. The tests were conducted in a greenhouse by growing wheat and alfalfa on two soil types by varying the ratio of polymer mixing and salinity of water used for irrigation. Results indicate that the use of polymers increase moisture content and yield, while also reducing irrigation frequency.

Keywords: Groundwater, Greenhouse, Irrigation loss, Polymer, Saudi Arabia.

INTRODUCTION

The climate of the Eastern Province of Saudi Arabia is exceptionally variable[1]. During the summer months (June, July, August), the temperature ranges from 41-44 ºC. Winter (December, January and February) is usually mild. Mean monthly temperatures inland lie between 11 and 22 ºC. The average annual percentage of sunshine is about 75 %. The most frequent direction of prevailing winds is from the West to Northwest. During mid-summer, strong northerly winds called "shamals" (in Arabic "shamal" means "north") occur in the Eastern Province. These winds decrease by the end of July and the minimum amount of northerly wind occurs during August. These strong winds decrease in frequency during the spring months (March, April and May). Relative humidity also exhibits considerable variation from place to place and year to year. Relative humidity highs during the winter (December through February) range from 65 to 73 % and relative humidity lows of 37 to 63 % while the summer (June, July, August) are observed along the Arabian Gulf Coast. Precipitation in the Eastern Province is scarce and the rainfall pattern is highly variable. Rainfall records of the Ministry of Agriculture and Water during the years 1952-1978 show an average annual rainfall of about 62 mm in the Eastern Province.

Due to the extremely arid climate, the groundwater recharge to deep aquifers is negligible. Therefore, reduction of water use for irrigation in the kingdom is of paramount importance for the sustainability of water resources. This reduction can be achieved by introducing new and advanced technologies to improve irrigation practices and soil conditions such as soil structure and moisture-holding capacities to reduce water losses and frequent irrigation applications, especially in sandy soils.

The irrigation water that is lost as a result of percolation down the light textured soil profile is estimated to be more than 25 % of the applied irrigation water (KFUPM/RI, 1993)[2]. This loss necessitates the introduction of new technologies to improve irrigation application efficiencies and to reduce irrigation water losses. The use of polymer in a particular ratio may lead to positive effects on irrigation water saving and in improving the soil moisture holding capacities.

In this study, the result of adding a polymer to agricultural soils to improve irrigation application efficiencies and to reduce irrigation water losses was evaluated.

EXPERIMENTAL

Greenhouse construction: A greenhouse made of fiber glass was constructed within the premises of King Fahd University of Petroleum and Minerals for testing the effect of polymers on soil under a controlled environment. The dimensions of the greenhouse were 29.5 m × 13.0 m × 3.25 m. The greenhouse was equipped with heating and cooling system in order to have a controlled environment throughout this study.

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Irrigation system: Five water tanks were installed to supply the irrigation water. The water salinity of 500, 1000, 2000 and 3000 ppm is prepared by mixing the sweet water with saline water. The water is pumped from the tanks to the greenhouse through a pressurized irrigation system.

A fully computerized automatic drip irrigation system was installed in the greenhouse. The computerized irrigation system used in this study is a Hunter IMMS central control system. Using the Irrigation Management and Monitoring System (IMMS), automatic irrigation systems at multiple pots was programmed for functions that would typically be handled directly at each site's controller. Scheduling of days to water, run times, start times, cycle and soak operations and more was done from a computer in the greenhouse office. Hunter ICC controllers were used in the experiment. The ICC has four fully independent programs each with separate day cycles and 8 start times, offering total flexibility for complex conditions. With independent day schedule options for each program, this will maximize scheduling choices (select days of the week, true odd/even days and skip days up to 31 days). Program data are retained during power outages, without the need for battery. Cycle and Soak capability by station offered by the use of the ICC, this allows run times to be divided into repeat cycles to minimize run-off. In this study, this capability was used.

The total number of pots used in the experiment was 240. All the pots were arranged in order and each of these pots was individually connected with a dripping nozzle.

Soil analysis: Field and laboratory measurements were carried out to define physical and chemical parameters of the soil. These parameters are required to calculate crop-water requirements (ET_{crop}) and irrigation schedule for the cultivated crops. Three soil samples from each treatment were analyzed for soil texture, bulk density, EC, pH, Na, K, Ca, Mg, SO_4, HCO_3, NO_3, P, Fe, Cu, Zn and Mn.

