FINAL REPORT

For the period: June 1995 - December 1998

Submitted to the office of the Science Advisor
U.S. Agency for International Development

Project Title: **Developing soil and water management to prevent the negative effects resulting from irrigation with marginal waters.**

Project Identification no.: CA14-028
Grant no. TA-MOU-94-CA14-028

Principal Investigator: **G.J. Levy**
Inst. of Soils and Water, ARO, The Volcani Center, Bet Dagan, Israel
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A.I.D. Grant Project Officer: David Mulenex, American Embassy, Tel Aviv, Israel

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3. Executive Summary

The ever growing shortage of good quality water in semi-arid and arid regions forces the use of alternative sources of water for irrigation, such as treated waste water and saline water. In Kazakhstan, agriculture and mainly irrigated field crops, is one of the main sources of income. The current main source of water for irrigation in many irrigation schemes in Kazakhstan, is saline ground water with high water table. The overall aim of the proposed research is to develop soil and water managements, that will enable safe irrigation with marginal water in cultivated soils, without causing a deterioration in soil properties, productivity and fertility. In Israel, studies under controlled laboratory conditions yielded the following results: (i) reclamation of sodic soils can be accomplished by means of the naturally occurring $CaCO_3$ in the soil, providing management conducive for $CaCO_3$ dissolution, such as enriching the soil environment with CO_2, is used; (ii) addition of synthetic organic polymers to the soil can delay crust drying and maintain a crust with a lower mechanical strength which subsequently does not impeed seed germination; and (iii) presence of potassium (K) in the irrigation water does not have a deleterious effect on soil hydraulic conductivity (HC) as long as exchangeable K does not exceed 15%; under these conditions K does not add to the reduction in soil HC beyond that caused by the presence of Na or other constituents in the waste water.

In Kazakhstan, a field experiment was conducted in three sites of the Tasotkel Massif irrigation scheme near the city Shu. In the study the effect of three water salinity levels (1, 2 or 4 g L^{-1}) used for irrigation of maize, on soil physical properties and yield were studied. In addition three different type of seeds were tested, commercial seeds and two groups of seeds that were treated to improve their resistance to salinity. The data showed that treatment of the seeds prior to sowing improved yields under irrigation with saline water. Irrigation with saline water increases the salinity and alkalinity of the soil profile and ground water. Amelioration of the soil with amendments containing Ca is therefore essential.

The studies preformed within the framework of this project indicated that various types of management tools can be applied to fields irrigated with water poor quality to prevent negative impacts on soil and crops associated with soil salnization and sodification. Further studies are necessary to incorporate the knowledge gained in the laboratory and field studies in order to develop management tools that will enable farmers to practice sustainable irrigated agriculture under harsh conditions of marginal water.

4. Research Objectives

The overall aim of the proposed research was to develop soil and water managements that will enable safe irrigation with marginal water in cultivated soils without causing a deterioration in soil properties, productivity and fertility.

More specifically, the research work focused on studying of (i) the effects soil amendments (phosphogypsum and organic polymers) application on improving soil permeability (i.e., preventing crusting) and on the leaching efficiency of rain water; (ii) determining the conditions which maximize the reclamation efficiency of naturally occurring lime in calcareous soils; and (iii) Improving irrigation management for marginal water.

In Kazakhstan intensifying agriculture led to exploitation of ground water, and drainage water and hence to a gradual deterioration of their quality. In Israel, it is estimated that by the turn of the 21st century out of ~800 million m^3 of water available for agriculture, 650 million m^3 will be saline and treated waste water. The possible hazards of irrigation with poor quality water on soil properties and productivity should be prevented. It is, therefore, essential to develop management tools that will enable individual farmers in Kazakhstan to practice sustainable agriculture albeit the use of marginal waters.

5. Methods and Results

5.1. Israel

Research activities included laboratory studies, which were summarized in two manuscripts that have been published and a report (see section 7). The topics of these studies were:

I. Sodic calcareous soil reclamation as affected by water chemical composition and flow rate.

II. Polymer effects on surface mechanical strength of a crusting loessial soil.

III. Effects of potassium (K) on soil hydraulic conductivity (HC).

Abstracts of these manuscripts are presented herein. The full manuscripts are enclosed in appendices 1, 2, and 3.

I. Sodic calcareous soil reclamation as affected by water chemical composition and flow rate

A. Nadler, G.J. Levy, R. Keren and H. Eisenberg

Abstract

Sodic soils exhibit poor physical conditions that adversely influence water and air movement, soil erodibility and plant growth. This study investigated the efficiency of naturally occurring $CaCO_3$ in

reclaiming a sodic loess soil (Calic Haploxeralf) with an exchangeable sodium percentage of 16. Soil columns (50 or 100 mm high) were leached with distilled water (DW), 1 dS m^{-1} tap water (TW), or CO_2-enriched TW at a flow rate of either 11.5 or 50 mm h^{-1}. The effluent from the columns was collected continuously, and its chemical composition was analyzed. When DW was used, $CaCO_3$ dissolution was the main source (85%) for replacing exchangeable Na. When TW was used, 80% of the (Ca+Mg) for replacing the sodic soil came from the leaching solutions. The slow water flow rate (11.5 mm h^{-1}) improved reclamation by ~30%, probably due to the higher concentration of (Ca+Mg) from $CaCO_3$ and the longer time available for Cadiffusion into soil aggregates. The CO_2-enriched TW was the most favorable treatment for $CaCO_3$ dissolution and thus the most efficient for soil reclamation. Our results suggest that reclamation of sodic soils can be accomplished by means of the naturally occurring $CaCO_3$ in the soil, providing management conducive for $CaCO_3$ dissolution is used.

II. Polymer effects on surface mechanical strength of a crusting loessial soil

G.J. Levy and I. Rapp.

Abstract

A study has been carried out to evaluate the mechanism for polymer addition contributing to reduction of crust mechanical strength in soil. Three polymers were used. Adding synthetic polymers to crusting soils usually helps seedlings to emerge. The effect is thought to be the result of lower mechanical strength of soil surface that is crusted. Samples of a silty loam calcareous loess were packed in round pots and polymer was added by spraying a concentrated solution. The pots were then exposed to 40 mm of simulated rainfall. In an additional study, polymer was added to tap water to form a dilute polymer solution which was then used in the 40-mm rain event. In most of the treatments, moisture content immediately after the rain was significantly higher than in the control. For a given moisture content, in general crust strength did not differ significantly between controls and the polymer-treated pots. Moisture content for a drying time was higher in the polymer treatments than in the controls. It seems polymer application delays crust drying and maintains a crust with a lower mechanical strength. Polyacrylamide with a low molecular weight applied at 40 kg/ha seems to be the most effective treatment.

III. Effects of potassium (K) on soil hydraulic conductivity (HC)

G.J. Levy, I. Shainberg, D. Goldstein and R. Keren

Abstract

Treated sewage water is becoming a substantial source of water for irrigation of cultivated fields. Salinity and sodicity are among the main problems associated with the use of treated waste water for irrigation. One way of reducing sodicity in the irrigation water is to replace Na salts with K salts at the source of contamination of the irrigation water. In numerous industries as well as in domestic use, NaCl is used for water softening. The use of Kcl instead of NaCl is possible. Because of the higher affinity of the soil to k compared with Na, increasing the K concentration in the irrigation water by a small amount may lead to a substantial increase in exchangeable K. The objectives of the study were to asses the effects of K on soil hydraulic conductivity in binary (K-Ca) and ternary (K-Na-Ca) systems. The hydraulic conductivity studies were carried out in the laboratory using soil columns. The results indicated that the presence of K in the irrigation water did not have a deleterious effect on soil hydraulic conductivity as long as the resultant exchangeable k did not exceed 15%. Under these conditions K did not add to the reduction in the hydraulic conductivity beyond that caused by the presence of Na or other constituents of the treated sewage water.

5.2. Kazakhstan

Research activities included only field studies, which were summarized in two reports. The topics of these studies were:

IV. Evaluation of long term effects on irrigation with marginal waters on ground water quality and soil properties in the Tasotkel massif irrigation scheme (one year) - Samples of (i) representative cultivated soils from three experimental sites, (ii) irrigation water and (iii) ground water at irrigated sites, were brought to the laboratory and analyzed. The data indicate that the waters used vary in their salinity levels and that the soil turn sodic and alkaline following the use of saline and sodic water for irrigation..

V. Water salinity and seeds pretreatments effects on soil physical properties and maize yield in the Tasotkel massif irrigation area (two years) - A field experiment was conducted in three sites of the Tasotkel Massif irrigation scheme near the city Shu. In the study the effect of three water salinity levels (1, 2 or 4 g L^{-1}) used for irrigation of maize, on soil physical properties and yield were studied. In addition three different type of seeds were tested, commercial seeds and two groups of seeds that were treated to improve their resistance to salinity. The data showed that treatment of the seeds prior to sowing improved

yields under irrigation with saline water. Irrigation with saline water increases the salinity and alkalinity of the soil profile and ground water. Amelioration of the soil with amendments containing Ca is therefore essential.

The full reports are enclosed in appendices 4 and 5.

6. Impact, Relevance and Technology Transfer

The principal investigators (PI) from Israel and Kazakhstan met a number of times during the project. The visits were used to summarize the past experiments and plan future ones. These visits were also used to transfer methodologies used in Israel, to the laboratory of the PI in Kazakhstan, for laboratory determinations of soil and irrigation water properties.

The project enabled a large scale study of the soils and irrigation and ground water in the Tasotkel massif region, the need for which has long been recognized, but lack of funding prevented its execution. A large group of both scientists and technical staff of the Soil Science Institute (SSI), Academy of Science of Kazakhstan, was involved in the project, and was thus exposed to the Israeli experience and expertise in the understanding of the chemical and physical effects of soil and water properties involved in the handling and reclamation processes of sodic soils. Realization of the project allowed the SSI to retain valuable equipment necessary for conducting this and similar studies.

7. Project Activities/Outputs

The Israeli principal investigator visited Kazakhstan at the beginning of the first year of the project. The visit was dedicated for a detailed planning of the field experiments. The visit helped the Israeli investigator to better understand the problems and difficulties involved in use of poor quality water for irrigation in Kazakhstan. The visit also helped the Israeli PI to adapt the experiments in his laboratory in Israel to the needs of Kazakhstan.

Prof. Akhanov and Dr. Shimshikov from SSI visited Dr. Levy in Israel during March 1997. The visit was used to discuss the field experiments in Kazakhstan (partial results of year 2 and plans for the experiments in year 3), as well the laboratory studies conducted in Israel and the possible implementation of the use of polymers in kazakhstan for improving seedling emergence.

The out put of the project was summarized in two papers that have been published, and three reports:

I. Nadler, A., G.J. Levy, R. Keren, and H. Eisenberg. 1996. Sodic calcareous soil reclamation as affected by water chemical composition and flow rate. Soil Sci. Soc. AM. J. 60:252-257.

II. Levy, G.J. and I. Rapp. 1999. Polymer effects on surface mechanical strength of a crusting loessial soil. Aust. J Soil Res. 39:91-101.

III. Levy, G.J., I. Shainberg, D. Goldstein and R. Keren. 1999. Effects of potassium (K) on soil hydraulic conductivity (HC).

IV. Akhnov, J.U., B.E. Shimshikov, H.G. Kadyrbaeva, and T.K. Tomina. 1999. Evaluation of long term effects on irrigation with marginal waters on ground water quality and soil properties in the Tasotkel massif irrigation scheme

V. Akhnov, J.U., B.E. Shimshikov, H.G. Kadyrbaeva, and T.K. Tomina. 1999. Water salinity and seeds pretreatments effects on soil physical properties and maize yield in the Tasotkel massif irrigation area.

8. Project productivity

The project made a contribution towards its goals and objectives. It is believed that irrigation with marginal water over high water table in Kazakhstan can be improved and made more sustainable by applying the management developed in the project.

9. Future work

A new proposal entitled: 'Improving water use efficiency and decreasing erosion in fields irrigated with poor quality water using surge irrigation' has been submitted by the Israeli and Kyrgyzian PIs to the US-Israel CAR program. The proposal was developed based on the results obtained in the current project, and is currently under evaluation.

10. Literature cited

List of relevant literature is given at the end of each manuscript/report appearing in the Appendices

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APPENDIX 1

Sodic Calcareous Soil Reclamation as Affected by Water Chemical Composition and Flow Rate

A. Nadler,* G. J. Levy, R. Keren, and H. Eisenberg

ABSTRACT

Sodic soils exhibit poor physical conditions that adversely influence water and air movement, soil erodibility, and plant growth. This study investigated the efficiency of naturally occurring $CaCO_3$ in reclaiming a sodic loess soil (Calcic Haploxeralf) with an exchangeable sodium percentage of 16. Soil columns (50 or 100 mm high) were leached with distilled water (DW), 1 dS m^{-1} tap water (TW), or CO_2-enriched TW at a flow rate of either 11.5 or 50 mm h^{-1}. The effluent from the columns was collected continuously, and its chemical composition was analyzed. When DW was used, $CaCO_3$ dissolution was the main source (85%) for replacing exchangeable Na. When TW was used, 80% of the (Ca^{2+} + Mg^{2+}) for reclaiming the sodic soil came from the leaching solution. The slow water flow rate (11.5 mm h^{-1}) improved reclamation by ~30%, probably due to the higher concentration of (Ca^{2+} + Mg^{2+}) from $CaCO_3$ and the longer time available for Ca^{2+} diffusion into soil aggregates. The CO_2-enriched TW was the most favorable treatment for $CaCO_3$ dissolution and thus the most efficient for soil reclamation. Our results suggest that reclamation of sodic soils can be accomplished by means of the naturally occurring $CaCO_3$ in the soil, providing management conducive for $CaCO_3$ dissolution is used.

SALINE–SODIC IRRIGATION WATER, coupled with limited rainfall and high evaporation, may significantly increase soil sodicity. For instance, irrigation with saline–sodic water (EC = 3–8.5 dS m^{-1} and SAR = 14–26) constantly increased soil sodicity (Mantell et al., 1985). Excessive exchangeable Na^+, associated with pH >8.4, impairs the physical condition of soils and adversely affects water and air movement, soil erodibility, and plant growth (Suarez et al., 1984; Gupta and Abrol, 1990).

Reclamation of sodic soils is achieved by leaching with or without chemical amendments added to the soil or irrigation water (Keren and Miyamoto, 1990). Chemical amendments are materials that supply divalent cations (usually Ca^{2+}) for replacement of exchangeable Na^+. Chemical amendments are grouped into three categories: (i) soluble calcium salts (e.g., $CaCl_2$); (ii) sparingly soluble salts ($CaSO_4 \cdot 2H_2O$, $CaCO_3$, dolomite); and (iii) acids or acid forms of chemicals (Miyamoto et al., 1975) added to calcareous sodic soils. This study deals with the second group.

One of the most common amendments is gypsum. However, gypsum in sodic soils may cause (i) Na_2SO_4 formation in the soil profile under natural conditions (Blume et al., 1985) or under intensive irrigation with sodic waters (Magaritz and Nadler, 1993), and (ii) addition of radioactive elements detected in the phosphogypsum (a by-product of the phosphorus industry). Excessive application of gypsum could lead to the accumulation of radioactive elements in the cultivated zone, and these elements could possibly enter the food chain.

Soils in arid and semiarid regions often contain significant amounts of carbonate minerals [e.g., $CaCO_3$, $MgCO_3$, $CaMg(CO_3)_2$], which may contribute Ca^{2+} and Mg^{2+} ions to the soil solution. This addition of divalent cations to the soil solution can reduce clay dispersion and increase HC in the soil profile (Keren and Miyamoto, 1990). However, at the soil surface, crust formation and related processes (runoff and erosion) will be less affected by soil $CaCO_3$ primarily because of the shorter contact time between an incremental volume of water and the surface area of $CaCO_3$ (Keren, 1989).

Adding $CaCO_3$ to reclaim sodic soils has been considered to be of limited value (Gupta and Abrol, 1990). However, under certain conditions, naturally occurring carbonate minerals can play a significant role in reclaiming sodic soils. This occurs because very fine particles of soil calcite have sufficiently high surface-free energies for their solubility to be higher than theoretically predicted values for well-crystallized calcite (Inskeep and Bloom, 1986).

Bower and Goertzen (1958) showed that adsorption of Na^+ decreased with increasing soil moisture content. They also noted that in soils containing plant roots, the presence of CO_2 enhanced $CaCO_3$ dissolution and resulted in a measurable, though limited, degree of replacement of adsorbed Na^+ (Goertzen and Bower, 1958). Rao and Ghai (1985) obtained more impressive soil reclamation results by growing trees for 12 yr and markedly improving the biological activity, which in turn enhanced CO_2 production and $CaCO_3$ dissolution. Dissolution rate of $CaCO_3$ is relatively fast under conditions where P_{CO_2} > atmospheric P_{CO_2} (Amrhein et al., 1985), therefore increasing the CO_2 level in the soil could be a possible option for reclaiming sodic calcareous soils.

Efficiency of soil reclamation with low solubility salts (e.g., gypsum) depends on the flow rate of the percolating solution. For gypsum, increased flow rates (i) reduced the thickness of the water film around the gypsum particles and (ii) reduced the contact time between a unit volume of water and the surface area of the gypsum particles (Kemper et al., 1975; Keren and O'Connor, 1982). In addition, increased flow rates reduce the opportunity for Ca–Na exchange. Kalo (1982) reported that the contribution of naturally occurring lime dissolution to the electrolyte concentration of the percolating solution decreased significantly, with increased flow rate.

Because of the increasing need to irrigate with saline

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Abbreviations: ESP, exchangeable sodium percentage; DW, distilled water; TW, tap water; EC, electrical conductivity; SAR, sodium adsorption ratio; HC, hydraulic conductivity; EDTA, ethylenediaminetetraacetic acid; TE, total electrolytes.

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sodic waters and the potential negative impact of long-term gypsum application on the environment, reclamation of sodic soils by naturally occurring $CaCO_3$ in the soil profile should be evaluated. In the past, chemical amendments have been used to reduce soil sodicity even in calcareous soils. We feel that naturally occurring $CaCO_3$ can be managed by controlling combinations of water quality, P_{CO_2}, and irrigation intensity, to increase reclamation efficiency of sodic soils. Therefore, the objectives of our study were to determine the effects of flow rate and ionic composition of the percolating solution, soil depth, and P_{CO_2} on the efficiency of naturally occurring $CaCO_3$ in reclaiming sodic soils.

MATERIALS AND METHODS

A loamy loess soil (Calcic Haploxeralf) from Nahal Oz in the northwestern region of the Negev, Israel, was used in this study. The soil was formed from windblown loessial material from the Sinai desert and contained 251 g kg^{-1} $CaCO_3$. The soil had a cation-exchange capacity of 17.6 $cmol_c$ kg^{-1} and an ESP of 16. The texture of the soil was 19% clay, 31% silt, and 50% sand.

Soil sampled from the upper 250 mm was air dried, crushed, and sieved (<2 mm). Soil columns were prepared by packing soil into plastic cylinders (50 or 100 mm tall and 50 mm i.d.) at a bulk density of 1.4 Mg m^{-3}. Each soil column was slowly wetted from the bottom with either DW, TW, or CO_2-enriched TW and was allowed to stay saturated for about 12 h. The saturating solution was then used for leaching. A flow rate of either 11.5 or 50 mm h^{-1} (referred to as the slow or fast flow rate, respectively), was delivered to the soil surface by a peristaltic pump. The EC of the TW was ~1.0 dS m^{-1}, and the ion concentrations expressed in millimoles of charge per liter were (Ca^{2+} + Mg^{2+}) 5.9, Na^+ 4.5, Cl^- 6.1, SO_4^{2-} 1.8, and HCO_3^- 2.4. The CO_2-enriched solution was obtained by bubbling 0.057 mol CO_2 into 3 L of TW for 2 h. The experiments were conducted at room temperature (22 ± 0.5°C). Leachate was collected in 0.025-L test tubes with a fraction collector and the EC, pH, and (Ca^{2+} + Mg^{2+}), Na^+, HCO_3^-, and Cl^- concentrations were measured. The (Ca^{2+} + Mg^{2+}) concentration was determined by EDTA titration, Na^+ by flame photometry, HCO_3^- by HCl titration, and Cl^- by a Haake Buchler chloridometer. After leaching, the soils in the columns were dried at 60°C for 48 h and then sectioned into two or four slices (according to column length), each 25 mm thick. The adsorbed Na and the cation-exchange capacity of the soil were determined for each slice. All leaching experiments were carried out in duplicate.

The cumulative amount (Q_i, $mmol_c$) of ion i in the leachate relative to its amount in the leaching solution was calculated as follows:

$$Q_i = \sum(C_{ij} - C_{ls})V_j \quad [1]$$

where C_{ij} and C_{ls} are the ion concentrations in the leachate and in the leaching solution, respectively, at a given volume V_j. A positive value of Q_i indicates an addition of ion i to the leachate, compared with the leaching solution, whereas a negative value indicates its depletion from solution and therefore accumulation by the soil. The electrolyte concentration, SC ($mmol_c$ L^{-1}), in the leaching and leachate solutions was evaluated with the following equation:

$$SC = 10\,EC \quad [2]$$

where EC is the specific electrical conductance of the solution (dS m^{-1}). The amount of total electrolytes in the leachate (TE, $mmol_c$) was evaluated with the following equation:

$$TE = \sum(SC_j V_j) \quad [3]$$

The average ESP of the soil in the column was calculated for each given cumulative leachate volume v with the following equation:

$$\text{Average ESP} = 100[Q(Na)_{init} - Q(Na)_v]/(CEC) \quad [4]$$

where $Q(Na)_{init}$ is the initial amount of Na adsorbed on the soil sample packed in the column ($mmol_c$), $Q(Na)_v$ is the amount of Na removed from the soil by the leachate after volume v of leaching solution has passed through the column ($mmol_c$), CEC is the cation-exchange capacity of the soil sample in the column ($mmol_c$ g^{-1}), and m is the weight of the soil packed in the column (g).

RESULTS AND DISCUSSION

The mean cumulative amounts of Na^+, (Ca^{2+} + Mg^{2+}), HCO_3^-, Cl^-, and TE in the leachate when DW was applied at the fast flow rate (50 mm h^{-1}) are presented in Fig. 1. Mean values were used because differences between replicates for each parameter tested for all the treatments to be discussed were smaller than 8%. Comparison of the total amounts of the cations determined [Na^+, (Ca^{2+} + Mg^{2+})] with the total amount of the anions measured (Cl^- and HCO_3^-) revealed that the amount of the cations was somewhat higher than that of the anions. Sulphate was assumed to be the anion that compensated for the observed difference in charge valance between measured cations and anions. A distinct deviation in the patterns of the Cl^- and HCO_3^- accumulation in the leachate was observed. Most of the Cl^- was removed from the soil during the first 0.080 L (~1.6 pore volume), indicating that the sources of the Cl^- were the highly soluble NaCl and $CaCl_2$ salts. A similar fast removal (~4 pore volumes) of Cl^- was also observed for each soil column. The release of HCO_3^- to the leachate solution was apparently a continuous process (Fig. 1) indicating that the source of the HCO_3^- was probably from the less soluble $CaCO_3$. When the sharp increase in the accumulation of HCO_3^- was contrasted with leachate volume, the increase in accumulated (Ca^{2+} + Mg^{2+}) was small, despite the fact that both ions originate from the same source, i.e., solid $CaCO_3$. The slow increase of Ca^{2+} in the leachate, we assume, resulted from the cation-exchange reaction between dissolved Ca^{2+} and adsorbed Na. The cumulative amount of Na^+ in the leachate increased at a rate similar to that of HCO_3^-. The average ESP of the soil decreased during leaching from 16 to 4 after applying 1.050 L (21 pore volumes) of DW to the soil columns (Fig. 1). The average ESP reduction rate was initially high, 8% per pore volume (i.e., ~0.050 L), but toward the end of leaching, the rate decreased to 2.5% per pore volume. The calculated final ESP value of 4 was comparable with the measured values at the end of leaching, ESP of 2.4 and 3.6 for the top and bottom of the column, respectively (Table 1).

The cumulative amounts of Na^+, (Ca^{2+} + Mg^{2+}), HCO_3^-, and TE in the leachate when DW was applied

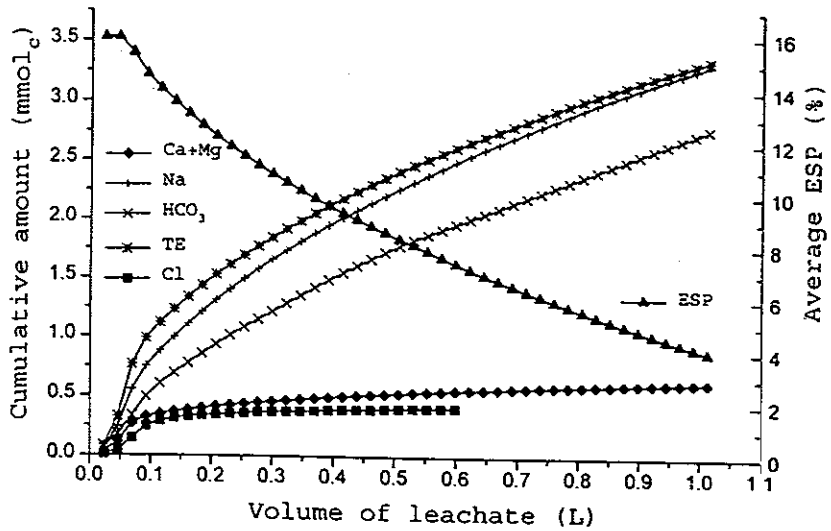

Fig. 1. Cumulative amounts of (Ca^{2+} + Mg^{2+}), Na^+, HCO_3^-, and total electrolytes (TE) and changes in average exchangeable sodium percentage (ESP), as a function of leachate volume, when leaching a 50-mm-long soil column with distilled water at a flow rate of 50 mm h^{-1} (symbol size represents the error bar).

at the slow flow rate (11.5 mm h^{-1}) are presented in Fig. 2. The HCO_3^- accumulation in the leachate in this system was higher than that observed for the soil leached at the fast flow velocity (Fig. 1) at any given leachate volume. This observation suggested that HCO_3^- dissolution and concentration in the soil solution depended on the contact time between solution and solid $CaCO_3$. The longer the contact time (resulting from slower flow rate), the higher the concentration of HCO_3^-. Similarly, the average ESP of the soil was lower than that calculated for the fast flow rate at any given leachate volume (Fig. 1 and 2). Reclamation efficiency of replacing Na^+ by (Ca^{2+} + Mg^{2+}) is commonly defined as volume of solution causing a change of 1 unit of ESP in a unit volume of soil. However, for reasons of simplicity, we evaluated reclamation efficiency from the ESP obtained at the end of the treatment. Reclamation efficiency increased as the flow velocity decreased. The higher efficiency at the slower flow rate was probably due to the higher concentration of Ca^{2+} in the solution and the longer time available for Ca^{2+} to diffuse into the soil aggregates.