The analyses, which were carried out by the regional Center for Agriculture and Water, indicated that the soil texture of SHADCO is sandy and TADCO is Loamy sand. The soil was non-saline (less than 4 mmhos/cm). The potassium and phosphorus contents were also very low. The soil chemical properties were defined using the Standard Method of Water and Wastewater Analysis[3]. The results of analysis are shown in Table-1. The soil bulk density was measured in the field. The test method which was used to measure the bulk density is an excavation method described in Black *et al.*[4]. The measured values of the bulk density ranged from 1.4-1.7 g/cm^3 for SHADCO soil and 1.7 g/cm^3 for TADCO soil. The results are shown in Table-2.

Soil sterilization: Before the start of the experiments, SHADCO and Tabouk soils were sterilized using Furedom and Nemacur sterilizing powder. Soil media was covered with agricultural plastic 100 Mic. and left for 72 h. The plastic cover was then removed and the soil media was ventilated for 72-96 h before the sowing date. Formaldehyde was used to spray all the items inside the greenhouse for the sterilization of the greenhouse.

Soil mixing with polymers: Twelve cubic meters of soil from both SHADCO (sandy soil) and Tabouk (sandy loam soil) were brought and mixed with a polymer. These two soils represent the common Saudi Arabia soils. The mixture was used for testing the relationship between soil and polymer when mixed together. After the sterilization of the soil, two types of polymers were mixed with SHADCO and Tabouk soils. The first polymer type was the water absorbent polymer and the second was the polymer used to enhance the soil physical properties.

The polymer was mixed according to the required concentration. After mixing properly, the soil mixture was transferred to the pots. Three pots (three replications) were kept under each treatment. Three types of polymer concentrations of 100, 70 and 30 % were used. One set of replication was kept as control (without polymer) and one other set was kept for the stress test without polymer.

Planting alfalfa and wheat in green house: The following variables were included in the tests in the greenhouse: (1) Three polymer concentrations, namely: 30, 70 and 100 % by volume and a control (without polymer). (2) Four levels of water salinity, namely: 500, 1000, 2000 and 3000 ppm. (3) Two types of soils, sandy soil of SHADCO and sandy loam soil from Tabouk. (4) Two types of crops, namely: alfalfa (Medicago sativa) and wheat (*Triticum* sp.).

TABLE-1
CHEMICAL PROPERTIES OF SOIL

Sample #	EC (dS/m)	pH	Na (meq/L)	K (meq/L)	Ca (meq/L)	Mg (meq/L)	SO_4 (meq/L)
SHADCO-1	0.936	7.23	1.057	0.052	4.982	2.710	2.95
SHADCO-2	0.803	7.32	0.875	0.044	4.272	2.673	2.375
SHADCO-3	0.707	7.44	0.685	0.042	3.987	2.579	2.285
TADCO-1	1.762	7.79	2.558	0.055	3.948	1.731	10.58
TADCO-2	1.625	7.87	2.100	0.048	3.748	3.105	10.715
TADCO-3	1.793	7.84	2.580	0.058	4.145	1.711	10.63

TABLE-2
PHYSICAL PROPERTIES OF SOIL

Sample #	Bulk density (g/cm^3)	Sat.	FC	W.P	Ks (m/s)
SHADCO-1	1.75	0.34	0.29	0.03	1.58E-04
SHADCO-2	1.73	0.35	0.28	0.03	1.34E-04
SHADCO-3	1.72	0.35	0.31	0.03	9.92E-05
TADCO-1	1.70	0.36	0.34	0.13	3.102E-08
TADCO -2	1.70	0.36	0.33	0.17	4.874E-08
TADCO -3	1.69	0.35	0.32	0.16	1.008E-07

RESULTS AND DISCUSSION

Effect of polymer on alfalfa and wheat shoots and roots: In testing the effect of polymer on the soil physical properties for both SHADCO and Tabouk soils, it is noticed that the average volumetric moisture content for the treated soil was higher than the control and the volumetric moisture content increased as the polymer concentration increased. After one month the measurements showed the same trend and when the soil was irrigated the measurements showed that the control had regained the moisture level after irrigation, while the soil mixed with the polymer did not.