The cumulative amounts of Na^+, (Ca^{2+} + Mg^{2+}), HCO_3^-, and TE in the leachate during leaching with TW at a flow rate of 50 mm h^{-1} are presented in Fig. 3. The amount of HCO_3^- increased slowly and reached 0.3 mmol$_c$ at the end of leaching (Fig. 3). By comparison, when DW was used, the amount of HCO_3^- in the leachate increased rapidly and reached a final high value of 2.8 mmol$_c$ (Fig. 1). The initial (Ca^{2+} + Mg^{2+}) and HCO_3^- concentrations in the TW were 5.9 and 2.4 mmol$_c$ L^{-1}, respectively. Hence, $CaCO_3$ dissolution diminished because of the common ion effect with respect to Ca^{2+} and HCO_3^-, and consequently, the net amount of HCO_3^- in the leachate was limited. The (Ca^{2+} + Mg^{2+}) depleted from the leaching solution was approximately equal to the amount of Na^+ in the leachate solution (Fig. 3). These results, together with the low HCO_3^- level, indicated that the (Ca^{2+} + Mg^{2+}) that replaced the exchangeable Na^+ came mainly (~80%) from the leaching solution (TW) and the rest (20%) from dissolved $CaCO_3$.

The reclamation efficiency of TW was higher than that of DW. For instance, an average ESP value of 5 was obtained after leaching the soil with 600 mL of TW (12 pore volumes; Fig. 3), in comparison with an ESP value of 8 for the same leaching volume, when DW was used (Fig. 1). Similar to the DW treatments, the calculated average ESP value of the soil after leaching with TW was in good agreement with the experimentally determined ESP values of 4.7 and 5.5 at the top and bottom of the column, respectively (Table 1).

Leaching the soil with TW resulted in an accumulation of Na^+ and a depletion of (Ca^{2+} + Mg^{2+}) in the leachate. This phenomenon could, under certain circumstances, lead to an increase in the residual alkalinity of the soil, which is defined as alkalinity in excess of the total amount of divalent ions. Residual alkalinity is enhanced upon shifting the proportion of monovalent cations relative to divalent cations (van Beek and van Breemen, 1973). This trend may lead to the undesirable increase in sodicity of the soil profile below the reclaimed horizon. However, no deterioration in soil physical properties is expected because the total electrolyte concentration in the soil solution will be high enough (due to evapotranspiration) to prevent clay swelling and dispersion.

When CO_2-enriched (0.83 g CO_2 L^{-1}) TW was used

Table 1. Experimental parameters and exchangeable sodium percentage (ESP) data.

Column length	Water quality	CO_2 enrichment	Solution flow rate	ESP† Top	ESP† Bottom	ΔESP‡
mm			mm h^{-1}	%		
50	DW		11.5	3.1	6.3	9.7
50	DW		50.0	2.4	3.6	12.4
50	TW		50.0	4.7	5.5	10.5
50	TW	+	50.0	2.1	2.2	13.8
100	TW	+	50.0	2.8	2.6	13.5

† ESP of the top and bottom quarters of the soil column, respectively.
‡ ΔESP = difference between initial ESP and final ESP of the bottom quarter of the soil column.

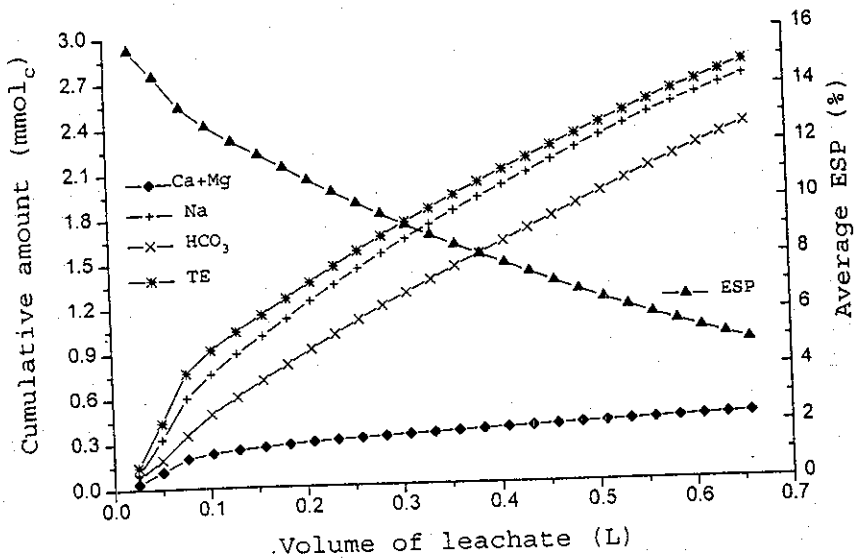

Fig. 2. Cumulative amounts of (Ca^{2+} + Mg^{2+}), Na^+, HCO_3^-, and total electrolytes (TE), as a function of leachate volume, when leaching a 50-mm-long soil column with distilled water at a flow rate of 11.5 mm h^{-1} (ESP = exchangeable sodium percentage).

for leaching the soil columns (Fig. 4) 0.2 L (~4 pore volumes) was needed to remove the exchangeable Na^+ in the 50-mm soil column. The average ESP dropped at a rate of 25% per pore volume. In addition, no significant change in the cumulative (Ca^{2+} + Mg^{2+}) was observed during leaching by the first 4 pore volumes (Fig. 4). By comparison, when TW alone was used for leaching, there was a constant depletion of (Ca^{2+} + Mg^{2+}) from the leaching solution (Fig. 3). These results indicate that (i) dissolution of $CaCO_3$ present in the soil was the main source of (Ca^{2+} + Mg^{2+}) needed to replace the exchangeable Na^+ and that (ii) $CaCO_3$ dissolution in TW was due to the enrichment of the TW with CO_2. Subsequent leaching of the soil after the first 4 pore volumes resulted in an accumulation of 2.3 mmol$_c$ of (Ca^{2+} + Mg^{2+}) in the leachate. Increasing the level of CO_2 in the irrigation water led to a near continuous dissolution of $CaCO_3$ during leaching, even after the sink for dissolved (Ca^{2+} + Mg^{2+}) ions (i.e., exchangeable Na) was depleted. The observed beneficial effect of enriching TW with CO_2 on $CaCO_3$ dissolution is in agreement with previous studies (Bower and Goertzen, 1958; Suarez et al., 1984).

Adding high CO_2 water to sodic soils may turn them alkaline and increase soil pH values (this did not occur in this study, the pH of the leachates for all treatments was <8.12). A theoretically based relationship between pH (for pH <9), alkalinity, and the partial pressure of CO_2 has been suggested by van Beek and van Breemen (1973):

$$\log \text{Alk} - \text{pH} = \log pCO_2 - 7.82 \qquad [5]$$

This relation indicates that a 10-fold increase in alkalinity or a tenfold decrease in pCO_2 is accompanied by a pH

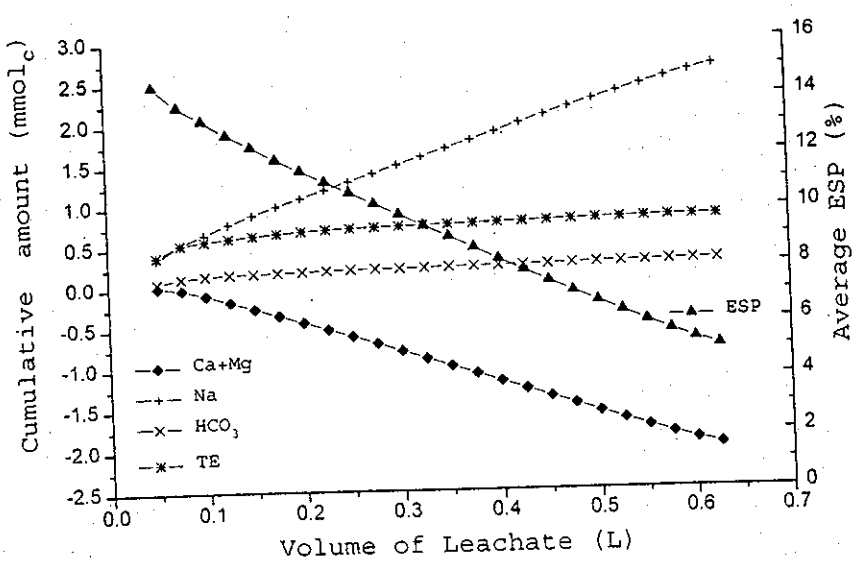

Fig. 3. Cumulative amounts of (Ca^{2+} + Mg^{2+}), Na^+, HCO_3^-, and total electrolytes (TE) as a function of leachate volume, when leaching a 50-mm-long soil column with tap water at a flow rate of 50 mm h^{-1} (ESP = exchangeable sodium percentage).

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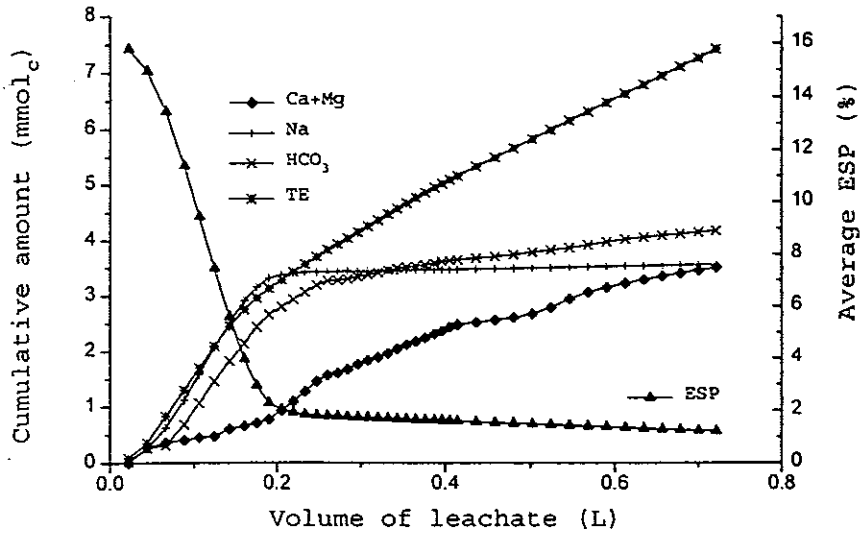

Fig. 4. Cumulative amounts of (Ca^{2+} + Mg^{2+}), Na^+, HCO_3^-, and total electrolytes (TE) as a function of leachate volume, when leaching a 50-mm-long soil column with CO_2-enriched tap water at a flow rate of 50 mm h^{-1} (ESP = exchangeable sodium percentage).

increase of 1 unit. Increased soil pH may affect the pH-dependent charge of clays and organic matter, that in turn could adversely affect soil structure and physical properties. These adverse effects on soil properties are less likely to happen in semiarid and arid conditions, because the ionic strength of the soil solution is sufficiently high and $CaCO_3$ dissolution will efficiently counteract increases in pH values (Gupta et al., 1984).

When the CO_2-enriched TW was applied to the 100-mm-long soil column at the fast flow rate (Fig. 5), 4 pore volumes (0.4 L) of solution were required to reduce the ESP from 16 to an average value of 3.8. The calculated average ESP value of 3.8 was similar to the measured value of 2.7 (Table 1). The same number of pore volumes was needed to reach a comparable ESP in the shorter column (Fig. 4). Similar to the observations with the short column, most of the (Ca^{2+} + Mg^{2+}) from both sources (dissolved $CaCO_3$ and TW) replaced the adsorbed Na until a final average ESP of 3.8 was attained. Thereafter, a steady increase in the amount of (Ca^{2+} + Mg^{2+}) in the leachate was observed (Fig. 5). However, the accumulation rate and the final concentrations of both (Ca^{2+} + Mg^{2+}) and HCO_3^- in the leachate were higher for the longer column than for the shorter one. As a result of the water flow being the same for both columns, the higher rate of (Ca^{2+} + Mg^{2+}) accumulation in the leachate of the longer column was probably due to the longer contact time between a unit volume of water and a unit surface area of the solid $CaCO_3$.

SUMMARY AND CONCLUSIONS

Reclaiming sodic soils with naturally occurring $CaCO_3$ was studied under various conditions (electrolyte concentration, flow rate, CO_2 concentration in the reclaiming solution, and soil depth). Soil reclamation with TW was

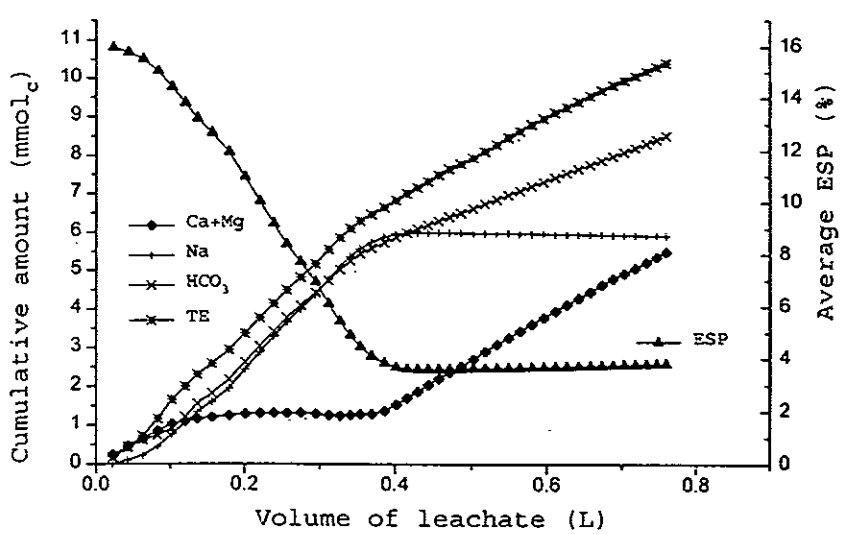

Fig. 5. Cumulative amounts of (Ca^{2+} + Mg^{2+}), Na^+, HCO_3^-, and total electrolytes (TE) as a function of leachate volume, when leaching a 100-mm-long soil column with CO_2-enriched tap water at a flow rate of 50 mm h^{-1} (ESP = exchangeable sodium percentage).

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observed to be more efficient (i.e., resulting in lower ESP values) relative to the use of DW. The mechanism responsible for soil reclamation differed for the two types of water. When DW was used, $CaCO_3$ dissolution was the main source of Ca^{2+} for replacing exchangeable Na. When TW was used, the main source of (Ca^{2+} + Mg^{2+}) was the leaching solution itself. Reclamation increased with a decreased flow rate, due to higher concentration of Ca^{2+} in the solution and a longer time available for Ca^{2+} to diffuse into soil aggregates. Enriching the TW reclaiming solution with CO_2 was the most favorable condition for $CaCO_3$ dissolution and efficient soil reclamation. Enriching irrigation water with CO_2 is highly recommended where readily available sources of CO_2 exist or for high value crops that can justify the process of CO_2 production. The advantages of enriching irrigation water with CO_2 for soil reclamation compared with the use of other amendments (e.g., gypsum, $CaCl_2$) are (i) the presence of CO_2 in the water leads to constant lime dissolution and to a continuous supply of Ca^{2+} that removes Na^+ from the exchange sites, as opposed to the use of other sources of Ca^{2+}, which are all being swept forward with the wetting front; (ii) CO_2 reclamation efficiency depends on soil ESP (the higher the ESP, the greater the efficiency), while the efficiency of other amendments depends on the amount added, and (iii) CO_2 is added to the soil with the irrigation water and thus is immediately effective.

Our results indicate that a successful reclamation of sodic soils can be accomplished by an adequate management of naturally occurring $CaCO_3$. We suggested that for calcareous soils, sodicity problems can be resolved by management that includes the use of CO_2 to maximize $CaCO_3$ dissolution. However, there is a need for further studies on comparing CO_2 efficiency in intermittent against continuous irrigation, saturated against unsaturated flow, and open against closed irrigation system.

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APPENDIX 2

Polymer effects on surface mechanical strength of a crusting loessial soil

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Abstract

Addition of synthetic polymers to crusting soils generally improves seedling emergence and this is thought to be caused by lower mechanical strength of the crusted soil surfaces. The objective of the present study was to evaluate the mechanism by which polymer addition contributes to the reduction in crust mechanical strength. Three polymers were used, 2 anionic polyacrylamides differing in their molecular weight, and a cationic polysaccharide. Samples of a silty loam calcareous loess (Calcic Haploxeralf) were packed to a depth of 78 mm in round pots having an internal diameter of 120 mm at the top. Polymer was added to the soil surface, at a rate of 20 or 40 kg/ha, by spraying a concentrated polymer solution. The pots were then exposed to 40 mm of simulated rainfall comprising either distilled water or tap water (electrical conductivity 0·97 dS/m). In an additional study, polymer was added to the tap water to form a dilute (20 or 40 g/m^3) polymer solution which was then used in the 40-mm rain event. After the exposure to rain, the pots were transferred to a temperature-controlled room (30°C). Weight of the pots, moisture content of the upper 10 mm of the soil, and crust strength (impedance) determined with a 3·24-mm diameter probe were measured periodically up to 95% water loss in the soil. In most of the polymer treatments, moisture content immediately after the rain was in the range of 32–39%, which was significantly higher than that in the control (27–29%). In general, for a given moisture content, crust strength did not differ significantly between the control and the polymer treatments. However, moisture content for a given cumulative drying time was higher in the polymer treatments than in the control, indicating that polymer application delayed crust drying and maintained a crust with a lower mechanical strength for a longer period of time. Polyacrylamide with a low molecular weight, applied at a rate of 40 kg/ha, emerged as the most effective treatment for maintaining high moisture content in the upper soil layer, and hence a crust with a low mechanical strength.

Additional keywords: polyacrylamide, polysaccharide, crust, rain simulation, moisture content.

Introduction

Crust formation at soil surfaces, because of the impact energy of raindrops or sprinkler irrigation, is a common feature of many cultivated soils worldwide. Surface crusts have prominent effects on numerous soil phenomena, e.g. decreasing infiltration rate, increasing runoff, and interfering with seedling emergence (Baver *et al.* 1972; Holder and Brown 1974; Bradford *et al.* 1987). Seedling emergence is affected by the crust because, upon drying, the mechanical strength of crusted surfaces becomes greater than that of non-crusted surfaces (Morton and Buchele 1960). The increase in the mechanical strength of the crust with drying depends on soil texture, bulk density, initial moisture content, and rate of drying (Morton and Buchele 1960; Lugo *et al.* 1975; Fapohunda *et al.* 1985).

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Increasing aggregate stability at the soil surface and preventing clay dispersion reduce soil susceptibility to crust formation. Addition of small amounts (10–40 kg/ha) of organic polymers, mainly anionic polyacrylamide (PAM) and cationic polysaccharides (PSD), improves the stability of surface aggregates and maintains high permeability in crusting soils exposed to rain or overhead irrigation (Levy 1995 and references cited therein). Shainberg *et al.* (1990) reported that following the addition of PAM solution to the surface of 2 soils exposed to simulated rain, the infiltration rate after 80 mm of rain increased from 2–3 mm/h in non-treated soils to 6·5–7·4 mm/h in polymer-treated ones. A combined application of PAM with a source of electrolytes resulted in very high final infiltration rates (FIR), 20·5–23·5 mm/h (Shainberg *et al.* 1990). Similar significant improvements in the FIR were reported when small amounts of PSD or PAM were added to the irrigation water to form very dilute (5–50 g/m^3) polymer solutions (e.g. Helalia and Letey 1988; Ben-Hur *et al.* 1989; Levy *et al.* 1992). The favourable effects of PAM and PSD in controlling seal formation were attributed to their ability to stabilise aggregates. Shainberg *et al.* (1992) showed for 3 different Israeli soils that >80% of PAM-treated aggregates remained stable after 9 mm of rain compared with <40% of aggregates that remained stable in non-treated samples.

The effect of polymer application on the mechanical strength of the crust has not received much attention. A number of studies have indicated that addition of polymers improved seedling emergence (e.g. Cook and Nelson 1986; Wallace and Wallace 1986; Globerzon *et al.* 1991). Thus, it may be inferred, on the basis of an indirect measurement (i.e. seedling emergence), that the polymer decreased the mechanical strength of the crust. Aly and Letey (1989) measured modulus of rupture, rupture stress, and tensile strength of 3 soils treated with PAM or PSD. These researchers hypothesised that (*i*) clay flocculation and the subsequent decrease in the number of contact points between particles reduce soil dry strength, and (*ii*) bonding of flocs at contact points is expected to increase soil strength. Thus, conditions favouring polymer adsorption (i.e. bonding of flocs), and reduction of its ability to flocculate the clay, should enhance soil strength (Aly and Letey 1989). Aly and Letey (1989) found that polymer application reduced soil dry cohesive strength compared with non-treated samples, with quantitative effects depending on polymer type, water quality, and soil type. However, only partial agreement was found between measured results and postulated ones (Aly and Letey 1989). Their results could thus not elucidate the mechanisms by which polymers reduce crust mechanical strength.

We hypothesised that the favourable effect of PAM and PSD on crust strength could stem from either or both of the following mechanisms.

(1) Addition of polymers stabilises surface aggregates, and leads to a crust with high permeability and of subsequent low mechanical strength.

(2) Polymer application results in a higher moisture content in the soil profile, specifically at the soil surface, compared with a non-treated soil. Consequently, crust drying and the development of its mechanical strength are slowed down.

The objectives of the present study were to assess these hypotheses, and to investigate the effects of polymer type, mode of application (surface application *v.* addition to the irrigation water), and water quality on the changes in surface mechanical strength of a crusting loess subjected to a controlled drying process.

Materials and methods

A sample from 0–250 mm depth of a silty loam calcareous loess (Calcic Haploxeralf) from the north-western Negev, Israel, was brought to the laboratory, air-dried, and crushed to pass through a 4-mm sieve. Soil texture was 25% clay, 23·3% silt, and 51·7% sand. The soil had a cation exchange capacity of 26·9 $cmol_c/kg$ and an exchangeable sodium percentage of 3·2; it contained 18·2% $CaCO_3$ and 0·87% organic matter.

Soil samples were packed in round pots which were perforated at the bottom to ensure drainage and had internal diameters of 120 and 95 mm at the top and bottom, respectively. The soil was packed to a depth of 78 mm, over a 32-mm layer of sand, and to a density of 1·37 Mg/m^3.

Three polymer types were studied: 2 negatively charged polyacrylamides with a low charge density (20% hydrolysis), one with a low molecular weight ($0·2–2\times10^5$ Da, designated PAM_L) and one with a high molecular weight (2×10^7 Da, designated PAM_H); and a cationic low-charged polysaccharide (PSD) with a medium molecular weight ($0·2–2\times10^6$ Da).

Crust impedance was determined with a 3·24-mm-diameter probe (a replica of a pocket penetrometer) connected to a mechanical push/pull force gauge (John Chatillon & Sons Inc., North Carolina, USA, Model DPP) (Rapp 1989). The gauge range covers 25 kg in 250-g steps, and 0·5% accuracy at full scale. The probe and the force gauge were installed on a vertical hand lever (Black & Decker, UK). Impedance was determined by lowering the probe in a uniform vertical motion at a rate of 3 mm/s, to a penetration depth of 6 mm.

Three experiments, differing in mode of polymer application and quality of water, were performed.

Experiment 1

Polymer was added directly to the surface of the soil in the pots by spraying a concentrated polymer solution. Polymer was added to tap water (electrical conductivity 0·97 dS/m;

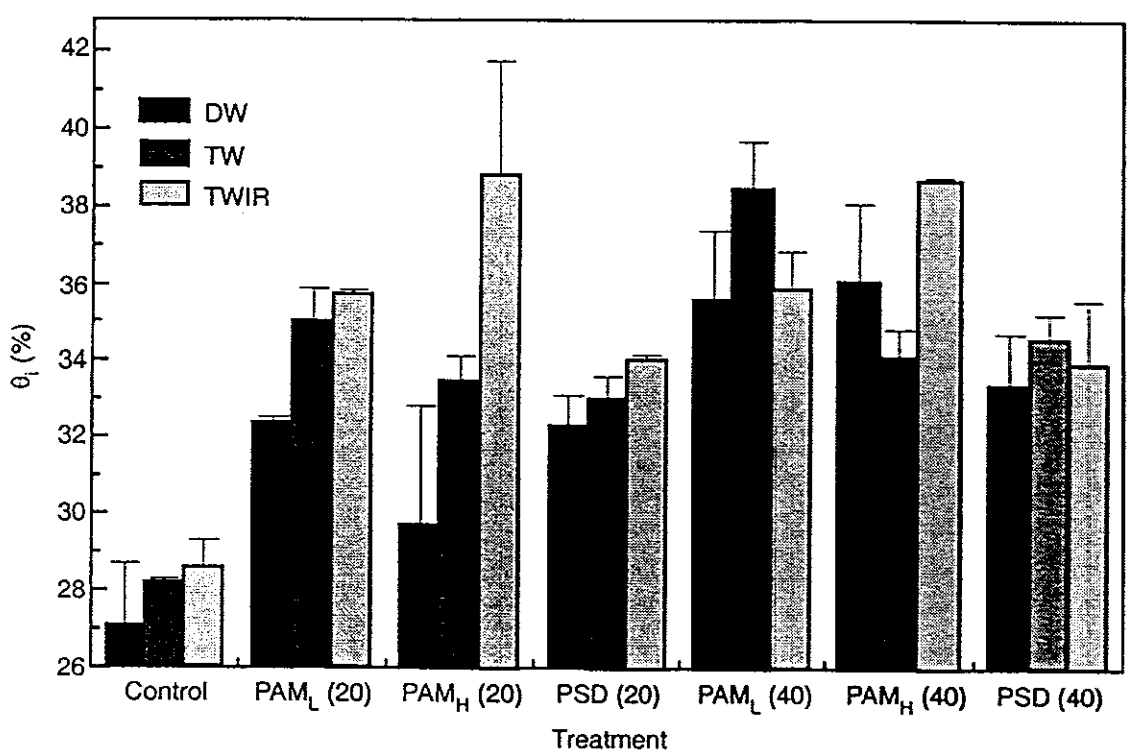

Fig. 1. Initial moisture content in the upper 10 mm (θi) as a function of the various treatments. DW, TW, and TWIR, are distilled water, tap water, and tap water containing polymer solution, respectively. PAM_L, PAM_H, and PSD are low-molecular-weight polyacrylamide, high-molecular-weight polyacrylamide, and polysaccharide, respectively. Numbers after polymer names indicate amount of polymer added, in kg/ha for DW and TW treatments, and in g/m^3 for the TWIR treatment.

sodium adsorption ratio = 2) to form a 1000 g/m^3 solution, and appropriate amounts of the solution were then sprayed onto the soil surface to provide polymer application rates of 0, 20, and 40 kg/ha. After polymer addition the pots were left to dry for 6 days in a temperature-controlled room at 30°C.

Eight pots were used per treatment (i.e. combination of polymer type and amount added). These pots were then divided into pairs and each pair was placed in a 175 by 285 by 125-mm hard plastic box, which served to ensure that the crust formed in each pot was not affected by moving the pots. The boxes containing the pots were then placed in a rainfall simulator at a 10% slope and subjected to 40 mm of rain with distilled water (electrical conductivity 0·045 dS/m) simulating rain.

After the rain simulation the boxes were transferred back to the temperature-controlled room (30°C) and weighed, and 4 measurements of crust strength (impedance) were made in each of the 2 pots in Box 1 of each treatment. In addition, 3 small samples (25 g of soil) were taken from the upper 10 mm of the soil in each of the 2 pots in Box 1 for gravimetric moisture content determination.

The boxes were weighed twice a day and 2 replicate measurements of surface strength and the associated moisture content were carried out at water losses of 50, 70, 80, and 95%, in Boxes 1, 2, 3, and 4, respectively, of each treatment.

Experiment 2

The entire experiment was similar to Expt 1, except that the soil in the pots was exposed to tap water (0·97 dS/m) to simulate irrigation. Surface strength and moisture content measurements were performed immediately after completion of the rain in Box 1 and at water losses of 30, 50, 70, and 85%, in Boxes 1, 2, 3, and 4 of each treatment, respectively.

Experiment 3

Polymer was added to tap water to form dilute solutions of 0, 20, and 40 Mg/m^3, and the soil in the pots was exposed to 40 mm of rainfall of these solutions, simulating polymer

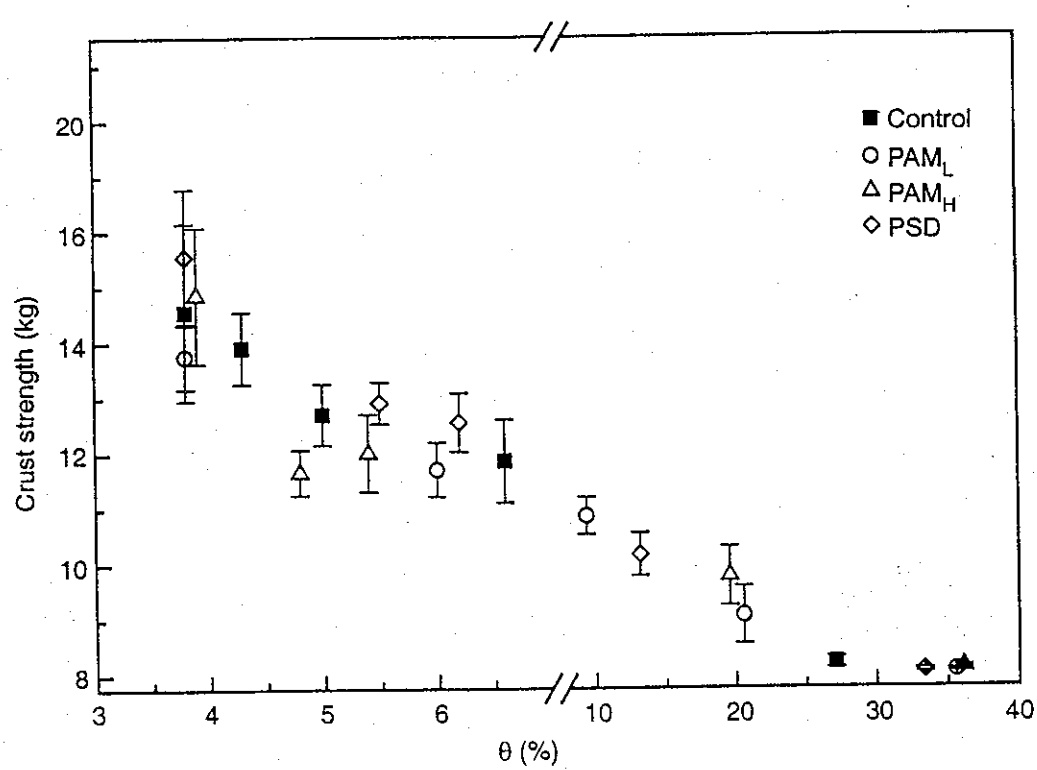

Fig. 2. Crust strength as a function of moisture content in the upper 10 mm (θ) for the samples treated with 40 kg/ha polymer, and exposed to distilled water rain. PAM$_L$, PAM$_H$, and PSD are low-molecular-weight polyacrylamide, high-molecular-weight polyacrylamide, and polysaccharide, respectively.

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application via the irrigation water. Surface strength and moisture content measurements were performed immediately after completion of the rain in Box 1 and at water losses of 30, 50, 65, and 85%, in Boxes 1, 2, 3, and 4 of each treatment, respectively.

Results and discussion

Moisture content in the upper 10 mm of the soil samples in the pots at the end of the rain application (θi) for the various treatments is presented in Fig. 1. In the control (no polymer application), θi was $\leq$29%. In the polymer treatments, with the exception of PAM_H applied at 20 kg/ha and subjected to distilled water rain, θi was in the range 32–39% (Fig. 1). Clearly, polymer addition, irrespective of polymer amount or mode of application, resulted in a significantly higher θi than in the control. Stable aggregates maintain a larger average pore size and hold more water than unstable aggregates (Levy and Miller 1997). The higher θi in the polymer treatments, compared with the control, indicated that the polymers tested stabilised the aggregates at the soil surface, and prevented the formation of a low-permeability layer (crust) at the soil surface, an observation that agreed with previously published data (Levy 1995, and references cited therein).

Crust strengths at various θ levels as affected by application of the 3 polymers at a rate of 40 kg/ha, followed by exposure to distilled water rain or tap water irrigation (i.e. data from Expts 1 and 2), are presented in Figs 2 and 3*a*. The effects on crust strength, of the 3 polymers, added to the irrigation water to

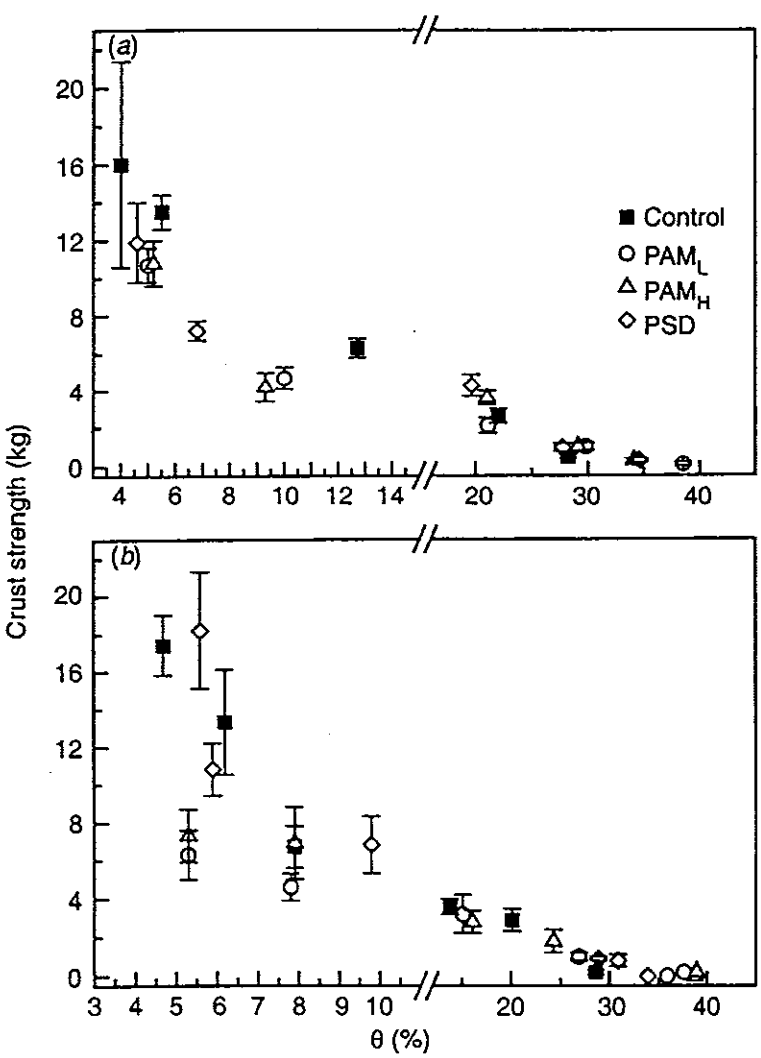

Fig. 3. Crust strength as a function of moisture content in the upper 10 mm (θ) for the samples treated with (*a*) 40 kg/ha of polymer and exposed to tap water irrigation, and (*b*) tap water containing 40 g/m^3 of polymer and exposed to tap water irrigation. PAM_L, PAM_H, and PSD are low-molecular-weight polyacrylamide, high-molecular-weight polyacrylamide, and polysaccharide, respectively.

form a polymer concentration of 40 g/m^3 (Expt 3), are presented in Fig. 3*b*. As expected, for all treatments the mechanical strength of the crust increased with decreasing moisture content (MC) of the upper soil layer. However, the results show that for any given θ level, no significant differences in crust strength were found between any of the polymer treatments and the control (Figs 2, 3*a* and *b*). Similar trends were noted for the lower application rates of the polymers: 20 kg/ha, or 20 g/m^3 (data not presented).

On the basis of the results of Aly and Letey (1989), who reported a decrease in soil dry cohesive strength following polymer application, it was expected that crust strength would be lower for polymer-treated soil surfaces, because the presence of polymer stabilises the surface aggregates, so that a permeable layer with larger aggregates and fewer contact points remains at the crusted soil surface. In the present study, crusts formed under the various polymer treatments and the control differed in their structure, as was evident from the θi data (Fig. 1). Yet, for any given degree of drying, crust mechanical strength was independent of treatment. Our results suggest, therefore, that the favourable effect of polymers on seedling emergence (Wallace and Wallace 1986; Globerzon *et al.* 1991) cannot be attributed to the effect of the polymers in reducing the mechanical strength of the crust, as was implicitly assumed in those studies.

The times required to reach various θ levels during drying, as affected by application of the 3 polymers at a rate of 40 kg/ha by spraying, followed by distilled water rain or tap water irrigation (i.e. data from Expts 1 and 2), are presented in Figs 4 and 5*a*. The effects of the polymers, added to the irrigation water to form a polymer concentration of 40 g/m^3 (Expt 3), on cumulative drying

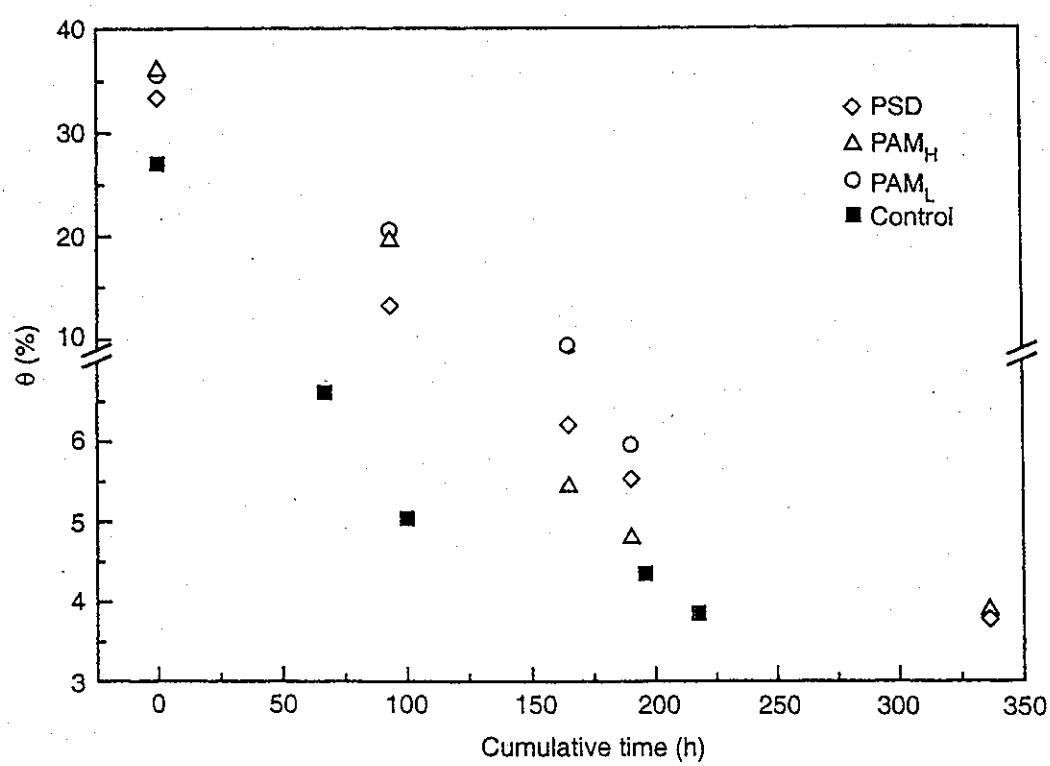

Fig. 4. Moisture content in the upper 10 mm (θ) *v.* cumulative drying time at 30°C for the samples treated with 40 kg/ha of polymer, and exposed to distilled water rain. PAM$_L$, PAM$_H$, and PSD are low-molecular-weight polyacrylamide, high-molecular-weight polyacrylamide, and polysaccharide, respectively.

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time are presented in Fig. 5*b*. The results indicate that, in general, drying time needed to obtain a given θ was shorter in the control than in the polymer-treated samples. Alternatively, for a given cumulative drying time, θ levels in the control were lower than those in the polymer-treated samples (Figs 4, 5*a* and *b*). Similar trends were noted for the lower polymer levels used (data not presented). The higher θi in the polymer-treated samples (Fig. 1) was probably the reason for

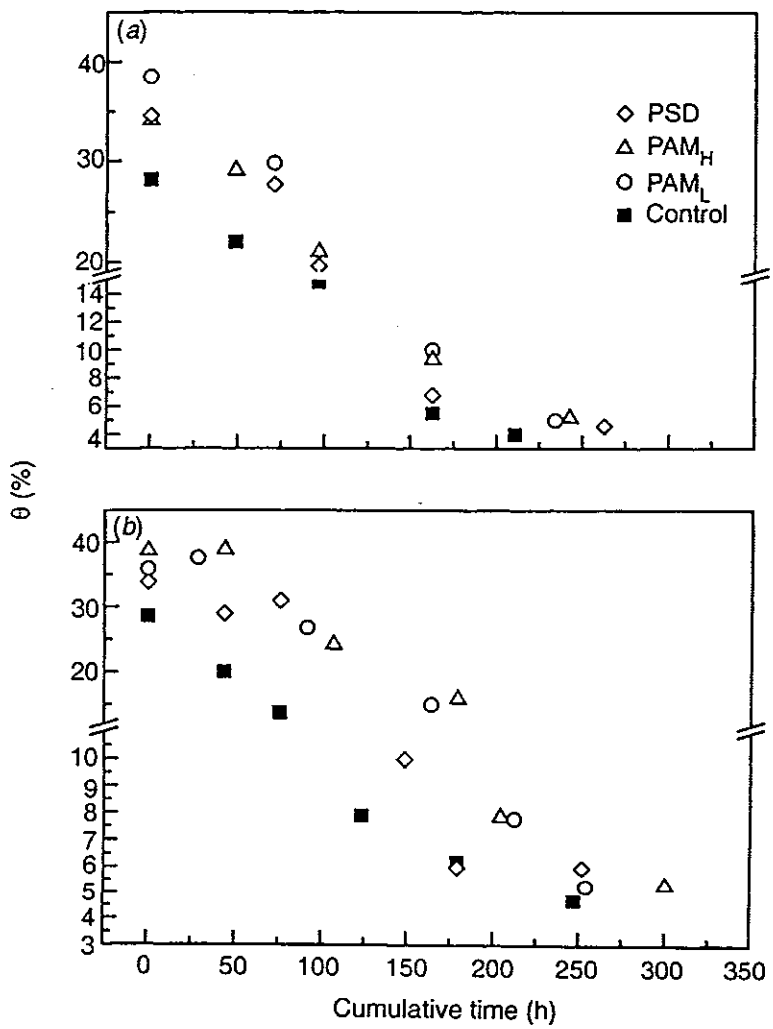

Fig. 5. Moisture content in the upper 10 mm (θ) *v.* cumulative drying time at 30°C for the samples treated with (*a*) 40 kg/ha polymer and exposed to tap water irrigation, and (*b*) tap water containing 40 g/m^3 polymer and exposed to tap water rain. PAM$_L$, PAM$_H$, and PSD are low-molecular-weight polyacrylamide, high-molecular-weight polyacrylamide, and polysaccharide, respectively.

Table 1. Analysis of variance for the effects of polymer type, water quality, and polymer amount, on initial moisture content in the upper 10 mm for surface application of the polymer

Source of variation	d.f.	Sum of squares	*F* value	Significance
Polymer type (PT)	2	15·01	4·49	*
Water quality (WQ)	1	17·82	10·67	**
Polymer amount (PA)	2	371·18	111·06	***
PT×WQ	2	3·03	0·91	n.s.
PT×PA	4	13·49	2·02	n.s.
WQ×PA	2	4·32	1·29	n.s.
PT×WQ×PA	4	13·86	2·08	n.s.
Residual	18	30·08		
Corrected total	35	468·83		

* $P < 0{\cdot}05$; ** $P < 0{\cdot}001$; *** $P < 0{\cdot}001$; n.s., not significant.

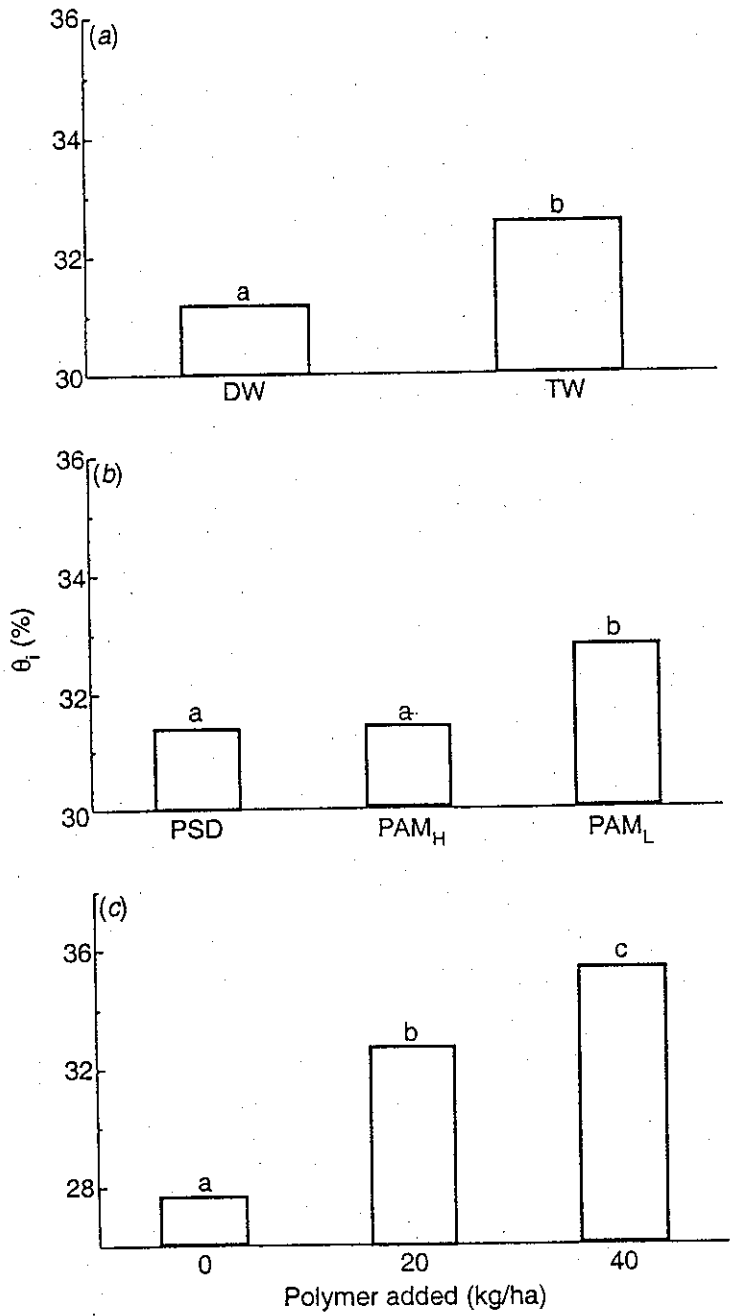

Fig. 6. Initial moisture content in the upper 10 mm (θi) as affected by (*a*) water quality (DW, distilled water; TW, tap water), (*b*) polymer type (PSD, polysaccharide; PAM$_H$, high-molecular-weight polyacrylamide; PAM$_L$, low-molecular-weight polyacrylamide), and (*c*) polymer amount in kg/ha, for the cases where polymer was added to the soil surface by spraying. Within a subfigure, bars labelled by the same letter do not differ at $P = 0 \cdot 05$.

Table 2. Analysis of variance for the effects of polymer type, mode of application, and amount on initial moisture content in the upper 10 mm for tap water rain

Source of variation	d.f.	Sum of squares	F value	Significance
Polymer type (PT)	2	20·91	10·74	***
Application mode (AM)	1	9·97	10·24	**
Polymer amount (PA)	2	407·98	209·59	***
PT×AM	2	26·18	13·45	***
PT×PA	4	13·00	3·34	*
AM×PA	2	8·08	4·15	*
PT×AM×PA	4	14·79	3·80	*
Residual	18	17·52		
Corrected total	35	518·43		

*$P < 0 \cdot 05$; **$P < 0 \cdot 001$; ***$P < 0 \cdot 001$.

the fact that longer time was needed to reach a given MC in the crusted soil surface of these samples than in that of the control. It is postulated that the efficacy of polymers in reducing the mechanical strength of the crust is related to their ability to delay its drying, thereby maintaining a crust of lower strength for a longer time.

Following the realisation that moisture content in the upper layer determines the effects of polymers in controlling the mechanical strength of crusts, a multifactor analysis of variance was carried out to test the effects of polymer type and amount, when added by spraying, and of water quality, on the θi (i.e. by comparing data from Expts 1 and 2). The 3 main treatments had significant effects on the θi; no significant interactions were found between the main treatments (Table 1). Results of a multiple-range test for the 3 main treatments revealed that PAM_L, polymer application at a rate of 40 kg/ha, and the use of tap water were the most successful treatments in obtaining high θi (Fig. 6).

The finding that using tap water was more effective than using distilled water was expected. Shainberg *et al.* (1990) showed that polymers were more effective in controlling crust formation in the presence of electrolytes than in their absence. Application of 40 kg/ha was more effective than application of 20 kg/ha in obtaining high θi, probably because it ensured a more uniform application of the polymer. Our observation disagreed with crust formation studies that reported both application rates to have a similar effect on crust final infiltration rate (e.g. Shainberg *et al.* 1990). The fact that PAM was more effective than polysaccharide in maintaining higher θ is also not surprising, as previous studies had found that the latter was less effective than PAM in reducing soil susceptibility to seal formation (Levy *et al.* 1992). However, the finding that PAM_L was

Table 3. Ranking of the various treatments affecting initial moisture content (IMC, %) in the upper 10 mm for tap water rain

PAM_H, high-molecular-weight PAM; PAM_L, low-molecular-weight PAM; PSD, polysaccharide; spray, polymer sprayed directly onto the soil surface, amount in kg/ha; via irrigation, polymer added to the irrigation water, amount in g/m^3. IMC values followed by the same letter do not differ significantly at $P = 0{\cdot}05$

Polymer type	Application mode	Amount	IMC
PAM_H	Spray	0	28·20a
PAM_L	Spray	0	28·20a
PSD	Spray	0	28·20a
PAM_H	Via irrigation	0	28·57a
PAM	Via irrigation	0	28·57a
PSD	Via irrigation	0	28·57a
PSD	Spray	20	32·98b
PAM	Spray	20	33·48b
PSD	Via irrigation	40	33·88b
PSD	Via irrigation	20	34·04b
PAM_H	Spray	40	34·14b
PSD	Spray	40	34·56bc
PAM_L	Spray	20	35·01bcd
PAM_L	Via irrigation	20	35·76bcd
PAM_L	Via irrigation	40	35·87bcd
PAM_L	Spray	40	38·52cd
PAM_H	Via irrigation	40	38·69d
PAM_H	Via irrigation	20	38·84d

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more effective than PAM_H in the present study was surprising. Levy and Agassi (1995) compared the effects for these 2 polymers on infiltration rate and soil loss for 3 Israeli soils and found that for a loess (similar to the one used in the current study), PAM_H was more effective than PAM_L in maintaining a high final infiltration rate. Levy and Agassi (1995) suggested that the inter-particle bridging efficiency of PAM_L was lower than that of the PAM_H, because of its shorter molecules (inferred from its lower molecular weight), thus making the PAM_L less effective. In the present study, PAM_L was more effective than PAM_H, the reason for which is not fully understood.