On November 4, 2006 alfalfa and wheat were planted in the greenhouse, the shoots and roots development for both crops was observed after 5, 6 and 7 days. Tables 3 and 4 show

TABLE-3
WHEAT SHOOTS AND ROOTS LENGTH IN SHADCO SOIL AFTER FIVE DAYS OF SOWING (NOVEMBER 4, 2006)

Pot #	Shoot length (cm)	Root length (cm)	Pot #	Shoot length (cm)	Root length (cm)
C EP1	10.5	5.1	70 EP7	12.0	13.6
C EP1	10.5	4.2	70 EP7	11.0	12.1
C EP1	9.7	4.9	70 EP7	11.0	15.5
C EP2	9.2	4.0	70 EP8	11.5	13.3
C EP2	9.1	5.0	70 EP8	12.0	14.5
C EP2	10.0	5.8	70 EP8	12.0	12.8
C EP3	13.0	5.8	70 EP9	10.2	13.0
C EP3	11.6	8.6	70 EP9	11.1	11.0
C EP3	9.6	7.8	70 EP9	12.0	18.1
C EP1	9.1	3.5	70 EP7	11.0	14.7
Total	102.3	54.7	Total	113.8	138.6
Average	10.23	5.47	Average	11.38	13.86
100 EP4	11.8	13.0	30 EP10	11.5	15.6
100 EP4	10.5	7.6	30 EP10	11.0	12.4
100 EP4	12.0	18.2	30 EP10	10.0	13.0
100 EP5	12.0	13.5	30 EP11	11.0	13.0
100 EP5	11.5	11.5	30 EP11	10.0	11.5
100 EP5	13.0	14.2	30 EP11	11.0	14.1
100 EP6	13.5	14.0	30 EP12	10.0	17.1
100 EP6	13.1	13.0	30 EP12	10.2	22.5
100 EP6	11.0	18.8	30 EP12	11.0	16.1
100 EP4	13.0	13.0	30 EP10	11.2	22.0
Total	121.4	136.8	Total	106.9	157.3
Average	12.14	13.68	Average	10.69	15.73

'EP1' to 'EP12' = Pot numbers, 'C'=Control: '100' = 100 % polymer: '70' = 70 % polymer: '30' = 30 % polymer.

TABLE-4
WHEAT SHOOTS AND ROOTS LENGTH IN TABOUK SOIL AFTER FIVE DAYS OF SOWING (NOVEMBER 4, 2006)

Pot #	Shoot length (cm)	Root length (cm)	Pot #	Shoot length (cm)	Root length (cm)
C CP2	11.0	5.0	70 CP7	10.2	8.3
C CP2	10.0	4.7	70 CP8	11.3	7.1
C CP2	9.2	3.4	70 CP8	10.8	7.5
C CP2	10.0	3.8	70 CP8	10.0	5.0
C CP3	10.0	4.0	70 CP8	10.2	8.7
C CP3	10.8	4.1	70 CP8	9.0	6.8
C CP3	10.5	5.5	70 CP9	11.0	7.7
C CP3	9.4	6.2	70 CP9	13.0	8.2
C CP13	9.4	3.6	70 CP9	12.0	7.2
C CP13	11.0	3.5	70 CP9	11.2	7.8
Total	101.3	43.8	Total	108.7	74.2
Average	10.13	4.38	Average	10.87	7.42
100 CP4	11.8	6.8	30 CP10	11.0	8.0
100 CP4	10.4	8.1	30 CP10	9.8	8.3
100 CP4	12.0	7.6	30 CP10	11.2	10.5
100 CP5	10.2	8.2	30 CP11	11.2	7.5
100 CP5	13.0	8.6	30 CP11	9.4	6.9
100 CP5	11.3	5.5	30 CP11	11.0	5.3
100 CP6	11.2	4.8	30 CP12	12.2	6.8
100 CP6	10.0	5.0	30 CP12	10.6	8.0
100 CP6	8.0	7.0	30 CP12	11.2	10.0
100 CP4	10.5	8.0	30 CP10	8.0	8.0
Total	108.4	69.6	Total	105.6	79.3
Average	10.84	6.96	Average	10.56	7.93

'CP2' to 'CP13' = Pot numbers, 'C'=Control: '100' = 100 % polymer: '70' = 70 % polymer: '30' = 30 % polymer.

that the wheat shoots and roots length in SHADCO and Tabouk soil, respectively, after five days of sowing.