Results of applying a multifactor analysis of variance to the effects of polymer type, amount, and mode of application, on the θi (i.e. comparison of data from Expts 2 and 3), are presented in Table 2. The main treatments as well as interactions between them had significant effects on the θi. Results of a multiple-range test among the individual treatments were not conclusive (Table 3), but a trend towards high θi levels as a result of the addition of PAM (irrespective of molecular weight) via the irrigation was noted. Evidently, a constant supply of polymer to the soil surface during the irrigation was more effective in controlling seal formation and maintaining higher θ in the soil than a single application of the polymer to the soil surface prior to the irrigation event. Similarly to the previous comparison, PAM was found as a more effective soil amendment than polysaccharide.

Summary and conclusions

We investigated the effects of 3 polymers, added to the soil surface, on the mechanical strength of a surface crust formed in a laboratory rainfall simulator. The following results were obtained.

(*i*) For comparable moisture contents of the upper 10 mm of the soil surface, polymer application did not significantly decrease the mechanical strength of crusted soil surfaces compared with a non-treated soil.

(*ii*) For comparable durations of drying, polymer application maintained a higher moisture content level in the upper soil surface and the crust than that in a non-treated soil; thus, the mechanical strength of the crust, after any given drying time, was lower in the polymer treatment.

(*iii*) For rain conditions, the low molecular weight PAM added at a rate of 40 kg/ha and supplemented with electrolytes was the most effective treatment for maintaining a crust with low mechanical strength. For irrigated farming, PAM added to the soil via the irrigation water was the most effective treatment for maintaining a crust with low mechanical strength.

The results suggest that despite the fact that polymers affect the permeability of the soil surface, these changes do not affect the mechanical strength of the crust. However, because of the higher permeability of the polymer-treated soil, longer time is required for the surface to dry, and the formation of a crust with high mechanical strength is delayed. This, in turn, may alleviate emergence problems of seedlings of many sensitive crops (e.g. vegetables) in crusting soils.

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Appendix 3

Effects of exchangeable potassium (K) on soil hydraulic conductivity

G.J. Levy, I. Shainberg, D. Goldstein and R. Keren

Introduction

Treated sewage water is becoming a substantial source of water for irrigation of cultivated fields. Salinity and sodicity are among the main problems associated with the use of treated waste water for irrigation. One way of reducing sodicity in the irrigation water is to replace Na salts with K salts at the source of contamination of the irrigation water. In numerous industries as well as in domestic use, NaCl is used for water softening. The use of Kcl instead of NaCl is possible. Because of the higher affinity of the soil to k compared with Na, increasing the K concentration in the irrigation water by a small amount may lead to a substantial increase in exchangeable K (10-15%). Knowledge of the effects of such levels of exchangeable potassium percentage (EPP) on soil hydraulic conductivity is meagre. The objectives of the study were to asses the effects of K on soil hydraulic conductivity in binary (K-Ca) and ternary (K-Na-Ca) systems having salinity levels similar to that found in treated sewage water.

Materials and methods

Soil samples from 0-250 mm depth from 24 cultivated fields in Israel, were used in the current study. The soils were predominantly smectitic and contained some kaolinite and illite. Selected physical and chemical properties of the soils are presented in Table 1.

Table 1. Selected chemical and physical properties of the soils studied

Soil	Particle size distribution			CEC†	$CaCO_3$	OM§
	sand	silt	clay			
		g kg^{-1}		$cmol_c$ kg^{-1}	g kg^{-1}	g kg^{-1}
Hamra	850	50	100	8.9	1.0	12
Loess	500	260	240	24.5	182	15
Grumusol	310	230	460	39.8	151	21

†CEC = cation exchange capacity.

§OM = organic matter.

Saturated hydraulic conductivity was studied in the laboratory. Soil columns were prepared by packing 120 g of air-dried samples (0-2 mm) in four portion of 30 g each into small cylinders (5.4 cm in diameter with a metal screen covered with 0.5 cm sand at the bottom). After adding a soil portions the soil was distributed evenly and slightly tapped. A filter paper covered the surface of the soil to minimize soil disturbance when replacing solutions. After packing, the soil columns were wetted from below with a concentrated solution (0.5M) of a given composition. Once the water level reached the top of the sample, the flow direction was reversed and the columns were leached from the top with a constant head device using the same concentrated solution. After the soil reached equilibrium with this solution, it was replaced by a more dilute solution, 20 meq/L (a concentration similar to that found in treated sweage water) of the same composition. During leaching, the leachate was collected continuously with a fraction collector, its volume, pH and EC were measured, and the HC was calculated. Each treatment was replicated two to four times and results were analyzed statistically. The average HC in the first pore volume (3 fractions of 15-20 mL each) in each columns was taken as the reference HC (HC_0).

After leaching for >5 pore volumes with the 20 meq/L solution it was replaced by distilled water (DW). The HC values obtained from the leaching with DW were expressed in terms of relative HC calculated as the ratio of measured HC to the HC_0. The relative HC values were plotted as a function of pore volumes of water that had flowed through the column.

The following solution composition were studied: (1) binary system - potassium adsorption ratio (PAR) of 1, 2 or 3, and (ii) ternary system - PAR of 0.5, 1.0 and 1.5 together with sodium adsorption ratio (SAR) of 6 and 8.

Results and discussion

1. K-Ca system

In a binary system (i.e., a system containing only K and Ca), when equilibrating the soil with PAR solutions of 1.0, 2.0 and 3.0, the expected exchangeable potassium percentage (EPP) level were 12, 19.7 and 25.9, respectively (US salinity Laboratory, 1954).

Changes in the HC of the three soils studied during leaching (i) with solution of 20 meq/L having the aforementioned PAR, and subsequently (ii) with DW, are presented in Figures 1-3. In addition, for the purpose of comparison, the changes in HC when a solution having SAR 4 was used, are presented. No decrease in HC was noted in the grumusol during the leaching with the 20 meq/L solution. Even when the EPP of the soil was 26% (PAR =3), no significant decrease in HC was noted (Fig. 1). In comparison, leaching this soil with a solution of SAR 4 led to a significant decrease in the HC. It can be concluded that when a grumusol is leached with a solution of the same salinity as treated sewage water, presence of K had no adverse effect on the HC of this soil.

Further leaching of the grumusol with DW caused a substantial decrease in the HC (Fig.1), even a calcium (Ca) saturated soil. The HC curve for a Ca-soil and soil previously equilibrated with a PAR 1 solution were similar. The HC curve for a soil equilibrated with PAR 3 was higher than that for the soil leached with the SAR4 solution (Fig. 1). It is postulated that in the grumusol when the EPP<12 than the soil behaved like a Ca-saturated soil. Presence of K at this level does not lead to a deterioration in soil structure and HC. Adverse effects of K were evident when the EPP≥19. However, even at such high EPP values its effect was less damaging that that of 4% exchangeable sodium (Na).

In the loess, leaching with the 20 meq/L solutions caused some reduction (<15) in the HC of the soil (Fig. 2). Evidently, the presence of electrolytes in the solution was enough to offset possible adverse effects of K and Na on soil swelling and clay dispersion. When the loess was leached with DW after the leaching of the different PAR solution its HC decreased significantly (Fig. 2). Similar to the grumusol, the HC of a soil leached with PAR 1 was similar to that of a Ca-saturated soil. When the higher PAR levels (2 and 3) the reduction in HC ware not as substantial as that observed for the SAR 4 treatment (Fig. 2). The observed decrease in HC were smaller in the loess than in the grumusol (Figs. 1 and 2). This was so because the higher the clay content of the soil the more severe the swelling, structure degradation, and decrease in HC, inflicted by the presence of exchangeable K and Na.

The hamra soil had only 10% clay and was therefore the less sensitive of the three soils to clay swelling and breakdown of soil structure. In this soil the decrease in HC was limited irrespective of water quality (saline solution or DW). The relative HC maintained >80% of the reference HC (Fig. 3), with the latter being determined

during the leaching with the concentrated 0.5M solution. Of the three soils the hamra was found as the least sensitive soil to exchangeable K.

2. K-Na-Ca system

In the ternary system we studied the effects of leaching the soil with solutions of the following compositions: PAR 0.5, 1 and 1.5 and SAR 0, 6 and 8. When leaching the soil with these solutions the expected respective EPP were 8.2, 12, 16.4 and the respective ESP were 0, 7.0 and 9.5.

Changes in the HC of the three soils when leached (i) with 20 meq/L solutions containing PAR 0.5 and SAR 0, 6 or 8, and subsequently (ii) with DW, are presented in Figures 4-6. In both the grumusol and loess some reduction in HC was noted when leaching with the 20 meq/L solution containing SAR 6 or 8. Subsequent leaching with DW resulted in a sharp decrease in the HC for these treatments, while for the SAR 0, the reduction in HC was less severe (Figs. 4 and 5). The reason for the decrease in HC was clay swelling. The electrical conductivity (EC) of the soil solution during leaching with DW (see Figs. 4 and 5) was high due to lime dissolution, and prevented clay dispersion.

The hamra behaved differently from the other two soils. Its reference HC was 40 times that of the grumusol and loess, because of its lower clay content and higher sand content (Table 1). Due to the low clay content in the hamra, no decrease in HC was noted during the leaching with the 20 meq/L solution. When DW was used, no decrease in the HC was noted for SAR 0 (data not presented). When SAR 6 or 8 was used the HC did not drop below 50% of the reference HC (Fig. 6). The hamra does not contain lime, therefore the EC of the soil solution was low, which allowed some clay dispersion to take place. Clay dispersivity and movement along the soil column

to palces where it narrowed or blocked conducting pores was considered the mechanism responsible for the observed decrease in HC. Swelling was not likely to happen in the coarse textured hamra.

Changes in the HC of the three soils when leached (i) with 20 meq/L solutions containing PAR 1 or 1.5 and SAR 0, 6 or 8, and subsequently (ii) with DW, are presented in Figures 7-12. In the grumusol it was evident that introducing high levels of PAR (1.0 and 1.5) which led to EPP values of 12 and 16.4 had no effect on the soil HC. The latter was determined by the SAR only when leached with the 20 meq/L solution and DW (Figs. 7 and 8).

In the loess presence of high levels of K did not affect the HC during leaching with the saline solution (Figs. 9-10). However, when leaching with DW, the HC for the PAR =1 treatment maintained the highest HC (fig. 9-10). It seems that exchangeable K of 12 has some favourable effect on stabilizing soil structure and the HC. This phenomenon suggests that there is an optimal exchangeable K level below and above which K has some adverse effects on the structural stability and HC of the loess. Since differences in HC were not large, further investigation of this aspect is required.

Effects of the different PAR and SAR levels on the HC of the hamra are presented in Figures 11 and 12. When SAR 6 was used, K had no effect on the HC irrespective of the PAR level used and the quality of the water (Fig. 11). However, for SAR 8 a phenomenon similar to that observed n the loess occurred, namely, the HC for PAR 1 (EPP 12) during leaching with DW was higher than that of the other two PAR levels tested (Fig. 12). As stated before, this phenomenon requires further studies.

Figure legend

Fig. 1: Relative hydraulic conductivity (HC) of soil samples from grumusol which were equilibrated with solutions having different PAR values, during leaching (i) with a 20 meq/L solution and subsequently (ii) with distilled water (DW). For comparison purposes the HC of a grumusol sample equilibrated with a solution containing Na (SAR=4) is also given.

Fig. 2: Relative hydraulic conductivity (HC) of soil samples from loess which were equilibrated with solutions having different PAR values, during leaching (i) with a 20 meq/L solution and subsequently (ii) with distilled water (DW). For comparison purposes the HC of a loess sample equilibrated with a solution containing Na (SAR=4) is also given.

Fig. 3: Relative hydraulic conductivity (HC) of soil samples from hamra which were equilibrated with solutions having different PAR values, during leaching (i) with a 20 meq/L solution and subsequently (ii) with distilled water (DW). For comparison purposes the HC of a hamra sample equilibrated with a solution containing Na (SAR=4) is also given.

Fig. 4: Combined effects of K (PAR=0.5) and different levels of SAR in the leaching solution on the relative HC in grumusol during leaching with 20 meq/L solution and subsequently with DW.

Fig. 5: Combined effects of K (PAR=0.5) and different levels of SAR in the leaching solution on the relative HC in loess during leaching with 20 meq/L solution and subsequently with DW.

Fig. 6: Combined effects of K (PAR=0.5) and different levels of SAR in the leaching solution on the relative HC in hamra during leaching with 20 meq/L solution and subsequently with DW.

Fig. 7: Combined effects of Na (SAR=6) and different PAR levels in the leaching solution on the relative HC in grumusol during leaching with 20 meq/L solution and subsequently with DW.

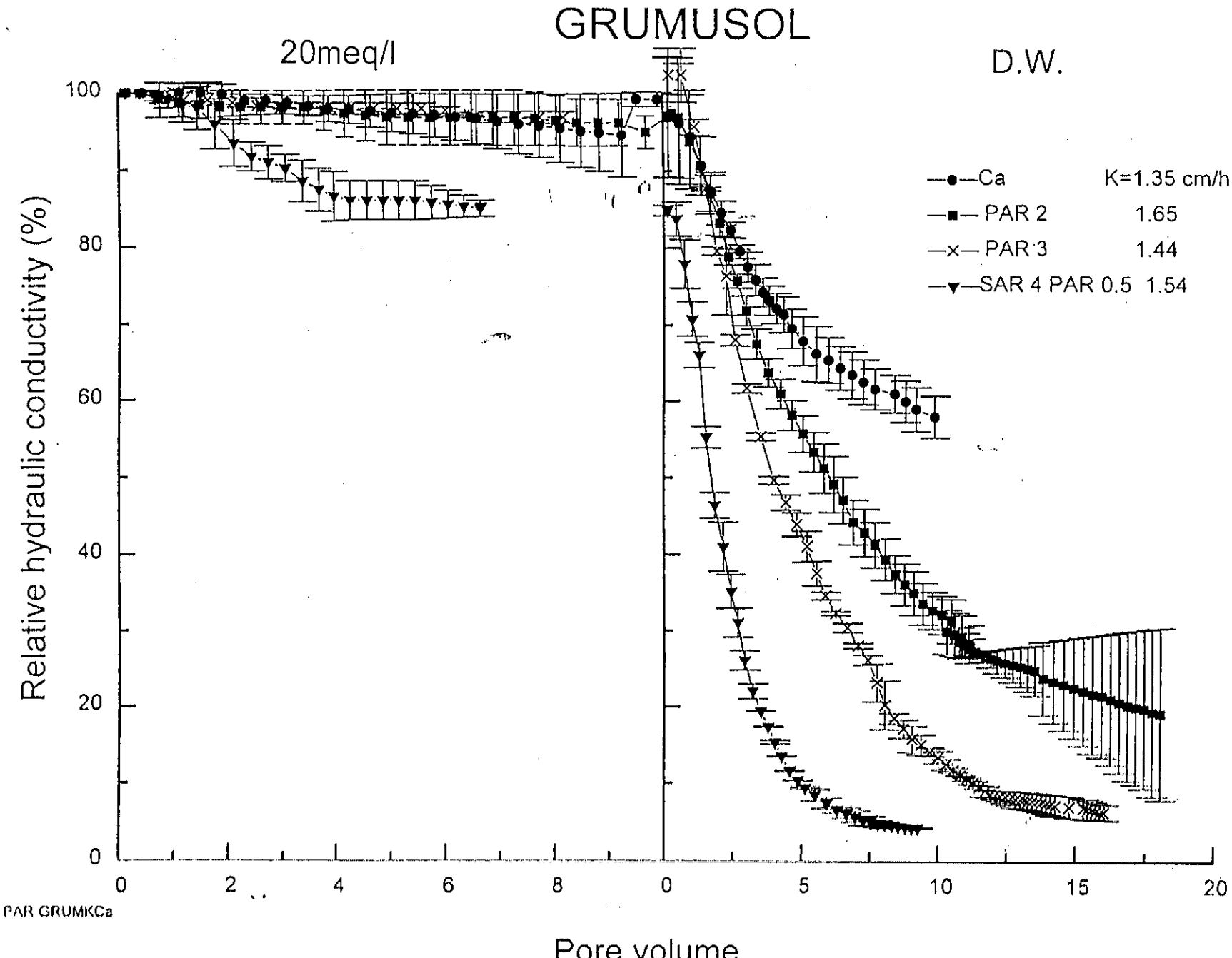
Fig. 8: Combined effects of Na (SAR=8) and different PAR levels in the leaching solution on the relative HC in grumusol during leaching with 20 meq/L solution and subsequently with DW.

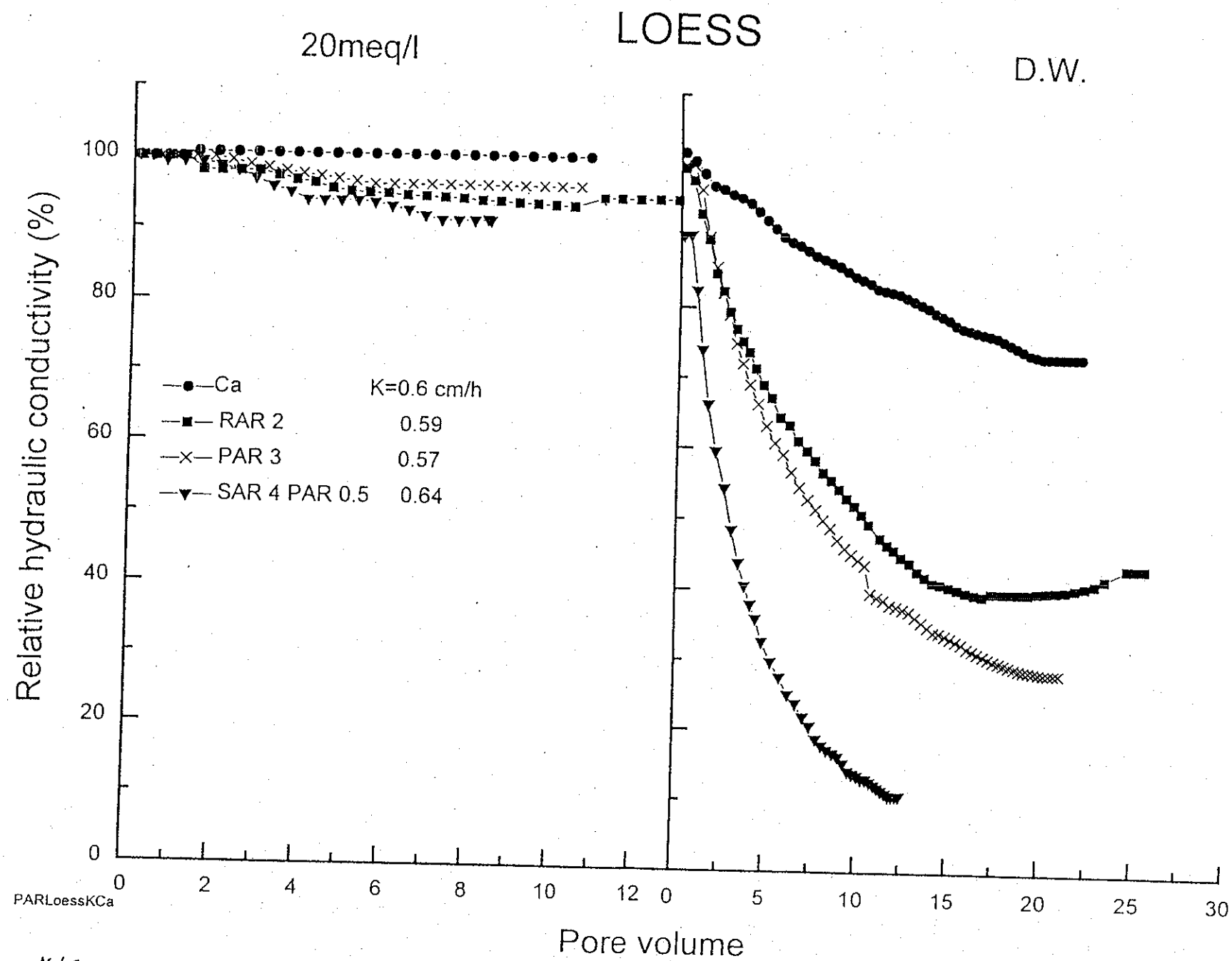
Fig. 9: Combined effects of Na (SAR=6) and different PAR levels in the leaching solution on the relative HC in loess during leaching with 20 meq/L solution and subsequently with DW.

Fig. 10: Combined effects of Na (SAR=8) and different PAR levels in the leaching solution on the relative HC in loess during leaching with 20 meq/L solution and subsequently with DW.

Fig. 11: Combined effects of Na (SAR=6) and different PAR levels in the leaching solution on the relative HC in hamra during leaching with 20 meq/L solution and subsequently with DW.

Fig. 12: Combined effects of Na (SAR=8) and different PAR levels in the leaching solution on the relative HC in hamra during leaching with 20 meq/L solution and subsequently with DW.

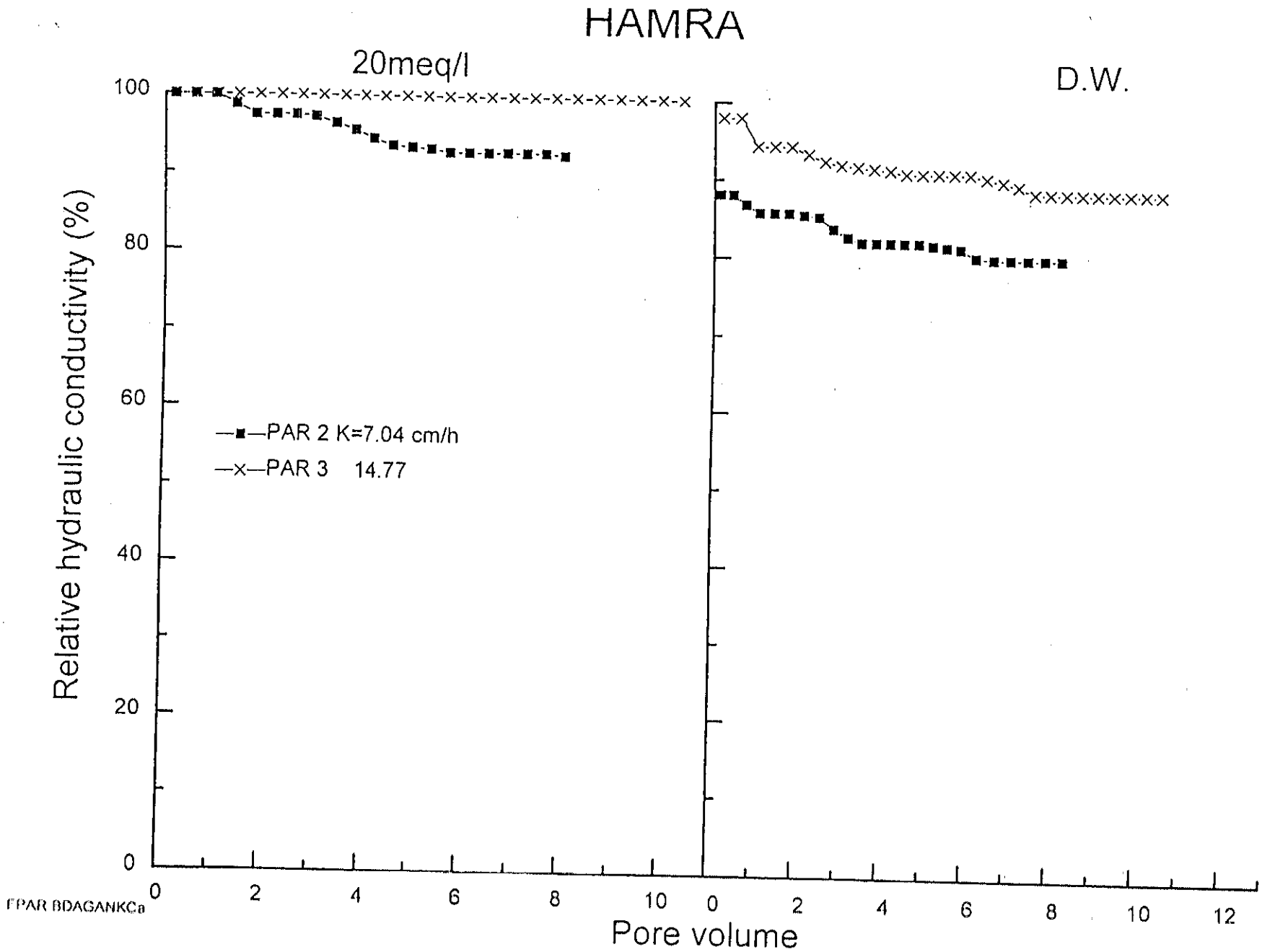

GRUMUSOL
20meq/l
D.W.
Relative hydraulic conductivity (%)
100
80
60
40
20
0
0
2
4
6
8
0
5
10
15
20
Pore volume
Ca K=1.35 cm/h
PAR 2 1.65
PAR 3 1.44
SAR 4 PAR 0.5 1.54
PAR GRUMKCa

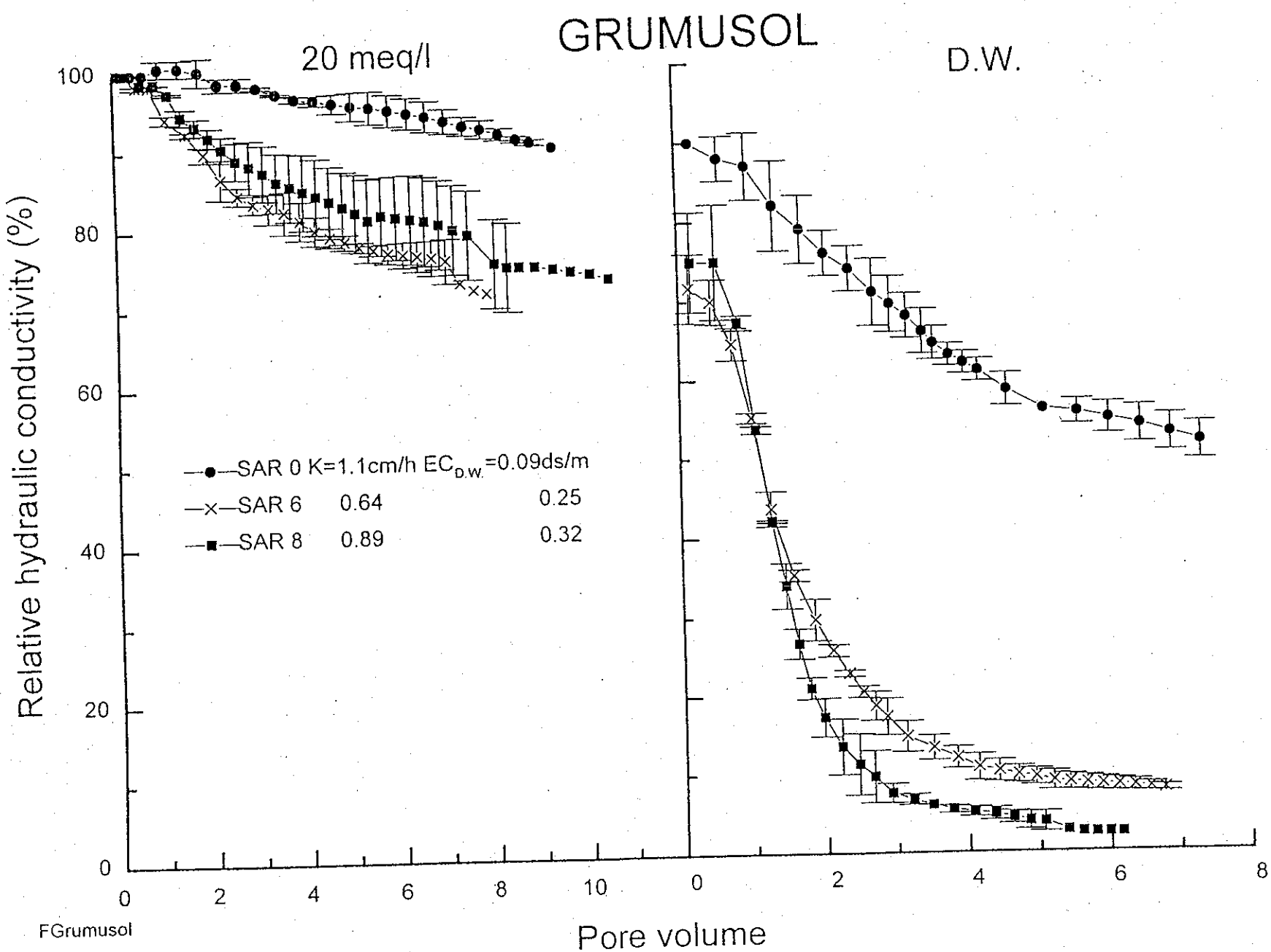

LOESS
20meq/l
D.W.
Relative hydraulic conductivity (%)
Pore volume
Ca K=0.6 cm/h
RAR 2 0.59
PAR 3 0.57
SAR 4 PAR 0.5 0.64
PARLoessKCa
0
20
40
60
80
100
0
2
4
6
8
10
12
0
5
10
15
20
25
30

2 ml/c

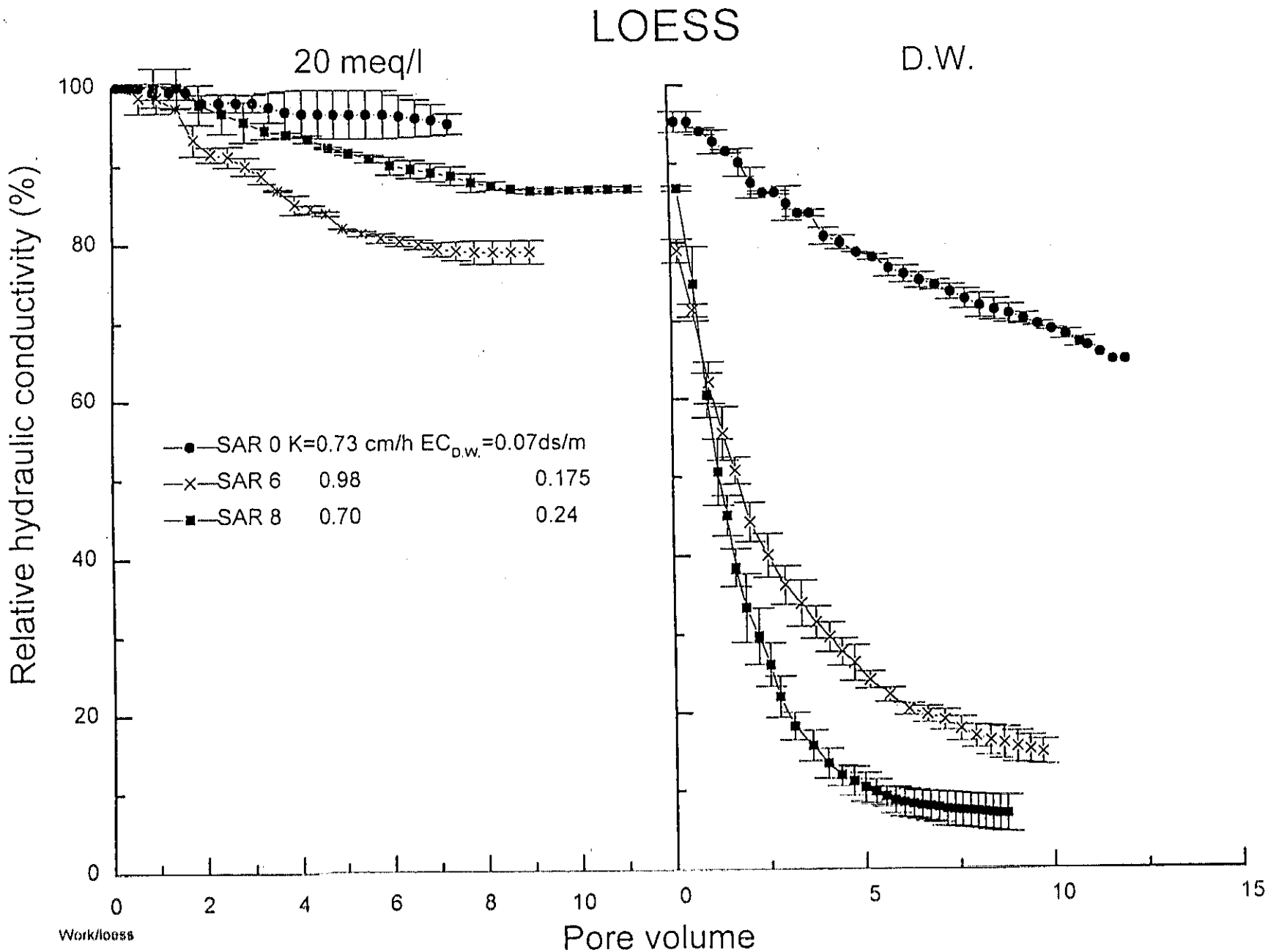
35

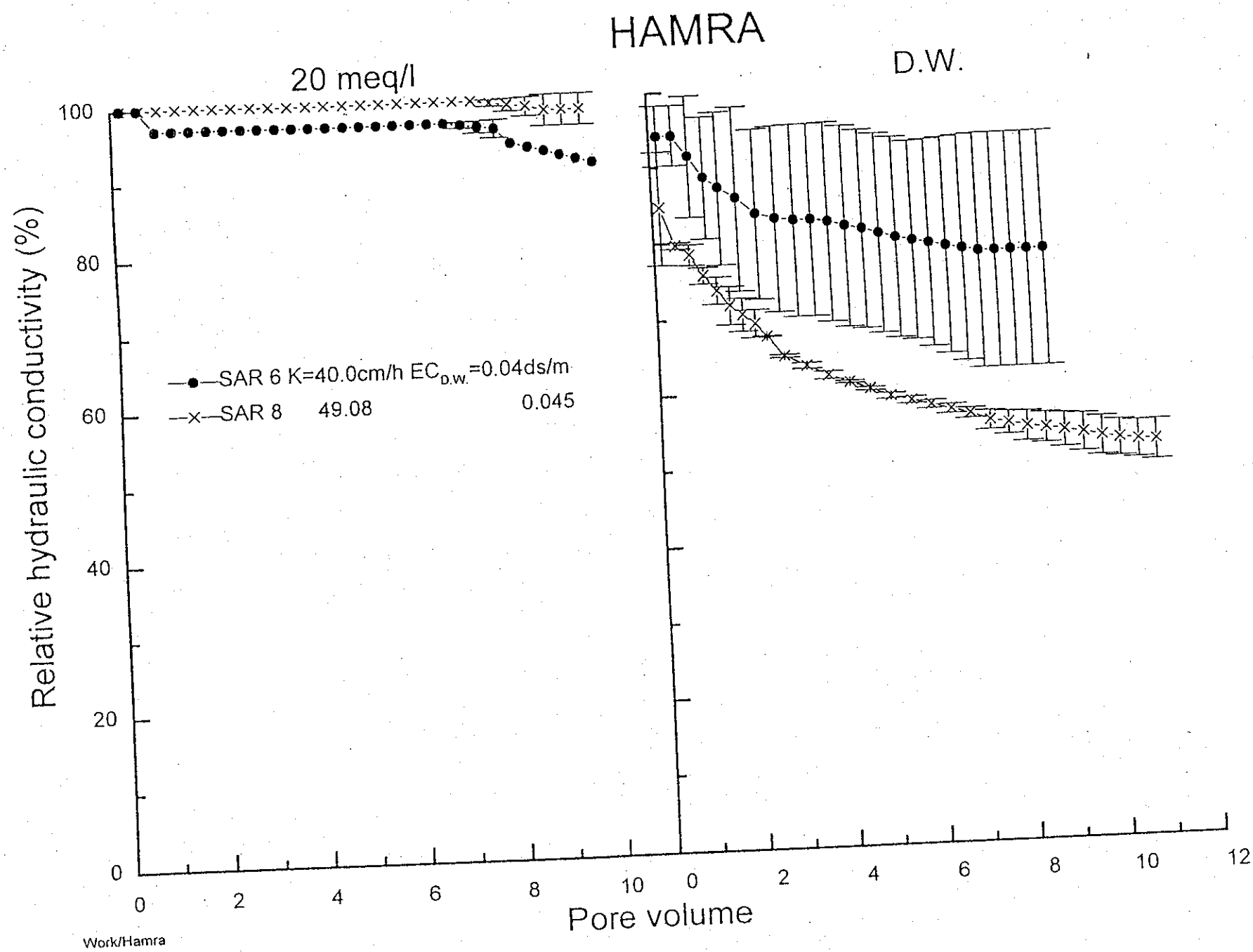
2 ml/c


HAMRA
20meq/l
D.W.
Relative hydraulic conductivity (%)
100
80
60
40
20
0
—■—PAR 2 K=7.04 cm/h
—x—PAR 3 14.77
0
2
4
6
8
10
0
2
4
6
8
10
12
Pore volume
FPAR BDAGANKCa


GRUMUSOL
20 meq/l
D.W.
Relative hydraulic conductivity (%)
100
80
60
40
20
0
0
2
4
6
8
10
0
2
4
6
8
SAR 0 K=1.1cm/h EC$_{D.W.}$=0.09ds/m
SAR 6 0.64 0.25
SAR 8 0.89 0.32
Pore volume
FGrumusol

4 ppc

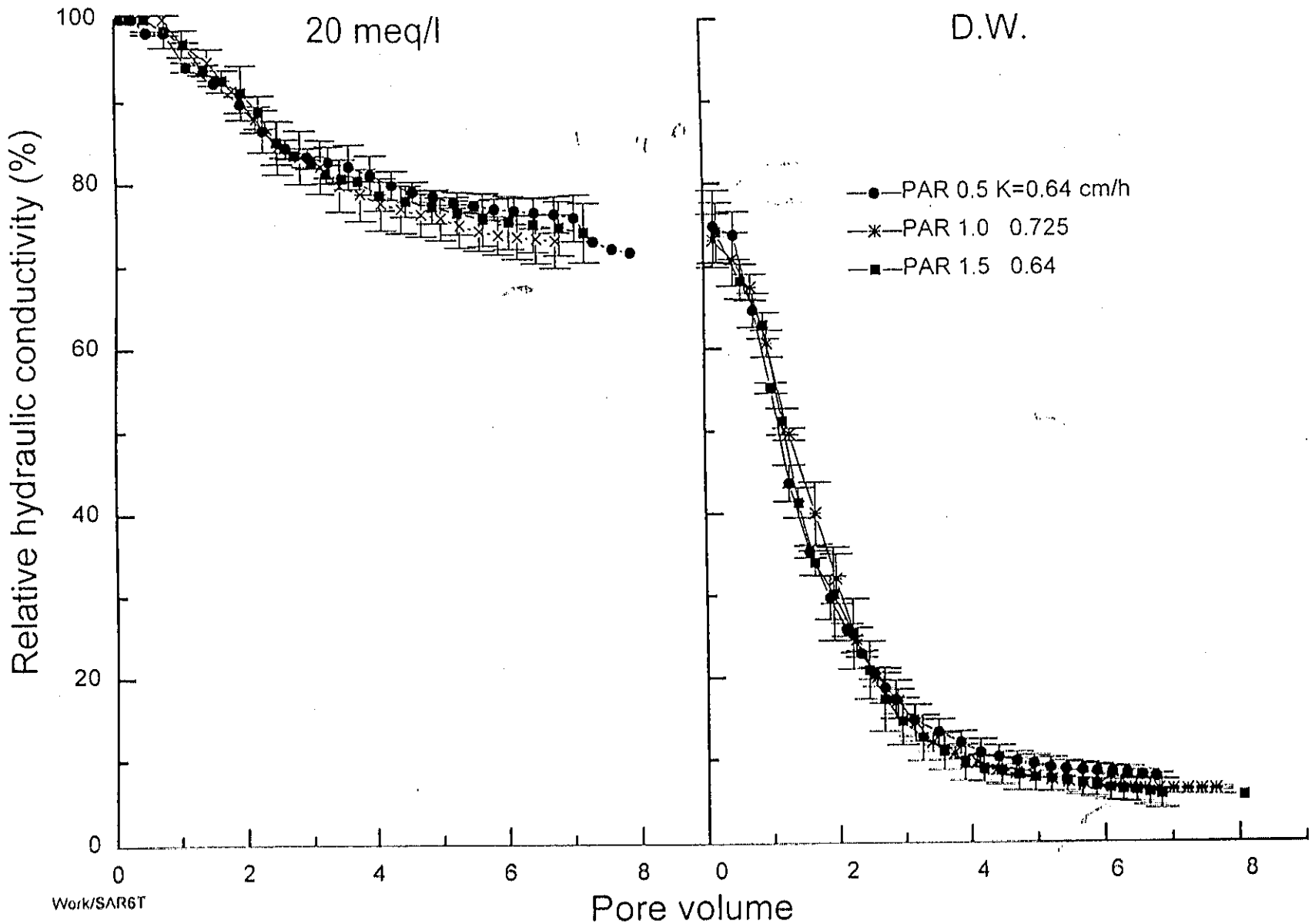

LOESS
20 meq/l
D.W.
Relative hydraulic conductivity (%)
100
80
60
40
20
0
SAR 0 K=0.73 cm/h EC$_{D.W.}$=0.07ds/m
SAR 6 0.98 0.175
SAR 8 0.70 0.24
0
2
4
6
8
10
0
5
10
15
Work/loess
Pore volume


HAMRA
20 meq/l
D.W.
Relative hydraulic conductivity (%)
100
80
60
40
20
0
SAR 6 K=40.0cm/h EC$_{D.W.}$=0.04ds/m
SAR 8 49.08 0.045
0
2
4
6
8
10
0
2
4
6
8
10
12
Pore volume
Work/Hamra