Table-3 showed that the average roots length of the control, 100, 70 and 30 % treatments were 5.47, 13.68, 13.86 and 15.73 cm, respectively. The increase in the roots lengths were 60, 60.5 and 65.2 % of the 100, 70 and 30 % polymer treatment, respectively. The average shoot length for the control, 100, 70 and 30 % were 10.23, 12.14, 11.38 and 10.69 cm, respectively. The percentage increase of the shoots was 15.7, 10.1 and 4.3 % for the 100, 70 and 30 % polymer treatment compared to the control. It is clear that the polymer treatment has an effect on the increase of the root length and the shoot length.

Table-4 shows the same results of the shoots and roots measurements for the wheat plants but this time in pots with Tabouk soils.

The average roots lengths for the control, 100, 70 and 30 % were 4.38, 6.96, 7.42 and 7.93 cm, respectively (Table-4). It is clear that the average roots length increased for the polymer treated pots compared to the control. The percentage increase in roots length was 37, 40.9 and 44.8 % for the 100, 70 and 30 % polymer treatments compared to the control, respectively. The average shoots lengths for the control, 100, 70 and 30 % were 10.13, 10.84, 10.87 and 10.56 cm, respectively. The percentage increase of the shoots was 6.5, 6.8 and 4 % for the 100, 70 and 30 % polymer treatment compared to the control. It is clear that the average roots lengths in SHADCO soil was higher compared to Tabouk soils and the same is true with respect to the average shoots lengths.

Table-5 shows the average shoots and roots lengths of alfalfa plants in SHADCO soils after six days of the initial sowing on November 4, 2006.

This table shows that the average roots depths for the control, 100, 70 and 30 % were 2.4, 7.75, 5.38 and 7.06, respectively. The average shoot lengths for the control, 100, 70 and 30 % were 1.62, 1.73, 1.79 and 1.71 cm, respectively.

Table-6 shows the average shoots and roots lengths of alfalfa plants in Tabouk soils after six days of the initial sowing on November 4, 2006.

As shown in this table the average roots lengths for the control, 100, 70 and 30 % were 1.93, 3.92, 3.23 and 4.72 cm. The percentage increase in the roots was 50.8, 40.2 and 59.1 % for the 100, 70 and 30 % polymer treatments compared to the control, respectively. The average shoots lengths for the control, 100, 70 and 30 % were 2, 2.23, 2.23 and 2.04 cm, respectively. This table shows the average total length of shoots and roots for the control, 100, 70 and 30 % was 3.93, 6.2, 6.06 and 6.76 cm, respectively.

Monitoring the alfalfa yield: The results of the effect of the polymer addition on the alfalfa yield are presented in Table-7. Nine alfalfa cuts were performed.

The highest dry matter yield was obtained in the 30 % polymer mix (52.3 kg) and the lowest dry matter yield was obtained in the control without polymer (40.0). The dry matter yield in the treatment of 70 % polymer was *ca.* 42.8 kg, while that of 100% polymer-treated soils was *ca.* 40.8 kg, which is almost same as the control.

Per cent dry matter averages were 22.7, 30.0, 24.1 and 23.1 % in the control, treatment 30 % polymer, 70 % polymer and 100 % polymer, respectively.

It was decided that the wheat yield would be measured during the field experiments, while in the experiments completed, the focus was only on the length of roots and shoots.

TABLE-5
ALFALFA SHOOTS AND ROOTS LENGTH IN SHADCO SOIL AFTER SIX DAYS OF SOWING (NOVEMBER 4, 2006)