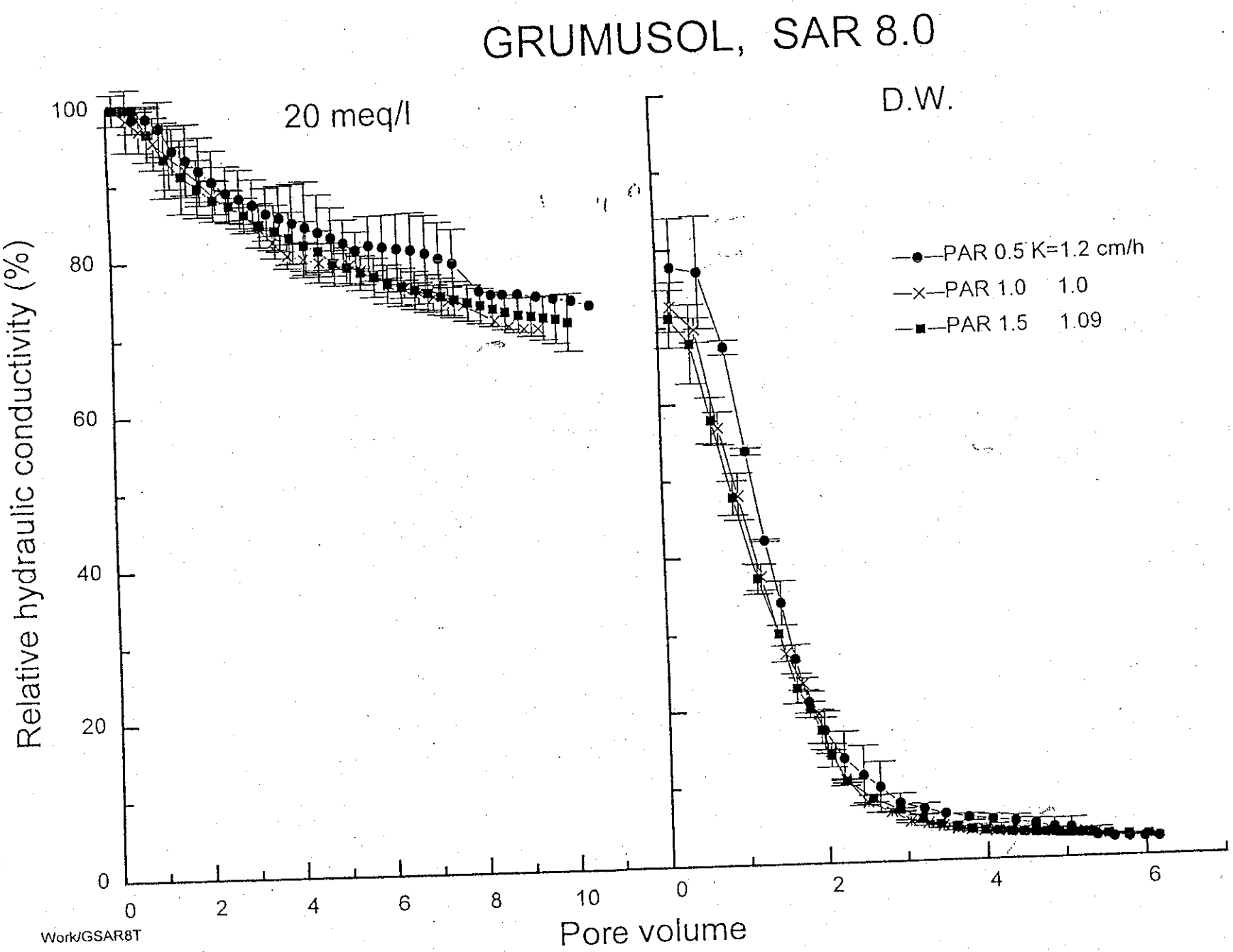
6 7/16

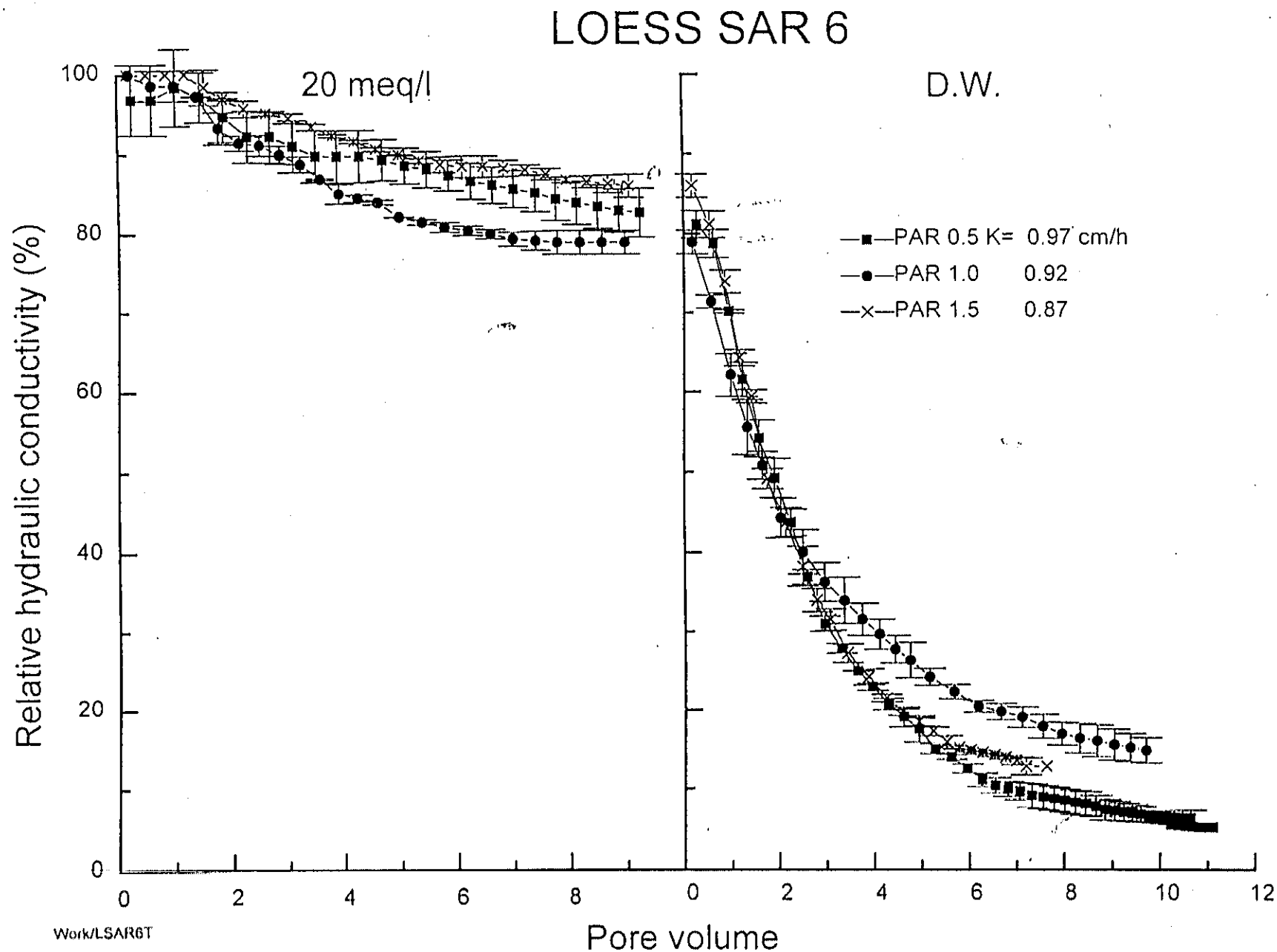
39

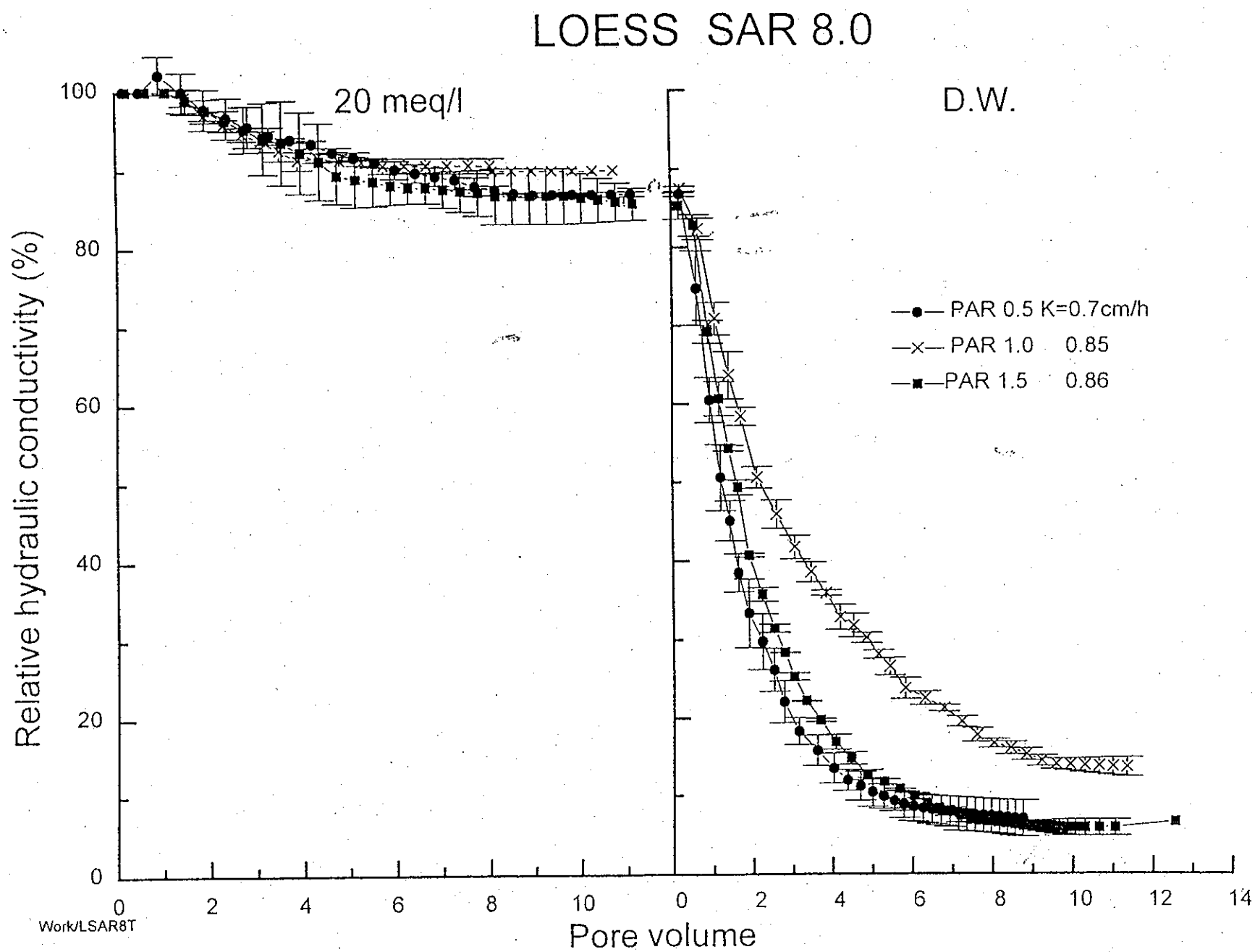
GRUMUSOL, SAR 6.0

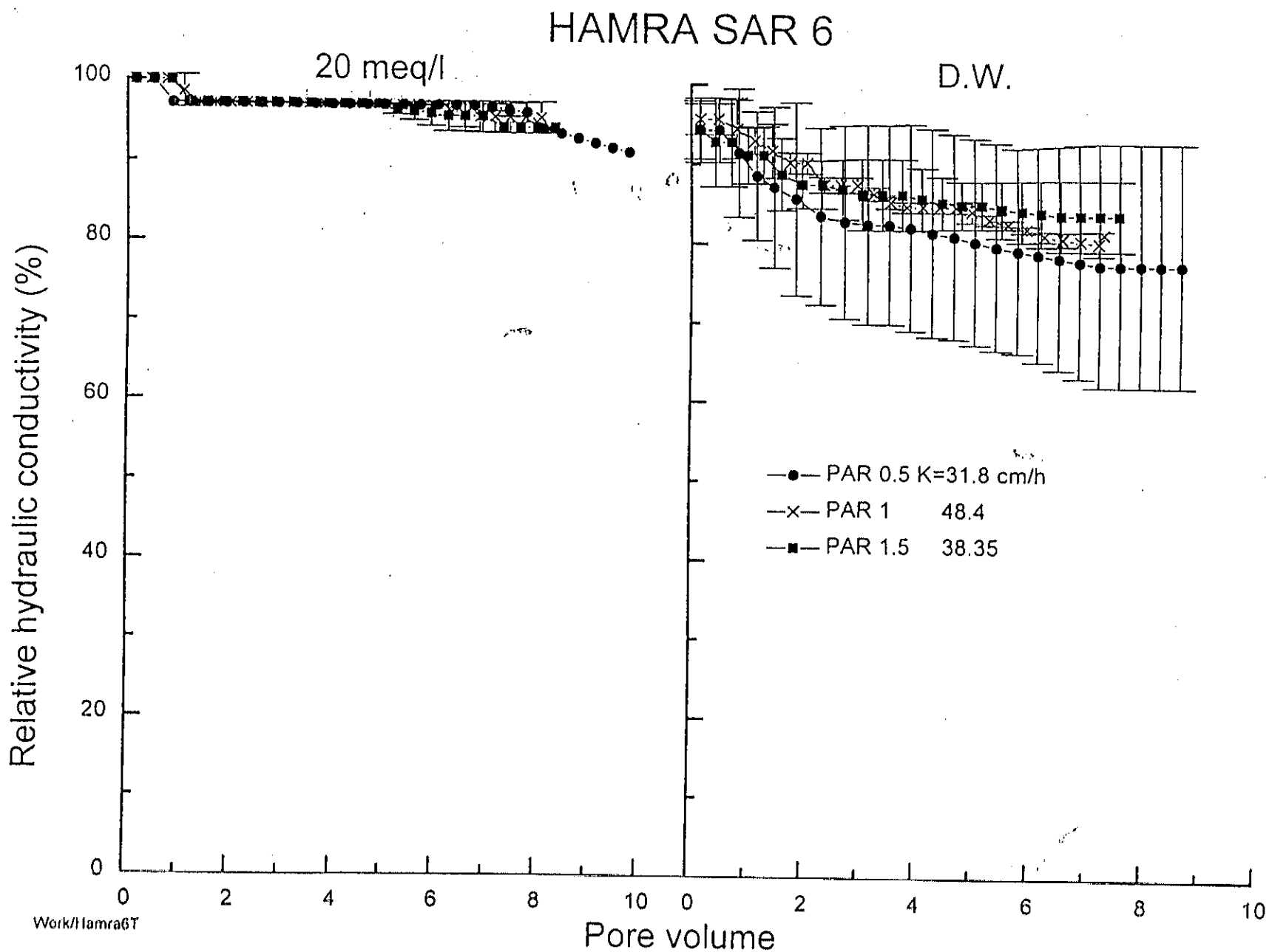


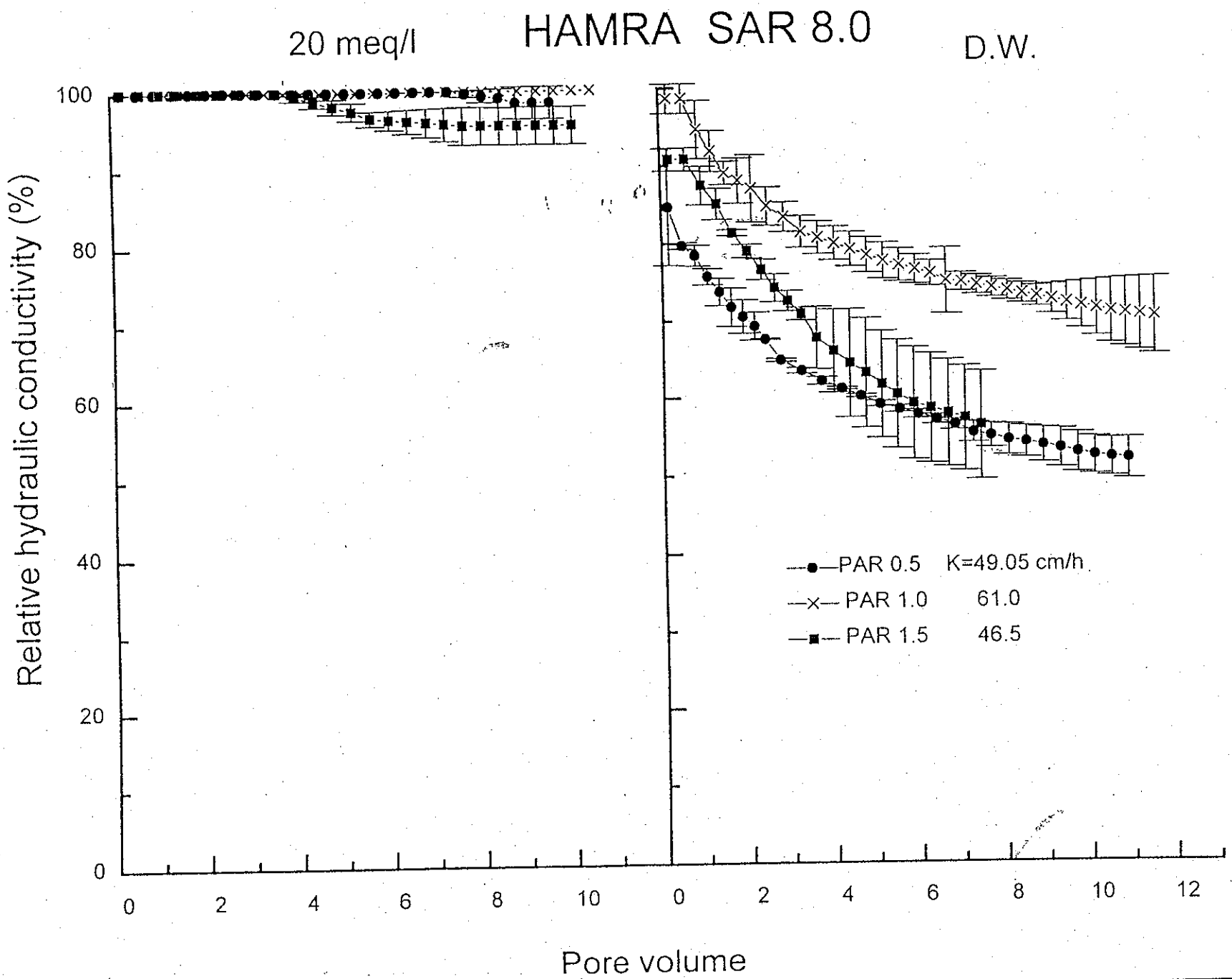
7 3/12


GRUMUSOL, SAR 8.0
20 meq/l
D.W.
Relative hydraulic conductivity (%)
100
80
60
40
20
0
0
2
4
6
8
10
0
2
4
6
Pore volume
PAR 0.5 K=1.2 cm/h
PAR 1.0 1.0
PAR 1.5 1.09
Work/GSAR8T


LOESS SAR 6
20 meq/l
D.W.
Relative hydraulic conductivity (%)
Pore volume
PAR 0.5 K= 0.97 cm/h
PAR 1.0 0.92
PAR 1.5 0.87
Work/LSAR6T


LOESS SAR 8.0
20 meq/l
D.W.
Relative hydraulic conductivity (%)
100
80
60
40
20
0
0
2
4
6
8
10
0
2
4
6
8
10
12
14
Pore volume
PAR 0.5 K=0.7cm/h
PAR 1.0 0.85
PAR 1.5 0.86
Work/LSAR8T


HAMRA SAR 6
20 meq/l
D.W.
Relative hydraulic conductivity (%)
100
80
60
40
20
0
0
2
4
6
8
10
0
2
4
6
8
10
Pore volume
PAR 0.5 K=31.8 cm/h
PAR 1 48.4
PAR 1.5 38.35
Work/Hamra6T


HAMRA SAR 8.0
20 meq/l
D.W.
Relative hydraulic conductivity (%)
100
80
60
40
20
0
0
2
4
6
8
10
0
2
4
6
8
10
12
Pore volume
PAR 0.5 K=49.05 cm/h
PAR 1.0 61.0
PAR 1.5 46.5

Appendix 4

Ministry of Science - Academy of Sciences Republic Kazakhstan
Institute of Soil Science after U.U.Uspanov

J.U.Akhanov
Director of Soil Science Institute
Associate Member of MS-AS RK, professor

REPORT

on

Evaluation of long term effects on irrigation with marginal waters on ground water quality and soil properties in the Tasotkel massif irrigation scheme

By

J.U. Akhnov, B.E. Shimshikov, H.G. Kadyrbaeva, and T.K. Tomina.

Almaty, 1997

Introduction

In 1995 Tasotkel massif of irrigation was selected as an object for investigations. The area of it's irrigation lands is 35 th.ha. The cultivated crops are sugar-beet,maize, alfalfa,winter wheat and others. The massif is irrigated by the water from the river Shu, the water is accumulated in Tasotkel reservoir with the storage capacity of 550mln.m3.It is planned to enlarge the irrigation area up to 60 th.ha, it will require additional amount of water. But even now deficit of water is observed during the period of intensive irrigation.

The storage capacity of drainage-flow waters of different mineralization degree gradually increases due to construction and exploitation of new irrigation and collector-drainage systems. The greater part of them can be used for irrigation and thus it is possible to enlarge the limited resources of surface waters. There was studied the data of previous investigations carried out on the territory, made probes of water from rivers, irrigation channels and vertical drainage holes, taken samples from the sites nearby the drains. The following chemical analyses were made in the laboratory: the composition of watersoluble salts in water probes and water extraction of soil samples according to Gedroyts' method;CO2 of carbonates - according to Sheibler; water free gypsum - according to Gedroyts; absorbed Ca and Mg - according to Shmuk; absorbed Na and K - by alcohol method;total nitrogen - according to Kyeldal; gross phosphorus - according to Pamberton; gross K - according to Smit; Mobile phosphorus and K - according to Machigin; hydrolized nitrogen-according to Tyurin-Kononov; total humus- according to Tyurin; granulometric composition - according to Kachinskiy; density of soil solid phase- by pycnosonde; pH - ionoselective method.

Field works were carried out by Shimshikov B.E. - senior scientific worker, Kadyrbaeva - senior scientific worker, Tomina T.K. Lab. analyses were carried out:by chemists - Ivanova R.M.,Balakina L.M. Tlekenova B.O.

Scientific coordination was accomplished by the Associate Member of NAN RK Prof. Akhanov J.U.

1. Physical conditions

1.1 Location

Tasotkel massif of irrigation is located in the middle stream of the river Shu.In the South it stretches to the juts of Kentyktas and Shybyr mountains. In the West it reaches the river Kuragaty, in the East and the North-East it reaches the Shu-Ili and Kendyktas mountains. Tasotkel massif of irrigation relate to the Shu region,Jambyl district. Village Tolebi and the town Shu are located in the middle of the administative center of the Shu region.

1.2 Climatic conditions

The data received at the meteostation of the village Tolebi and the reference book "Agroclimatic resources of Jambyl region" were used. As far as moisture and heat providing is concerned the main part of the territory relates to the zone of hot arid desert steppes.Arid and continental climate of the massif is conditioned by it's geographical position. It is located within the Euroasia continent and remote from the oceans. Sharp temperature contrasts from day to night, from winter to summer, quick changes from winter to summer are observed.Hydrothermic coefficient ranges within 0,3-0,6 C; average annual temperature ranges from 8,7 -10,3 (table 1.2).Average temperature of the coldest month January ranges from -3 to 11 C; the hottest months July August from +23 to 26 C. Absolute maximum temperature is in July (+40,+41 C), absolute minimum - in January (-23,31 C). Stable snow cover appears at the 1-2 decade of December. The number of days with snow cover is 70-90 a year. Snow melting stops at the 2nd decade od February - 1st decade of March. Vegetation period is 217-224 days may be shotter due to late spring and early autumn frosts. The frost free period is from 148 to 183 days. Heatproviding of the region is high. The total sum of the period with temperature above 10 C makes up 3500-3700 C. Average annual total radiation reaches 105-125 kkal/cm2. Evaporation of precipitation is 0-14 kkal/cm2, radiation balance makes up 28-36 kkal/cm2.Moisture providing of the vegetation period is rather low. Precipitation falling in a small amount (250-350mm/year) are subjected to a considerable variation from year to year. The greater part of precipitation fall is in spring (March-May 111,2 mm), minimum fall is at the second part of summer and beginning of autumn (July-September 25,2 mm).In summer deficit of air and soil humidity appears, it achieves 2140-235 mm for the period with temperature above 10 C.

The territory of the massif is subjected to the systematic wind influence,which maximum is in winter and spring, when the wind speed is from 2,5 to 7,6 m/sec. Dust storms are observed in summer during the dry weather.They make up 18-21 days a year. Drought conditions of arid winds are unfavourable phenomena which are observed every year. The greatest number of arid wind days are in June, July, August.

Comparative analysis of the mentioned above data speaks about the contrast climatic conditions. Deficit of moisture is observed on the background of thermic resources'surplus during the vegetation period. These factors and active wind activity causing arid winds condition some difficulties for agricultural development of the territory where irrigation agriculture and cattle-breeding prevail.

1.3 Hydrogeology

Tasotkel massif of irrigation ischaracterized by complex hydrogeologoamelioration conditions,caused by geologic structure, relief nature and climatic factors.

Regional retainer is quaternary-Neogene deposits including several water-bearing horizons on the right bank which are hydrolically connected and they form a hydrolic stream with common conditions of intake and relief capacity from 2 to 112 m. Artesian waters are distributed in sandy and sandy-pebble deposits of Neogene red clays and in the weathering crusts of paleozoic period.Input of artesian waters into ground waters makes up 10-12 mln.m3/year.(Beresina,1975).

On the left bank, this water-bearing complex is located at the 95-120 m depth and separated from ground waters by thickness of clays up to 50 m,causing lower velocity of vertical and horizontal waterexchange and conditions formation of pressure horizons of ground and underground waters.

Two types of ground water regimes were determined due to results of observations on the territory of irrigation massif:1-natural type (seasonal intake) and 2nd - artificial regime.

1. Natural regime is formed under the influence of some natural factors, the main of which is climatic.This type of regime is characterized by spring-autumn raise of the level and summer abatement with maximum in August-September. Average annual variations of ground waters is 0,3-1,0m. Income part of the balance consists of infiltration of atmospheric precipitation and input from mountain slopes and the expenditure part - evaporation and transpiration,outcrop of ground waters into the rivers Shu and Kuragaty. The North part of the massif, a narrow belt 2-4 km along the West boundary, South-West part and almost the whole East part of the massif within the sloping piedmont plain of Shu-Ili and Kendyktas mountains can be related to the sites with natural type of ground water regime.

2. Artificial type of regime is at the central part of the massif. Two peaks of maximum are typical for it: spring maximum which is connected with irrigation period when the amount of underground water increases. Average annual amplitude of the level variation makes up 0,5-1,3 m and amplitude of seasonal mineralization change is from 0,1 to 1,0 g/l.Three classes of regime were determined.

Depending on the location of ground water level concerning the critical value adopted at the massif 2,5 m, there were defined 3 classes of regime:

Class A - stable favourable regime, the level is lower 2,5 m during the whole year. It is typical for the major part of the right bank area; piedmont sloping plain; partially - for the second fluvial terrace above flood-plain.In the Central

part of the massif it is developed in the belt of 2 km width, siding with flood-plain and fluvial terrace above flood-plain at the both banks of the river Shu.

Class B - unstable regime (considerable variation of the level regarding to the critical one) which is spread in the central part of the massif as separate contours, narrow belt at the right bank of Kuragaty river and at both sides of the river Shu with width from 500m to 3 km.

Class C - stable unfavourable regime (level is constantly higher than 2,5 m) is spread at the 2nd fluvial terrace above flood-plain of the North part of the right bank and in the central part of the river Shu left bank.

2. Quality of water and possibility of drainage flow for irrigation

2.1.Quality of water in rivers and irrigation channels

The main water ways of the massif are the river Shu and it's feeder the river Kuragaty flowing into the Shu river from the North part of the massif. The river Shu devides the massif into 2 parts: right- and leftbank,Kuragaty borders on Moiynkum sand from the West.Within the massif the river Shu flows to the North with some removal to the West. It's banks are precipitous up to 9 m height and the river-bed width is 50-120 m. The river has a snow- glacier intake and spring-summer flood which is transformed because of regulation flow and irrigation development.At the upper part of the massif at the river Shu, Tasotkel reservoir was built with the useful capacity - 550,5 mln.m3.

The river bed is almost dry in summer at the downstream of Tasotkel diversion, but the river flow increases at the middle and northern parts of the massif due to return flow. The ground water outcrop into the river near the village Tolebi reaches 10-15 m3/sec.

Change of the river Shu flow and ceasing of flooding at the lower reaches of the river after the regulation of flow by reservoir caused desertification of soils in Ulanbel and Kamkalin deltas and also increase of solonchaks areas in Gulyaev delta.

Change of flooding and hydrogeologic regimes of soils activizes salt accumulation.Salt concentration in river water increases from spring to summer from 0,43-0,49 to 0,69-0,74 g/l. The composition of waters is sulphate-hydrocarbonate,but the composition of ions varies from season to season:hydrocarbonates of Ca prevail under low mineralization and Na sulphates - under high mineralization.

The source of the river Kuragaty is located in piedmonts of Kyrgyz ridge, the main source of intake is atmospheric precipitation. Deep erosion is 2-3 and the width of the flood-plain -20-40 m. Hydrothermic regime isn't stable: maximum discharge falls on spring months reaching sometimes 27 m3/sec.(average annual 2,1 m3/sec.) Water mineralization is

0,9-1,5 g/l. It's composition is hydrocarbonate-sulphate magnesium-sodium, potentially alkaline.

Due to the fact that the river drainages the territory, water mineralization increases in summer up to 2,2-2,8 g/l. Water of the river Kuragaty is unfavourable for irrigation according to all data excluding temperature and can provoke salinization and alkalinization of soils, prevention of which requires annual washings with outflow of drainage waters in the amount of 20-25% from the water supply. (Kovda,1977) and application of gypsum in 0,35 t/1000 m3 of water.

Water works facility of Tasotkel reservoir has Leftbank and Rightbank canals (MC).The capacity of the leftbank MC is 11,9 m3/sec at the head part, it's length is 44,2 and together with water allocation is 152 km. The capacity of the rightbank MC is 13,1m3/sec, it's length - 49 km. Full supply factor of irrigation system ranges within 0,65-0,70 decreasing at the moments of the greatest water diversion up to 0,49-0,63.

Observation show that the greatest salt concentration of water is in June-August (0,60-0,82 g/l). Ion composition of irrigation water varies from sulphate-hydrocarbonate, calcic-sodium to hydrocarbonate-sulphate, sodium-calcic. Periodical short-term occurence of sodium carbonate in spring in the amount of 0,08-0,40 mg/equ is typical for river water. But it dissapears in summer. Increase of mineralization is observed as it's advancement along the irrigation system from the place of water diversion to the terminal point. Thus salt concentration gradually increases from 0,69-0,70 to 0,82-0,9 g/l, pH of irrigation waters ranges within 8,1-8,5. Their changes from the lower reaches of the river to the upper reaches are determined by the change of carbonate equilibrum depending on the temperature and the rate of water saturation O2 and CO2.

2.2. Quality of underground waters of drainage outflow along the vertical drainage holes

Seven holes of vertical drainage are used at the experimental plots from 1979. The range of drainage waters mineralization changes from 1,1 to 7,7 g/l. Ion composition varies from hydrocarbonate to sulphate, calcic-sodium to chloride-sulphate with share of soda, sodium (table 3). Hydrochemical and hydrothermical (t=13,9-14,1 C) regimes are stable in all time. The following data were determined on the basis of the existing classifications for evaluation of irrigation water quality and chemical data (table 4):

Water from the drainage hole 1, hydrocarbonate-sulphate, calcic-sodium type of chemism with salt concentration 1,1 g/l, pH - 7,8 is rather useful for irrigation.Hazard of salinization isn't high and hazard of alkalinization is very small.

Water from the drainage hole 2 also has low mineralization 1,32 g/l and weakly alkaline reaction (pH=8,1). Ion composition changes from hydrocarbonate-sulphate to chloride-sulphate with share of soda, sodium. Application of this water is possible but it's presence in the composition of narmal soda in 0,2-1,7 mg/equ amount provides for a possibility of alkalinization processes development, preventing of which requires preventive amelioration measures.

Water from the drainage hole 3 with salt concentration 1,83-2,68 g/l of hydrocarbonate-sulphate,sodium chemism type (pH=7,7-7,8) is considered to be of limited usefulness with small possibility of alkalinization and moderate salinization.Water use from drain 3 must be accompanied by application of reagents in soil and water which neutralize the toxicity of salts and by periodical washings.

Water from the drainage hole 4 is considered to be of agreed usefulness. Ion composition - chloride-sulphate with soda participation, magnesium- sodium, pH 7,6-8,1. Concentration of salts 3,34 g/l causes a real hazard of salinization , and presence of carbonates (0,3-0,47 mg/equ) and becarbonates (4,2-5,6 mg/equ) causes processes of alkalinization. Thus application of this drainage water is possible only together with development of amelioration measures aiming at preventing of salinization and alkalinization processes. Drainage water from drain hole 5 isn't useful for irrigation due to a high salt concentration (c=7,7 g/l) and presence of sodium carbonate (1,5-2,0 mg/equ).

Water from the drain holes 6,7 and 8 is also of limited usefulness for irrigation.Salt concentration from 1,65 to 4,12 g/l. Chemism type of salinization is chloride-sulphate, magnesium-sodium. Conditions of it's application are the same as it is required for water from the holes 3 and 4.

3. Soils in the massif area

3.1. General characteristics

Formation of the modern soil cover of the massif is conditioned by it's geomorphologic structure and geologo-hydrogeologic conditions. At present anthropogenic factor actively influences on soil formation process.

Soil development of the massif is going on by the following scheme (Orlova and et al.1970):alluvium evolves into the light sierozems through meadow soils,sierozemic-meadow and meadow-sierozemic soils.In modern conditions evolution sequence at the first terrace above flood-plain is represented by soils of swamp sequence and drying meadow alluvial soil; at the second - by meadow, sierozemic-meadow and meadow-sierozemic; on the piedmont plain - by light poor in carbonates sierozems changing into the gray-brown soils in the North.

Intensive moisture evaporation from the surface of

hydromorphic soils formed on terraces led to the surface alkalinization of the profile. Underground evaporation promoted salinization of middle and salinity control of upper horizons and promoted changes of hydromorphic surface-salinized soils into semi hydromorphic soils with decrease of the base level of erosion and lowering of the ground water level.

Presence of bicarbonate and normal alkalinity is a pecularity of soils in the modern dale of the river Shu mostly of the leftbank part of the 2nd fluvial terrace above flood-plain. They occure without dependence on salinization rate anf irrigation-agricultural exploitation of lands.

Soils of the south and central parts of the rightbank are not saline, salinization increases to the South boundary and becomes extremely high. Non-saline and weakly saline soils at the leftbank stretches along the river Shu as a narrow belt. Soils of the leftbank are moderate- and high saline.

Alkaline soils forming complexes with non-alkaline soils are observed in the northern part of the rightbank and along the whole leftbank. Solonchaks are not numerous, mainly, they spread in the North-West part of the massif forming complexes with less saline soils.

During the study of the soil cover at the Tasotkel massif of irrigation special attention was paid to the lands used in agriculture located at the second fluvial terrace above flood-plain of the river Shu.At present these lands are almost all ploughed but 25% of the area is irrigated.

Meadow-sierozemic (44686 ha) sierozemic-meadow (30718 ha) and meadow (9750 ha) soils mostly prevail (J.U.Akhanov, V.A.Korobkin, 1982) at the second fluvial terrace above flood-plain. Up to 74% of the area with meadow-sierozemic soils are located on the rightbank part,
sierozemic- meadow soils are located equally, about 75% of meadow soils are located on the leftbank. Salinization increases together with hydromorphyty: 50% of meadow-sierozemic soils are salinized, sierozemic-meadow -61%, meadow - 83%. The major part of soils is alkalinized due to the presence of soda in composition of
salts:meadow-sierozemic - by 48%; sierozemic- meadow - by 37%, meadow - by 39%.

Meadow-sierozemic soils are located on the flat site along the river Shu and on the South rightbank.Ground waters are at the 3-5 m depth, mainly they are fresh or weakly mineralized. Capillary fringe ranges in the interval of 60-140 cm from season to season, thus signs of gleying appear lower than 1 m.

Lightloamy varieties, medium- and heavy-loamy soils according to the granulometric composition can be met in the northern part of the rightbank. Profile has a weakly displayed bedding. It has a homogeneous medium- and light-loamy structure on the rightbank. The content of the silt fraction in alkaline soils of solonetzic horizon increases. Thickness

of the humus horizon makes up about 30 cm, the content of humus and nutrition elements in it is low.

Low (up to 0,1%) content of salts in sulphate-hydrocarbonate composition is typical for the non-saline and deep solonchak-like soils; solonchak-like soils have up to 0,49% of salts in salt horizon, calcium hydrocarbonates and sodium sulphates prevail.

High solonchak-like soils have up to 0,33% of salts in the horizon 30-50 cm, their spreading along the profile is conditioned by the character of soil exploitation: in virgin lands their maximum is located in the middle part of the profile, in irrigated sites - in the lower part. Private and usual alkalinity appear in the lower part of the profile. Solonchak-like soils have up to 0,04% in the layer 0-30 cm,the mostly salinized horizon is 30- 1000 cm (0,8%), at the 2nd place - 0,6% Types of salinization which prevail: hydrocarbonate-sulphate and sulphate with share of soda.

Solonetzic soils (8,9 th/ha) are concentrated in the northern part of the massif. Solonetzic horizon is located at the 15-35 cm depth and the following signs are typical for it:brown colour, compaction, lumping-and lumpiness-nutty structure.Absorbing capacity sometimes exceeds 12 mg/equ, magnesium often prevails in absorbing complex.Medium-alkaline types are the most widely spread among them. As a rule they are solonchakous (4,9 th/ha) with salt storage in the upper meter up to 150 t/ha. They are different from the other soils by high even above normal alkalinity,maximum of which is located in solonetz horizon (0,5 mg/equ).Hydrocarbonates and sodium sulphates prevail among the salts with share of soda. The highest salinization (0,8-1,1%) is observed at the depth 70-110 cm, deeper - it decreases up to 0,15-0,30%.

Sierozemic-meadow and meadow soils are similar according to their physico chemical indices, they are different only by the depth and degree of gleying display. They occupy 40,5 th/ha, 60% of them are located on the leftbank. These soils are formed in weakly displayed flat padings with comparatively close (1,5-2,5 m)depositing of mineralized ground waters. Despite of the more dark colour of the upper horizon in comparison with meadow-sierozemic soils, they slightly differ from them by the humus content. Signs of gleying are displayed at the 40-60 cm depth.

Absorbing capacity isn't large - from 6 to 13 mg/equ per 100 g/soil. Share of Mg is great in composition of exchangeable basis. In the layer up to 50 cm, it makes up 25-40 %,lower 50 cm - up to 50 %. Probably, just it makes the soils compact and gives morphologic alkalinity for them.

The main part (up to 65%) is salinized. Non-saline genera are met as separate mottles under irrigated crops with average depth of ground water location - 1,8 m and mineralization 1,2-1,9 g/l. Solonchakous soils prevail among saline soils.

The depth of ground waters changes from 1,7 to 2,1 m in summer. Water mineralization 3-7 g/l is typical for weakly- and medium-solonchakous genera, for highly solonchakous - 8,4 g/l is typical for weakly- and medium-solonchakous genera, for highly solonchacous - 8,4 g/l and more. A distinct differentiation is observed in salt profile - maximum of salts (up to 0,3 %) is concentrated at the depth of 20-50 cm, watersaturated horizons are not saline or they are weakly saline.Sodium sulphates and soda dominate in salt composition, chlorine is concentrated in small amount near the surface.

The amount of soda ranges in wide limits: traces are marked in non-saline types rarely, whereas it's content in solonchakous soils reaches 0,08; in solonchaks - 0,4-0,5 mg/equ,at the depth of 20-30 cm.

More than 30% of meadow and sierozemic-meadow soils are alkaline. The soils located on the leftbank are the most alkalinized, the area of their location is 12,4 th/ha. The greater part of soils refer to medium and weakly alkaline soils according to the content of the absorbing sodium and morphologic structure. Alkali horizon is of dark colour unlike the same in meadow-sierozemic soils, some solodization is observed at some sites.

Alkalinized soils don't differ from the non-alkalinized by salt distribution along the profile, but soda appears from the surface or from 50 cm (from 0,5-0,8 to 1,1-1,5 mg/equ per 100 g of soil).

Swamp and meadow-swamp soils are observed at the second fluvial terrace above flood-plain along the talwegs and padings.

Hydromorphic and semihydromorphic soils of terrace refer to the most fertile lands of the massif due to the main physico-chemical properties. But their major part requires optimization of water and salt regimes and improvement of water-physical properties.

3.2 Soils of the experimental sites

Representation of the selected sites for field experiments plays a great role in substantiation of measures developed for application of mineralized waters and further introduction into production.

The II crop rotation was chosen for the field experiments at the territory of the collective-farm "Asha"(former collective-farm "Novotroitskiy") the area of which is 750 ha. The site is typical for this territory according to the complexity of soil cover and diversity of amelioration-hydrogeologic conditions.

Soil cover is saline to different degree and ground water mineralization ranges from 1 to 11 g/l. Deposits of the lower Quarternary-Neogene age serve as regional retainer.Sharp heterogeneity of rocks'lithologic composition both in vertical

pit and horizontal plan is a typical pecularity of the water bearing horizon. Water permeability of the water-bearing horizon changes within wide limits 200-1600 m3/day decreasing to the South-West direction. 4 categories of lands are notable for conditions of drainage and application of vertical drainage at the experimental site:

1.- with very favourable coditions, water conductivity is more 1000 m3/day.

2.- with favourable conditions,water conductivity is 500-1000 m3/day.

3.- with low favourable conditions, water conductivity is 200-500 m3/day.

4.- with unfavourable conditions, water conductivity is less 200 m3/day.

The source of intake for the water-bearing horizon is infiltration of atmospheric precipitation and irrigation water and the lateral ground water input of the lieing above territories.

3.2.1 Site I

this site has a poor natural and artificial drainage which refers to the II categories of lands with favourable conditions and water conductivity of waterbearing layer 500-1000 m3/day.

The level of the ground water ranges within 1,3 - 1,6 m for vegetation under mineralization 3-4 g/l of soda-sulphate type of chemism.

Soil cover is represented by hydromorphic medium columnar alkali soils. The surface is clotted-lumped. It is covered by compact surface cap (1,0-3,0 cm),vegetation is practically absent excluding some specimen of Alhagi pseudalhagi. Effervescence of HCl is rapid from the surface. Whitish mottles of salts are observed at the depth of 16-54 cm along the pit profie. Cappilary fringe is visually determined from the depth 10 cm. The level of ground water - 190 cm with mineralization of soda-sulphate type of chemism 2,2 g/l.

Morphologic structure of the profile. Horizon A with 14 cm thickness is completely sheared under the laying-out (in 1977).

Horizon B1 0-20	Dark-brown, fresh, heavy-loamy, highly indurated, fine-porous, rarely crackous, nutty, visible transition.
Horizon B2 20-40	Dark-brown, humid, medium-loamy, indurated, fine-porous, structureless, sharp transition.
Horizon C1 40-161	Brown-gray, humid, from 110 cm it is damp, sandy, indurated, structureless, sharp transition.
Horizon C2 161-200	Yellow-gray, wet, medium-loamy, indurated, structureless.

Granulometric composition of the ground is not homogeneous. Fraction of fine sand prevail (36-45%), content

of silt fraction in alkali horizon makes up 12-16 %.

Density of soil structure is high with maximum in alkali horizon -1,73-1,84 g/cm3. Correspondingly porosity is low 36-42 %. The least moisture capacity doesn't exceed 13-19% from the soil density. Considerable induration and low moisture capacity of soils together with the saturation of the absorbing complex by sodium condition bad hydrophysical properties.

Filtration coefficient according to the data on water permeability is 0,02-0,06 m/day.

Humus content in horizon A makes up 0,6-1,2%, it,s content reduces with the depth up to 0,2%.Gypsum amount is small - 0,152-0,136%.

In composition of soil absorbing complex sodium (35-40% from the total sum of cations) prevail. Content of calcium cations 1,2-3,4 mg/equ makes up 30-42% and magnesium 1,0-3,0 mg/equ - 12-13% from the exchange capacity.

A distinctive pecularity of hydromorphic solonetzes is high alkalinity of soil solution (pH 9,8-10,0) caused by normal soda presence up to 0,6-0,8 mg/equ. and by sodium carbonate 2,9-4,4 mg/equ.

Salt maximum (0,31-0,64%) is located in horizon 20-80 cm. The amount of sulphate sodium in horizons of salt maximum is 1,7-3,3 mg/equ. Salts storage in the 30 cm layer of active salt exchange reaches 100 t/ha. Toxicity of soil solution displayed in mg/equ of chlorine is determined by high content of sodium carbonate and makes up 4,8 mg/equ.

Content of CO2 carbonates is 4,5-8,5% along the profile and it's storage in 1 meter layer is 1500-1850 t/ha.

Calcium carbonates despite the low desolution under the optimal moisture supply ability and high biogenity of arable layer give great amelioration effect. It is caused by increase of carbonic acid concentration promoting increase of calcite desolution and bicarbonates formation:

$$CaCO_3 + CO_2 + H_2O - Ca(HCO_3)_2$$

3.2.2. Site II

This site is represented by solonetzic medium-saline sierozemic-meadow soils. The site is located in the zone of intensive drainage influence of vertical drainage hole II.

The source of irrigation is underground drainage flow with mineralization 0,9-1,9 g/l of hydrocarbonate-sulphate composition with periodical share of soda (spring). Temperature of water is constant in time 14,2 C.

In initial condition sierozemic-meadow solonetzic soils are characterized by low content of watersoluble salts, 0,12-0,45% from the soil density. Chemism of salinization varies from sulphate-soda to soda-sulphate, sodium. Presence of carbonate soda in the profile in the amount 0,1-0,5 mg/equ, and also bicarbonate soda 1,4-1,8 mg/equ per 100 g of soil

makes the toxicity of soil solution high. The total effect of toxic ions (Basilevich, Pankova,1968) in the layer 0-100 cm makes up 3,3-5,2 mg/equ.

Morphologic description of the soil profile with sierozemic-meadow solonetzic soils is characterized by the pit made under Alnagi pseudoalhagi + Artemisia terrae-albae association with some share of Cynodon dactylon and Atriplex.

The soil cover is relatively flat, weakly clotted, crackous. Effervescence of HCL is rapid from the surface. Carbonate horizon is observed at the depth of 50-8-cm,watersoluble salts - from 55 cm.

A arable 0-19 - Dark-gray, fresh, light-loamy, indurated, powder-like-clotted, visible transition by the density of structure.

B1 19-30 - Dark-gray-fresh, loamy, indurated, clotted-lumped, rarely crackous, visible transition.

B2 30-45 - Dark-brown, wet,medium-loamy,lumped,indurated,rarely crackous, visible transition.

B3 45-58 - Brown, wet, medium-loamy, structureless, highly indurated, whitish due to carbonates,clear transition.

BC 58-78 - Whitish-brown, wet, medium-loamy, structureless, indurated, gradual transition.

C 78-115 - Yellow-brown, wet, medium-loamy, structureless, indurated, clear transition.

C 115-140 - Yellow-brown, damp, loamy-sandy, structureless, indurated, visible transition.

C 140-220 - Brown-gray, damp, sandy,indurated,structureless.

Ground waters of soda-sulphate sodium type of chemism with mineralization 4,2-4,6 g/l are located at the depth 2,10-2,40 m. Effect of vertical drainage hole II results in decreasing of ground water level up to 4-5 m. Irregular work of the hole causes a wide range of ground water level but the hydrochemical regime is relatively stable in time.

Granulometric composition of soils isn't homogeneous. The upper horizon is represented by light loams. At the depth it changes into medium-loamy, the content of physical clay in illuvial horozon makes up 34-45% and clay fraction -19-26%.

At the 115 cm depth soils are bedded by the loam-sand deposits and fine-grain sand.

Density of arable horizon (0-20 cm) is low 1,15-1,28 g/cm3 but it increases with the depth up to 1,61-1,67 g/cm3.Illuvial horizon is the most indurated.

Soils porosity makes up 37-52% from the volume. The least moisture capacity is 18-22% from the density.Distinctive alkalinity provides for low fertilization ability of sierozemic-meadow soils -0,06-0,08 m/day. In SAR composition sodium dominates with maximum 3,6-4,2 mg/equ (30-42% from the total sum of cations) in illuvial horizon. The share of calcium and magnesium is approximately equal 25-35% from the exchange capacity. pH of water suspension makes up 9,3-9,7 in surface (0-19 cm) horizon. Alkaline reaction of soils

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increases with the depth reaching pH 9,9-10,4 in horizons of maximum content of the absorbed sodium (19-30 and 30-45 cm).

Humus content is within 0,25-1,25% gradually decreasing from the top to the bottom.Gypsum is observed in the amount of 0,37-0,54%, soil carbonates prevail -4,5-7,0%.

Content of watersoluble salts in a meter layer is 25-50 t/ha and in 3 meter soil -ground thickness - 70-150 t/ha.

3.2.3. Site III

This site is represented by meadow sierozemic soils which undergone considerable changes of soil profile during radical laying out of irrigation lands(1977). Natural upper horizon A is practically absent. Ground waters are located at 4-5 depth during vegetation period. Soil processes are formed in conditions of intensive drainage influence of vertical hole IV. Drainage flow with mineralization 3,4-4,9 g/l of hydrocarbonate-sulpfate type of chemism with share of normal soda of hydrochemical composition is a source of irrigation. Temperature of water is 14 C.According to drainage conditions the site of irrigation relates to the 3d category of lands with water permeability of the waterbearing layer 200-500 m3/day.

The soil surface is flat with small cracks. Effervescence of HCL is going on from the surface.

Morphologic description of medium-sierozemic soils.

A1 - absent,sheared while laying out.

A2 0-4 - Yellow-brown, dry, light-loamy, indurated, clotted-silt, clear transition by the structure and density.

B1 4-54 - Yellow-brown,fresh,light-loamy, compact,lumbed-clotted,gradual transition.

B2 54-70 - Yellow-brown, weakly-humid, light-loamy, compact, structureless, gradual transition.

BC 70-158 - Yellow-brown, humid,light-loamy, indurated, structureless, clear transition.

C 158-200 -Brown with yellow hue,wet, medium-loamy, indurated, unstable, clotted-nutty, clear transition.

C 200-250 - Brown with yellow hue, damp, medium-loamy with sandy streaks, indurated,structureless.

Salt content along the profile is slight 0,07-0,20%. Whitish efflorescences are observed at the depth 69-142 cm.Prevailance of sodium sulphate (0,6-1,2 mg/equ per 100 g of soil) is visible in ion composition. Carbonate soda in the amount of 0,03-0,05 mg/equ is periodically met in some horizons. Alkaline reaction of soil solution in arable horizon ranges within pH 7,8-8,3.

Calcium (2,0-4,0 mg/equ or 30-40%) and magnesium (2,5-4,0 mg/equ or 35-63% from the sum of the absorbed bases) prevail in composition of the absorbed bases. The share of

exchangeable sodium doesn't exceed 0,1-0,6 mg/equ (2-6%).

Salts are weakly humous from 0,4 to 1,2%. The content of the organic matter rapidly decreases with depth. Gypsum storage makes up 0,10-0,21% and carbonates -3,7-5,3% fromthe soil density.

Granulometric composition is mainly represented by light loams and they increase in weight by one gradation deeper 1,5 m. Capillary fringe is determined visually at 138 cm from the surface.

Density of soil structure ranges within 1,48-1,61 g/cm3,the total porosity is 39-53%. The least moisture capacity ranges from 16 to23%. Water permeability in arable horizon changes from 0,20 to 9,7 m/day, in the under arable horizon - from 0,07 to 0,12 m/day. Decrease of ground water level from 2,8 to 4-5 m and the tendency for dessolution in water-salt regime of soils is observed at the site III during the work of the IV hole of vertical drainage.

Salt storage at present doesn't exceed 50 t/ha in 3 meter thickness.According to the ion composition ground waters with mineralization 3,2-4,1 g/l relate to chloride-sulphate type of chemism with share of soda, sodium prevails among cations.

Conclusions

Tasotkel massif of irrigation is a suitable object for investigations on application of collector-drainage mineralized waters for irrigation. Irrigation is developed at the 2nd fluvial terrace above flood-plain of the river Shu where holes of vertical drainage were built for regulation of water-salt regime of soils. Mineralization of the pumped waters ranges from 1,08 (drain I) to 7,66 g/l (drain V).

Irrigated soils are mainly represented by meadow-sierozemic and sierozemic meadow soils, among which contours of sodium saline,solonetzes are met. All the soils are saline to some extent due to irrigation by mineralized waters thus it is necessary to work out a complex of amelioration measures to prevent salinization and alkalinization of soils. Application of drainage flow waters for irrigation will enable to decrease a water discharge from the river Shu and it's intake into the low reaches of the river. It will increase the productivity of hay meadow and pastures now subjected to anthropogenic impact.

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Table 1.1. Hydrothermic coefficient and seasonal distribution of precipitation.

Climatic region	Hydro-thermic coeffi-cient	The total sum of tem-perature above 10'C	Precipitation, mm				
			spring	summer	autumn	winter	Total sum
Dry hot desert steppe	0,3-0,6	3500-3700	111,2	54,0	60,8	89,2	315,2

Table 1.2. Average month & annual distribution of air temperature & the amount of precipitation (mm) for 1978-1994 of observations.

Indi-ces	M o n t h e s												
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	I-XII
Air tempe-rature 0s.	-7,3	-5,7	3,6	13,1	17,5	22,6	26,1	22,9	17,4	11,2	4,2	-2,2	10,3
Pre-cipi-tati-on, mm	19,6	25,3	26,4	45,6	39,2	40,6	6,4	7,0	11,7	12,8	36,3	44,3	314,5

Table 2. Mineralization of irrigation waters in the irrigationcanals of Tasotkel massif.

Date of sampling	Mineralization, C, g/l	Ion composition % / mg-equ per 1 l HCO3-	CO2--	Cl-	SO4--	Ca++	Mg++	Na+	K+	pH
		1. Tasotkel reservoir								
VI.95	0,69	0,228	traces	0,034	0,216	0,060	0,034	0.076	0.006	8,31
		3,75		0,96	4,50	3,00	2,71	3,32	0,15	
		2. Rightbank main canal (hydropost)								
VI.95	0,822	0,222	0,004	0,036	0,326	0,066	0,030	0,130	0.008	8,4
		3,64	0,17	1,00	6,80	3,30	2,47	5,64	0,20	
		3. Leftbank main canal (hydropost)								
VI.95	0,673	0,232	0,004	0,036	0,216	0,062	0,030	0,085	0,008	8,3
		3,81	0,17	1,00	4,50	3,10	2,47	3,71	0,20	
VII.95	0,595	0,182	-	0,040	0,216	0,028	0,044	0,079	0,06	
		2,99		1,13	4,50	1,40	3,62	3,45	0,15	
VII.95	0,625	0,212	-	0,037	0,206	0,056	0,030	0,078	0,006	
		3,47		1,04	4,29	2,80	2,47	3,38	0,15	
		4. Bed of the river Shu (hydropost at the inlet of the v. Tolebi)								
VII.95	0,749	0,240	no	0,040	0,264	0,070	0,033	0,098	0,004	8,1
		3,94		1,13	5,50	3,50	2,71	4,26	0,10	
		5. Underground water diversion (water supply of the village Tolebi)								
VII.95	0,986	0,357	no	0,065	0,331	0,042	0,082	0,125	0,004	7,4
		5662		1683	6,90	2,10	6,70	5,45	0,10	

Table 3. Level and mineralization of ground water at irrigated sites and pores of vertical drainage of Tasotkel massif.

Source of diversion unit	Depth m	Ion composition mg/egu per 1 l								
		HCO3-	CO3--	Cl-	SO4--	Ca++	Mg++	Na+	K+	pH
1	2	3	4	5	6	7	8	9	10	11
Drain 1	1,08	0,275	0,010	0,137	0,336	0,064	0,036	0,216	0,006	7,8
		4,51	0,33	3,87	7,00	3,20	2,96	9,40	0,15	
Inlet pore 1a	1,80	0,586	0,031	0,088	0,54	0,015	0,018	0,504	0,008	
0,018 of drain	1,79	9,60	1,03	2,48	11,25	0,75	1,48	21,93	0,20	
1(IX.95)										
Inlet pore 1b	1,84	0,844	0,024	0,121	0,816	0,020	0,033	0,715	0,010	
of drain 1(IX.95)	2,58	13,83	0,80	3,41	17,00	1,00	2,71	31,08	0,25	
Drain 2	1,32	0,197	0,006	0,125	0,582	0,040	0,030	0,331	0,008	8,1
		3,24	0,20	3,52	12,14	2,00	2,50	14,40	0,20	
Inlet pore 2a	2,20	0,805	0,017	0,150	0,960	0,050	0,040	0,732	0,014	
of drain 2 (IX.95)	2,77	13,19	0,57	4,22	20,00	2,50	3,29	31,82	0,37	
Inlet pore 2b	2,40	1,080	0,053	0,217	0,912	0,050	0,021	0,907	0,016	
of drain 2	3,26	17,17	1,77	6,13	19,00	2,50	1,72	39,44	0,41	
Drain 3	1,83	0,539	0,038	0,128	0,576	0,030	0,043	0,471	0,007	7,7
		8,83	1,27	3,61	12,00	1,50	3,54	20,50	0,17	
Inlet pore 3a	2,80	0,483	0,027	0,237	1,112	0,130	0,064	0,612	0,010	
of drain 3	2,68	7,92	0,88	6,68	23,16	6,50	5,28	26,61	0,21	
Inlet pore 3b	2,45	0,530	0,029	0,255	2,424	0,198	0,104	1,120	0,007	
	4,67	8,68	0,97	7,17	50,49	9,88	8,55	48,70	0,18	
Drain 4	3,34	0,346	0,011	0,456	1,51	0,120	0,140	0,749	0,010	8,1
		5,7	0,37	12,85	31,46	6,00	11,51	32,57	0,27	
Inlet poil 4a	3,45	0,256	-	0,286	0,708	0,030	0,049	0,485	0,013	7,7
of drain 4 (IX.95)	1,83	4,20	-	8,00	14,75	1,50	4,03	21,08	0,34	
Inlet poil 4b	6,85	0,206	0,014	0,305	0,744	0,020	0,052	0,514	0,010	
of drain 4	1,87	3,33	0,47	8,59	15,50	1,00	4,28	22,34	0,27	

Table 3: Continued

Source of diversion unit	Depth m	Ion composition mg/egu per 1 l								
		HCO3-	CO3--	Cl-	SO4--	Ca++	Mg++	Na+	K+	pH
1	2	3	4	5	6	7	8	9	10	11
Drain 5	7,66	0,642 10,52	0,046 1,52	0,806 22,71	3,798 79,12	0,090 4,50	0,267 22,02	2,003 87,10	0,010 0,25	7,8
Drain 6	4,12	0,459 7,52	0,012 0,40	0,442 12,44	1,974 41,13	0,090 4,50	0,187 15,40	0,952 41,40	0,008 0,20	7,9
Drain 7	2,01	0,586 9,60	0,009 0,30	0,400 11,27	0,423 8,82	0,036 1,80	0,106 8,72	0,442 19,22	0,010 0,25	7,8
Drain 8	1,65	0,292 4,64	- -	0,412 11,60	0,422 8,79	0,058 2,90	0,054 4,44	0,403 17,54	0,006 0,15	7,8
Plot 1	1,42 1,75	0,566 9,28	traces	0,068 1,91	0,600 12,50	0,050 2,50	0,027 2,22	0,432 18,80	0,007 0,17	7,8
Plot 2	1,63 3,42	0,856 14,04	0,029 0,97	0,179 5,04	1,320 27,49	0,060 3,00	0,055 4,52	0,916 39,82	0,008 0,20	8,2
Plot 3	1,57 3,08	0,913 14,96	0,037 1,24	0,193 5,44	0,996 20,75	0,030 1,50	0,034 2,78	0,871 37,86	0,010 0,25	8,1
Plot 4	1,57 4,34	0,891 14,60	0,010 0,33	0,116 3,27	1,992 41,49	0,050 2,50	0,037 3,04	1,242 54,00	0,006 0,15	
Plot 5	1,80 2,01	0,590 9,68	traces	0,400 11,27	0,423 8,82	0,017 0,85	0,106 8,72	0,459 19,95	0,010 0,25	

Table 4. Classification of irrigation and drainage waters according to their suitability for irrigation at Tasotkel massif.

Sourse of diversion unit	Mineralization, g/l	pH	Evalution of quality					
			Irrigation coefficient	SAR coefficient	According to Boldyrev	Degree of suitability	Hazard	
							Salinization	Alkalinization
Supply ditch	0,60	8,3	39,8	4,5	I-1	suitable	low	very low
Drain 1	1,08	7,8	13,8	12,3	I-2	suitable	low	very low
Drain 2	1,31	8,1	11,4	13,3	II-2	limited suitability	low	low
Drain 3	1,83	7,7	4,5	25,6	II-3	Limited suitability	moderate	low
Drain 4	3,32	7,6	3,0	27,9	III-4	agreed suitability	moderate	high
Drain 5	7,66	7,8	1,4		IV-4	useless	high	high
Drain 6	4,12	7,9	3,4	34,0	II-4	limited suitability	high	low

Table 5. Main indices of soil chemical properties of fluvial terraceabove flood-plain.