Pot #	Shoot length (cm)	Root length (cm)	Total shoot plus Root (cm)	Pot #	Shoot length (cm)	Root length (cm)	Total shoot plus root (cm)
C FP16	1.2	1.9	3.1	70 FP22	1.8	3.5	5.3
C FP16	1.6	2.1	3.7	70 FP22	1.5	2.6	4.1
C FP17	1.1	2.4	3.5	70 FP23	1.8	2.8	4.6
C FP17	1.1	2.6	3.7	70 FP23	1.5	2.3	3.8
C FP18	1.9	2.2	4.1	70 FP24	1.8	2.4	4.2
C FP18	2.1	2.2	4.3	70 FP24	1.8	2.4	4.2
C FP16	1.7	2.9	4.6	70 FP22	2.4	7.5	9.9
C FP16	1.5	1.6	3.1	70 FP22	1.8	3.8	5.6
C FP17	2.0	2.9	4.9	70 FP23	1.9	3.9	5.8
C FP17	2.0	3.2	5.2	70 FP23	1.6	4.7	6.3
Total	16.2	24.0	40.2	Total	17.9	35.9	53.6
Average	1.62	2.40	4.02	Average	1.79	3.59	5.38
100FP19	1.4	8.7	10.1	30 FP25	1.6	3.4	5.0
100FP19	2.1	6.0	8.1	30 FP25	1.5	3.0	4.5
100FP20	1.5	10.2	11.7	30 FP26	1.8	9.7	11.5
100FP20	1.8	5.0	6.8	30 FP26	1.5	3.3	4.8
100FP21	1.5	5.3	6.8	30 FP27	2.0	3.5	5.5
100FP21	1.6	9.0	10.6	30 FP27	1.7	6.5	8.2
100FP19	2.0	7.2	9.2	30 FP25	2.0	7.1	9.1
100FP19	2.0	8.5	10.5	30 FP25	1.7	5.3	7.0
100FP20	2.1	6.7	8.8	30 FP26	1.8	9.0	10.8
100FP20	1.3	10.9	12.2	30 FP26	1.5	2.7	4.2
Total	17.3	77.5	94.8	Total	17.1	53.5	70.6
Average	1.73	7.75	9.48	Average	1.71	5.35	7.06

'FP16' to 'FP27' = Pot numbers, 'C' = Control: '100' = 100 % polymer: '70' = 70 % polymer: '30' = 30 % polymer.

TABLE-6
ALFALFA SHOOTS AND ROOTS LENGTH IN TABOUK SOIL AFTER SIX DAYS OF SOWING (NOVEMBER 4, 2006)

Pot #	Shoot length (cm)	Root length (cm)	Total shoot plus Root (cm)	Pot #	Shoot length (cm)	Root length (cm)	Total shoot plus root (cm)
CAP16	1.8	2.4	4.2	70AP22	2.4	3.2	5.6
CAP16	1.5	3.0	4.5	70AP22	3.0	3.5	6.5
CAP17	2.5	1.5	4.0	70AP22	2.5	3.5	6.0
CAP17	2.6	2.5	5.1	70AP23	2.0	3.2	5.2
CAP18	1.6	1.2	2.8	70AP23	2.5	3.7	6.2
CAP18	2.0	2.4	4.4	70AP23	1.6	4.5	6.1
CAP28	1.5	1.3	2.8	70AP24	2.1	4.7	6.8
CAP28	1.5	1.0	2.5	70AP24	2.0	4.0	6.0
CAP29	2.3	1.2	3.5	70AP24	2.2	3.6	5.8
CAP30	2.7	2.8	5.5	70AP22	2.0	4.4	6.4
Total	20.0	19.3	39.3	Total	22.3	38.3	60.6
Average	2.0	1.93	3.93	Average	2.23	3.23	6.06
100AP19	1.9	4.2	6.1	30AP25	2.0	5.5	7.5
100AP19	2.0	3.0	5.5	30AP25	2.5	6.0	8.5
100AP19	1.8	3.7	5.5	30AP25	2.1	4.9	7.0
100AP20	2.1	4.7	6.8	30AP26	2.4	5.6	8.0
100AP20	2.4	3.8	6.2	30AP26	1.8	4.2	6.0
100AP20	2.4	4.1	6.5	30AP26	1.8	4.5	6.3
100AP21	2.4	4.2	6.6	30AP27	1.8	4.8	6.6
100AP21	2.5	4.0	6.5	30AP27	2.0	3.2	5.2
100AP21	2.4	3.4	6.5	30AP27	2.0	4.0	6.0
100AP19	2.4	4.1	6.5	30AP25	2.0	4.5	6.5
Total	22.3	39.2	62.0	Total	20.4	47.2	67.6
Average	2.23	3.92	6.2	Average	2.04	4.72	6.76

'AP16' to 'AP30' = Pot numbers, 'C' = Control: '100' = 100 % polymer: '70' = 70 % polymer: '30' = 30 % polymer.

TABLE-7
EFFECT OF POLYMERS ON ALFALFA YIELD

Block ID and poly. conc.	Alfalfa yield (kg)								
	First (17-6-2008)	Second (31-7-2008)	Third (3-9-2008)	Fourth (5-10-2008)	Fifth (6-11-2008)	Sixth (17-12-2008)	Seventh (11-2-2009)	Eighth (14-3-2009)	Ninth (18-4-2009)
70 % (1)	2.3	4.6	4.6	4.5	4.8	5.6	5.3	5.7	6.4
100 % (2)	3	5	4.9	4.8	5.2	5.8	5.5	6.0	6.8
30 % (3)	3.9	6.1	6.2	6.1	6.9	7.9	7.2	7.1	7.5
Control (4)	3.1	3.8	3.8	3.8	4.1	5.6	5.3	5.2	5.3
30 % (5)	2.5	3.6	4.3	4.4	4.8	5.8	7.3	7.6	6.5
70 % (6)	3	3.8	4	4.1	4.3	5.7	5.4	5.3	5.3
Control (7)	3.1	3	4.3	4.2	4.4	4.9	5.4	5.3	5.4
100 % (8)	2.2	3	3	3.1	3.2	4.5	5.2	4.9	5.4
Avg.	2.9	4.1	4.4	4.4	4.7	5.7	5.8	5.9	6.1
Total	23.1	32.9	35.1	35	37.7	45.8	46.7	47.0	48.5

Conclusion

Irrigation benefits: Adding polymer to the soil had a major advantage which was to reduce the frequency of irrigation in both soils. The amount of water used in irrigation was less as the polymer concentration increases, except for the case of SHADCO soil where the 30 % polymer concentration mixed with soil took more water compared to 0 % concentration (control). The explanation for this could be due to the fact that the 30 % polymers mix did affect the soil physical properties like the permeability and its water holding capacity, but at the same time the amount of water stored in the water absorbent polymer was not high compared to the 70 and 100 % concentrations. So, the amount of water stored in the water absorbent polymer did not compensate for the loss of irrigation water due to the increase in the soil permeability caused by the water dissolved polymer added to the 30 % treated soil. At all irrigation salinities, the 100 % polymer concentration needed the least amount of irrigation water compared to the control or to the 30 and 70 % polymer concentrations.

Plant growth and development: The addition of the polymer had a pronounced effect on the roots length and shoots length of both wheat and alfalfa plants in SHADCO and Tabouk soils. It is clear that the polymer treatment has an effect on the increase of the roots length and the shoots length. The average roots and shoots lengths in SHADCO soil were higher compared to Tabouk soils.

The polymer treatment of soil did affect the plant early development and the plants grown in treated soils were more advanced. It could be noticed that there were more seedlings with three shoots in the polymer treated pots compared to the control pots.

Crop yield: In all the treatments the treated soil did consume less water per yield compared to the control. The highest dry matter yield in grams in the average was 25.4 g for the 70 % treatments irrigated with 3000 ppm, the average for the control was 5.8 g. This means the yield is four times the dry matter yield from the 70 % treatment compared to the control. However, in some cases the yield is more than 20 times the yield from many treatments such as the 70 % under 2000 ppm irrigation water compared to the control.

Even more important than the increased yield is the less water consumed per yield. For example, the amount of water used for the control under 500 ppm was 39 m^3/kg compared to 0.9 m^3/kg for the 100 % treatment. This is almost 40 times saving in water. But, on average the saving was between two to three times.

Leaching: In general, the Tabouk soil mixes that contain a lower polymer concentration (30 %-content) did not leach and no samples were collected for analysis, while the soil mixes that contain high polymer concentrations (70 %-content) showed high levels of polymer material (1500-2000 ppm) drained after irrigation. It was also noticed for Tabouk soils that salinity of the irrigation water did not significantly affect the amount of polymer leached with the irrigation water of the 70 %-content soil mixes in the first batch. However, higher salinity leads to higher leaching rate especially with increased time of the experiment.

In case of the sandy soil, it was observed that increasing the water salinity increased the polymer leaching substantially. The amount of polymer that leached was uniform throughout the experiment. Unlike the loamy soil mixes, the concentration of polymer in the leachate from sandy soils did not significantly decrease overtime. Increasing polymer concentration resulted in increasing the amount of polymer in the leachate for samples collected at early times.

Biodiversity: The addition of the polymer did increase the number of plants types and variety in the plots compared to the controls. This is a significant advantage and a positive effect of the polymers on the biodiversity of natural vegetation.

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