Soils	Calculation layer, cm	Humus, %	saCO3, %	Absorved bases mg-eq per 100 g soil					
				Ca	Mg	Na	Total sum	K_2O	P_2O_5
Meadow nonsaline	0-30	1,65	6,15	8,93	3,78	0,18	12,89	409	4,4
	30-50	0,71	12,31	8,17	4,14	0,26	12,57	390	3,1
Meadow solonchakous	0-30	0,62	13,36	7,50	3,80	0,50	11,80	310	17,7
	30-50	0,28	15,50	6,45	4,52	0,43	11,39	402	-
Sierozemic-meadow nonsaline	0-30	1,52	6,61	8,34	2,36	0,14	10,84	395	12,1
	30-50	1,02	4,74	8,04	1,12	0,30	9,46	520	2,5
Sierozemic-meadow solonchakous	0-30	1,12	8,2	5,70	1,90	0,35	7,95	863	9,7
	30-50	0,78	10,9	6,00	2,20	0,42	9,62	843	8,1
Sierozemic-meadow weakly solonetzic solonchakous	0-30	1,41	11,97	5,35	2,85	0,85	9,05	328	13,6
	30-50	0,48	12,45	3,84	2,62	0,94	7,40	140	9,0
Sierozemic-meadow	0-30	0,92	8,85	4,65	1,65	0,90	7,20	311	20,5
	30-50	0,40	13,54	2,05	2,15	2,10	6,30	134	8,1
Meadow-sierozemic nonsaline	0-30	1,02	6,27	4,40	2,56	0,31	7,27	294	14,8
	30-50	0,46	7,67	4,23	4,64	0,40	9,27	280	11,5
Meadow-sierozemic solonchakous	0-30	0,62	5,70	8,40	3,90	0,64	12,94	604	22,0
	30-50	0,45	8,47	9,10	3,55	0,50	13,54	328	10,2
Meadow-sierozemic	0-30	0,46	8,94	3,97	1,80	0,32	6,09	489	12,1
	30-50	0,43	9,23	2,23	3,23	0,30	5,76	575	9,0
Meadow-sierozemic moderately solonetzic-solonchakous	0-30	0,91	8,89	4,63	2,10	0,90	7,63	515	14,0
	30-50	0,52	11,5	3,60	3,56	2,48	9,64	388	9,5

Table 6. Chemical properties of soils at experimental site of Tasotkel irrigation massif.

Calculation cm	Humus %	Humus t/ha	Absorbed bases mg/equ per 100g soil / % from the total sum: Ca	Mg	Na	K	total sum	Salinization by water cytradion: Storage of water soluble salts t/ha	Degree of salinization meq/equ	$CaCO_3$ t/ha	$CaSO_4$ $2H_2O$ t/ha
Site I. Meadow-solonetzic, sodic saline											
0-20	0,57	17,8	5,5	2,0	1,8	0,6	9,9	8,1	3,0	363	3,7
			55,5	20,2	18,2	6,1					
0-60	0,50	45,2	3,5	1,3	3,1	0,5	8,4	20,5	3,0	1080	8,5
			41,6	15,5	36,9	6,0					
0-100			3,1	1,2	2,4	0,5	7,2	33,0	3,0	1798	13,3
			43,1	16,7	33,3	6,9					
Site II. Sierozemic-meadow solonetzic											
0-20	1,75	47,6	2,7	2,3	4,2	0,8	10,0	3,1	0,5	21,5	2,6
			27,0	23,0	42,0	8,0					
0-60	0,80	96,8	2,5	3,2	3,5	0,6	9,8	18,6	1,7	1305	12,3
			25,6	32,6	35,7	6,1					
0-100			2,4	3,4	3,4	0,5	9,7	32,8	2,3	1979	30,7
Site III. Meadow-sierozemic weakly saline.											
0-20	0,82	25,4	3,5	4,0	0,3	0,5	8,3	4,3	0,5	216	5,5
			42,2	48,2	3,6	6,0					
0-60	0,31	48,4	2,2	4,6	0,4	0,4	7,6	11,1	0,7	719	18,1
			28,9	60,5	5,3						
0-100			1,9	4,8	0,5	0,3	7,5	17,9	1,0	1323	29,8
			25,4	64,0	6,6	4,0					

Table 7. Physico-mechanical characteristics of soils at the experimental site of Tasotkel irrigation massif.

Calculation cm	Hygroscopicity, %	Mg, %	Granulometric/microaggregated composition: Content of fractions (mm) in % for abs.dry soil: sand 1-0,25	sand 0,25-0,05	dust 0,05-0,01	dust 0,01-0,005	dust 0,005-0,001	silt / 0,001	physical clay / 0,01	Factor: Dispersion	Structure	Degree of aggregation
Site I. Meadow solonetzes, sodic saline												
0-30	1,0	2,77	0,1	42,6	26,5	6,7	8,1	16,0	30,8	-	46,9	23,5
			0,1	55,7	20,8	5,4	9,5	8,5	23,4	53,1		
30-50	0,8	2,21	0,1	33,8	21,6	3,2	7,8	13,5	24,5	-	28,9	44,3
			0,1	60,6	20,3	1,6	7,8	9,6	19,0	-		
Site II. Sierozemic-meadow solonetzic												
0-30	1,2	3,12	-	47,0	25,5	6,6	6,2	14,7	27,5	-	87,8	21,3
				60,2	27,5	4,8	5,7	1,8	12,3	12,2		
30-50	1,0	3,00	-	48,5	18,5	5,7	5,4	21,9	33,0	-	70,3	
				44,7	29,9	5,9	13,0	6,5	25,4	29,7		
Site III. Meadow-sierozemic soils												
0-30	1,2	3,08	0,1	38,5	29,6	5,5	12,1	14,2	31,8	-	93,7	27,1
			0,1	52,7	32,3	6,8	7,0	0,9	14,7	6,3		
30-50	1,2	3,16	0,1	38,5	24,7	3,5	9,9	23,3	36,7	-	59,2	14,2
			0,1	44,9	24,2	6,9	14,4	9,3	30,8	40,8		

Appendix 5

Ministry of Science - Academy of Sciences Republic Kazakhstan
Institute of Soil Science after U.U.Uspanov

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REPORT

on

Water salinity and seeds pretreatments effects on soil physical properties and maize yield in the Tasotkel massif irrigation area

By

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Introduction

In the South of Kazakhstan where irrigation agriculture is developed, deficit of irrigation water with good quality forces the use of underground and drainage-waste waters. Kazakhstan possesses a large reservoir of ground waters, which can be devided according to the level of mineralization: up to 1 $g.l^{-1}$ - 1130; 3 $g.l^{-1}$ - 427.3; from 3 to 5 $g.l^{-1}$-72.2 m^3/sec.

Current total volume of drainage-waste waters in Central Asia achieves 32-33 km^3/year, 20.3 km^3 of contaminated waters are thrown down to the rivers, and 12.4 km^3 are drained to natural depressions and inclinations (E.M.Chembarov, 1990).

Recently in some rivers, in Syrdarya for example, mineralization of water raised as a result of increased downthrow of collector-drainage waters (up to 1.5 $g.l^{-1}$). The lands irrigated by such water aren't refered to the category of irrigated mineralized waters for the present, though irrigation water, containing more than 1 $g.l^{-1}$ of salts should be refered to weakly mineralized one. From this point of view, a large area of lands in our republic are irrigated by waters with high mineralization.

Necessity in additional resources of irrigation from one side, increase of water quantity with different mineralization and water chemizm and progressing water salinization in rivers from other side requires to conduct research work on their use for irrigation. Specific soil processes occure under irrigation by mineralised waters, the coarse of which depends on water and soil chemizm, regime of irrigation, drainage and waterpermeability of soilground. The problems of soils' protection from harmful processes which decrease their fertility became especially actual.

First of all this is a real estimation and prognosis of negative effect caused by mineralized water on soil processes and yielding ability of cultivated crops. Indices for ameliorative estimation of irrigation water and requirements for soil-amelirative conditions where irrigation is performed are necessary for preventing of soil deterioration under irrigation by highly mineralised water. Our researches within the project, conducted together with the Israel Institute of Soil and Water, are aimed at the study of these indices and requirements.

The programme of investigations envisaged field experiments with exploitation of drainage-waste waters with different levels of salinization at Tasotkel massif of irrigation. Aims and objectives of the experiment and also characteristics of the object, description of investigation methods were given in previous reports. In this report we deal with the main results of investigations. In 1995 we were occupied with selection of a suitable object for our experiments and studied soil conditions, irrigation and drainage water. In 1996-1997 we carried out field experiments at the selected plots. In 1998 we specified the results of the investigations by repeated chemical analyses of soil samples and statistical treatment of the data.

1.Conditions of field experiments conduction.

1.1 Status of the problem at Tasotkel massif.

In irrigated fields of Tasotkel massif, levels of ground water are close to the critical , and at some places it is even higher (critical is > =2.5 m). In order to prevent the processes of soil secondary salinization, drainage is required. Thus drainage holls of vertical drainage were built here which pumped mineralized ground water and threw it down into the river Shu and it's feeder Kuragaty, increasing salt content in them.

As a result of it the problem of drainage-waste water with high mineralization use for irrigation appeared.

Mineralization of drainage (and ground)water in the zone of the river Kuragaty influence is 3.5-4.5 $g.l^{-1}$ (SAR=11-12), in the zone of the river Shu - 1.0-2.5 $g.l^{-1}$ (SAR=4.6).

Field experiments included 3 experiments with different levels of irrigation water mineralization.

Experiments N1 and N2 were conducted at one and the same plot at village Enbek, located 12 km to the West from the river bed Shu.

Experiment N3 was located at the village Sautbek, 10 km to the West from the rail way station and 15 km to the East from the river bed of Kuragaty (feeder of the river Shu).

1.2. Climatic conditions during the years of experiments conduction were as follows. Stable snow cover appeared during the last decade of November, snow melting finished during the first decade of March.Duration of vegetation period made up 219-222 days. Average month temperature of air during the hottest month July was +27.3 C and the coldest month is January - 7.1 C. The main amount of precipitation was in autumn-winter period 130-140 mm and in spring - 100-105 mm, precipitation was about 50 mm in summer.

1.3 Evaluation of drainage water quality, used in experiments for irrigation, includes 3 aspects: determination of it's toxiciy for plants, estimation of salinization ans soil alkalinization and taking into account properties of irrigated soils.

National and foreign methods for determination of soil usefulness were taken under irrigational evaluation of water quality (supplement, table). Data on salt content in water extractions were used for determination of irrigation toxicity (supplement, table 10). Total mineralization of irrigation water, prevalent anions and cations were taken into account firstly under determination of salinization hazard. The possibility of soil alkalinization is determined by content and size of alkaline and alkalineland cations' ratio and also by toxic alkalinity (HCO_3-Ca) in mg-equ.l^{-1}.

Under the ratio Na/Ca >1.0, Na/Ca+Mg>0.6 and toxic alkalinity HCO_3> 0.8 mg-equ.l^{-1}, CO_3^{-2}>0.3 mg.equ.l^{-1} irrigation water is considered to be useless for irrigation even with total low mineralization.

In experiment N1 water for irrigation was used from drainage holl of open type. Water level in the holl before irrigation (in spring) was at the depth of 2.3 m and in autumn it was at 2.8 mdepth. Water mineralization in 1996 ranged within 2 $g.l^{-1}$, in 1997 - within 1,75 - 1.91 $g.l^{-1}$.

The type of salinization is hydrocarbonate-chloride-sulphate and refers (according to Alyokhin O.A.) to the second hydrochemical type. Total alkalinity in HCO_3 in 1996 made up 10.4-12 mg.equ.l^{-1} and in1997 was 4.8-6.8 mg.equ.l^{-1}, but in return alkalinity appeared from normal carbonates (0.97 mg-equ.l^{-1}), which gradually decreased during vegetation (up to 0.17 mg-equ.l^{-1}). Transformation of Cl- and SO_4^{-2} anions is slight (supplement, table 2).

According to pH index the water is alkaline (8.4-8.9).

Content of Na+ cations for vegetation period increased in 1996 from 7.6 to 9.4 mg-equ.l^{-1} and in 1997 - from 9.76 to 15.28 mg-equ.l^{-1}. The ratio Na/Ca and Na/Ca+Mg in irrigation water was lower (0.63-1.57 and 0.36-0.46 correspondingly), than in 1997 (2.79-3.29 and 0.65-1.17 correspondingly). SAR value ranged in1996 within 2.11-2.79, and in 1997 increased to 5.0-5.9. Irrigational quality of water can be estimated as water of limited usefulness.

In experiment N2 water was pumped for irrigation from drainage holl of closed type. Water mineralization during irrigation in 1996 was 1.1-1.3 $g.l^{-1}$, in 1997 1.03-1.06 $g.l^{-}$

^{1}. The type of salinization changed from sulphate-hydrocarbonate to hydrocarbonate-sulphate. Water refers to II hydrochemical type. SAR value changed in 1996 within 2.6-3.06 and in 1997 - within 4.03-5.4. The cations ratio Na/Ca and NA/Ca+Mg was in 1996 within 0.85-1.16 and 0.43-0.60, in 1997 within 1.85-2.90 and 1.11-1.59 correspondingly (supplement 2). By all the indices water is considered to be useful for irrigation though pH (8.2-8.5) is alkaline.

In experiment N3 irrigation water was pumped from drainage holl of closed type, where mineralization ranged in 1996 within 4.4-4.5 $g.l^{-1}$ and in 1997 within 4.24-4.59 $g.l^{-1}$.

The type of salinization in spring is hydrocarbonate-chloride-sulphate, in summer and autumn - chloride-hydrocarbonate-sulphate. According to Alyokhin O.A. classification, the water refers to II hydrochemical type and irrigational coefficient according to Priklonskiy is equal to 9.5. By this index it is of limited usefulness. According to pH (8.7-9.1) the water is highly alkaline. Total alkalinity in HCO_3 in 1996 was high (20-23 $mg\text{-}equ.l^{-1}$), in 1997 spring it made up 9.2 $mg\text{-}equ.l^{-1}$ and gradually increased, and achieved 18 $mg\text{-}equ.l^{-1}$ in autumn. Alkalinity from normal carbonates in CO_3^{-2} in 1996 was not observed, in spring 1997 it made up 1.27 $mg\text{-}equ.l^{-1}$ and it gradually decreased to autumn up to 0.17 $mg\text{-}equ.l^{-1}$. Sulphates (SO_4^{-2} from 26.2 to 41.7 $mg\text{-}equ.l^{-1}$) prevail among anions, among cations - Na (Na+ from 32.6 to 43.8 $mg\text{-}equ.l^{-1}$). A small decrease of sulphate content and increase of Na cations were observed during water pumping. The ratio Na/Ca was within 15.6-13.3, the ratio Na/Ca+Mg was within 1.6-1.5. SAR of irrigation water changed for vegetation period in 1997 from 14.28 to 8.27, and in 1997 - from 11.1 to 11.57 (supplement,table 2). According to complex estimation of irrigational quality of water is not useful as a whole, salinization and alkalinization of soils are possible (supplement,table 3.1).

Chemical analysis of irrigation water showed that it's mineralization during the vegetation period isn't constant and there is a tendency of it's increase from spring to autumn. Total mineralization of water from drainage holls in 1997 slightly decreased (by0.1-0.2 $g.l^{-1}$), and essential changes took place in ionic composition. In water of all three holls alkalinity from normal carbonates in $CO_3^{-2}$was observed, anions content SO_4^{-2} and cations content Na+ increased, cations content K+ increased in experiment N3.

For irrigated soils it is valuable to determine hydrophysical indices, which show available and unavailable moisture volumes for plants in soil. Optimal irrigational rates are calculated by them. In our experiments unavailable moisture volume for plants makes up in a meter layer 551-674 m^3/ha, maximum productive moisture is about 1800 m^3/ha, maximum moisture that desolves salts (after irrigation) - is about 2000 m^3/ha. Water permeability of soils makes up in experiment N1 - 0.61, in experiment N2 - 0.67, in experiment N3 - 0.56 mm/min (supplement, table 8).

Density of soil solid phase makes up in upper horizons 2.55-2.87 g/cm^3, in low horizons - 2.65-2.88 g/cm^3. Density of soil structure in upper horizons changes from 1.20 to 1.36 g/cm^3 and depends on soil tillage and irrigation. Density of soil structure in low horizons changes slightly (1.40-1.54 g/cm^3).

Content of watersoluble salts is low according to the data of water extraction. In experiment N1 and N2 the sum of salts doesn't exceed 0.067%, in experiment N3 up to 1 m - 0.07- 0.087%, deeper than 1 m - 0.126-0.178%. The type of salinization in upper horizons is mainly sulphate-hydrocarbonate, in low horizons sometimes it changes to hydrocarbonate-sulphate or chloride-sulphate one (supplement, table 10).

Ground water was deposited in experiment N1 at 170 cm depth with the sum of salts 1.98 $g.l^{-1}$ of hydrocarbonate-sulphate type, in experiment N2 - at 165 cm depth with the sum of salts 1.34 $g.l^{-1}$ of hydrocarbonate-sulphate type, in experiment N3 - at 150 cm depth with the sum of salts 7.5 $g.l^{-1}$ of hydrocarbonate-chloride-sulphate type of salinization (supplement, table 13).

According to pH index (8-9) soils are alkaline. Effervescence is from 10% solution HCl from the surface. According to calcit content the soils are high carbonate. Calcit content up to the 30 cm depth is within 7-9%, and it increases with depth up to 14-16%.

Gypsum content is low and in experiments N1 and N2 it is within 0.07-0.12%, and in experiment N3 - 0.15-0.17% (supplement, table 10).

In composition of the absorbed bases, before the experiments the sum of Ca and Mg made up 80-90%, Na quota made up 7-8%, K quota in experiments N1 and N2 made up 2-3%, and in experiment N3 - 9-11% . Absorbing capacity in experiments N1 and N2 was within 9.3-10.7, and in experiment N3 - 10.5-13.5 mg-equ per 100 g of soil (supplement, table 14).

The fertility level of sierosemic-meadow soils is mean. Thickness of humus horizon is 35-40 cm. Humus content in soils of experiment N1 and N2 in arable layer (0-20 cm) is 1.01-1.39 %, and in subarable horizon it is two times smaller, the content of available nitrogen mobile forms for plants (56-70 mg per 100 g of soil) is evaluated as satisfactory. Content of phosphorus (P_2O_5 13-20 mg per 1000 g of soil) is low, content of K (K_2O more than 300 mg per 1000 g of soil) - high (supplement, table 15).

In experiment N3 humus content (2.53-4.43%) and mobile forms of macroelements is high, as large rates of manure were applied here earlier (40t/ha).

1.4.Soil conditions of experiments

Soil experiments are located on the fluvial terrace above flood plain of the river Shu, where meadow-sierozemic soils with different levels of salinization are forming. The soils used in experiments have small differences according to granulometric composition.

Granulometric composition (supplement,table 5) of upper horizons is moderately loamy, prevailing fraction is fine sand (0.25-0.05), the second place is occupied by coarse silt (0.05-0.01). Horisons located below are represented by moderate loams, where also fractions of fine sand and coarse silt prevail. Fractions 0.25-0.01 (77-86%) prevail in microaggregate composition of these soils. (supplement, table 6). Data ratio of granulometric and microaggregate compositions (table 2 and 3) will permit to judge about the potential ability of soils to aggregation, about the status of plasma and waterstability of soil structures (supplement, table 7).

Coefficient of dispersion (Cd) N.A.Kachinskiy called the percentage ratio of silt content, received under microaggregate analysis (Sm), to it's content under granulometric one (Sg):

$$Cd = \frac{Sm}{Sg} \cdot 100\% \qquad S \text{ - silt}$$

Coefficient of dispersion serves as an indirect index of plasma ability to formate waterstable aggregates. The higher is Cd, the less is waterstability of micro- and macroaggregates and lower soil ability to aggregation. In our experiment Cd was lower in experiment N2 and higher in experiment N1 and N3.

Coefficient of structure condition (Cs) according to Fageler has the formula:

75

$$Cs=\frac{(Sg-Sm)}{Sg} \cdot 100\%$$

Cs in experiment N2 is higher than in experiments N1 and N3.
With the same aim Bevert and Roades suggested to determine coefficient of aggregation level (Ca), where the content of fractions >0.05 mm under microaggregate (Sm) and granulometric (Sg) analyses is used.

$$Ca=\frac{Sm-Sg}{Sm} \cdot 100\%$$ S - sand

In our experiments aggregation level is higher in humus horizons in experiment N1 and N2 (22.2-22.7), and in experiment N3 in upper 0-10 cm soil layer (25.9), where manure (40t/ha) was applied.
A.F.Vadyunina suggested to use granulometric index of structure condition(Cg) for estimation of potential ability of soil to aggregation only by results of granulometric composition.

$$Cg=\frac{S}{FS+MS+CS} \cdot 100\%$$

Where S - silt, FS - fine silt, MS - moderate silt, CS - coarse silt.
This index was higher in experiment N1 and N2, than in experiment N3.
Data estimation of granulometric and microaggregate analyses showed that raising of irrigation water mineralization leads to increase of dispersion and decrease of structural aggregates (supplement, table 7).

1.5 Scheme of experiments

Experiments were different only by mineralization of irrigation water and consisted of 3 variants:
Variant 1. Control without seeds treatment.
Variant 2. Preseeding treatment of seeds by 0.01-0.1% solutions of humates.
Variant 3. Preseeding treatment of seeds by 1.0% solution of Zn sulphate. 3-fold repetitions of experiments. The area of a plot is 10 m^2. Shelter border between the plots is 0.300.4 m. Maize is a cultivated crop.
In order to increase salt resistance and germenation ability, seed were treated by humate and Zn sulphate solutions before seeding.
For the first year maize -Kazakhstanskiy 40 was used. In variant 2 the seeds were treated by 0.1% solution of Na humate with further laying for 5 days. In variant 3 the seeds were treated by 1.0% of Zn sulphate solution with further laying for 8 days.
For the second year maize - Yugoslavian hybrid LPSC 599 was used. In variant 2 the seeds were treated by 0.01% solution of HA:VEE (ratio 10:1)
HA - humic acid
VEE - Vinil ether ethanolamin.
The time of maciration is 30 minutes, time of laying is 5 days.
In variant 3 the seeds were treated by $ZnSO_4$ solution, time of maceration is 30 minutes, time of laying 7 days.
Besides leaf surface of plants was sprayed by the same solutions before the phase of ear emergence in variants 2 and 3.
Before experiments establishment (in 1995), manure (10 t/ha) was applied in experiment N1, manure wasn't applied in experiment N2, in experiment N3 manure (40t/ha) was used.

1.6. Regime of irrigation

Water from drainage holls was pumped to distributor, irrigation was executed by flooding along furrows. Vegetational irrigations were held in 15-20 days as far as drying of arable horizon of soil achieved 60-7O% from the maximum moisture capacity. Irrigation rate made up 700-600 m^3/ha at the beginning and middle of vegetation, and at the end of vegetation it decreased to 500-600 m^3/ha. During the vegetation period there were 6 irrigations. Irrigation rate made up 4500-4600m^3/ha in 1996, in 1997 - 4600-4900 m^3/ha.

2. Results of investigations

2.1. Experiment N1

Mineralization of irrigation water ranged within 2.04-2.06 $g.l^{-1}$ in 1996, in 1997 - within 1.75-1.91 $g.l^{-1}$, the type of salinization is hydrocarbonate-sulphate and hydrocarbonate-chloride-sulphate. Total alkalinity in HCO_3 decreased from 12 to 10 mg-equ under intensive pumping of water from drainage holls (first year), but at the same time alkalinity from normal carbonates in CO_3^{-2} appeared. From spring to autumn 1997 total alkalinity gradually increased (from 4.8 to 6.8 mg-equ), and alkalinity from normal carbonates decreased (from 0.97 to 0.17 mg-equ). If in the first year the content of cations Na+ began to decrease from 9.4 to 7.0 mg-equ.l^{-1} in irrigation water during vegetational period, so in the second year it quickly increased from 9.76 mg-equ.l^{-1} in spring to 15.28 mg-equ.l^{-1} in autumn. The ratio Na/Ca was within 2.8-3.3, the ratio Na/Ca+Mg was within 0.6-1.2. SAR of irrigation water in 1996 didn't exceed 3, and in 1997 it increased from 3.56 to 5.97. Irrigation rate made up in 1996 - 4500 and in 1997 - 4600 m^3/ha.

Salt intake into soil from irrigation water was in 1996 - 9.178, in 1997 - 8.311 per 1 ha. (Supplement, table 4). Intake of alkaline anions (HCO_3+CO_3) exceeds intake of Ca cations, it leads to increase of alkaline salts in soil, in part of -$NaHCO_3$ and Na_2CO_3, it causes soil alkalinization. Often irrigations resulted in washing regime of irrigation and salt intake increased ground water salinization.

Salt content in ground water increased from 1.98 to 2.29 $g.l^{-1}$. Content of watersoluble salts in soil increased, and mineralization of ground water decreased (to 1.12 g/l).

It can be explained as follows: after ceasing of irrigation and washing regime, ascending flow of moisture from ground water caused salinization of soil profile. Descending flows of moisture under vegetational irrigations in 1997 decreased again the content of watersoluble salts in soil and their balance for this year was negative along the whole profile, and mineralization of ground water became higher. But the salt balance for two years was positive in all calculated layers. (Supplement, table 11). In a meter layer of soil the salt content increased by 2, and in a meter and a half layer - by 3 t/ha.Among anions HCO_3- prevails, among cations - Na+. For the first year in composition of the absorbed bases essential changes were not observed. For the second year in all variants of the experiment, replacement of the absorbed K and partially Mg for Na took place, i.e. the process of soil alkalinization is going on.By the autumn of 1997 the part of the absorbed Na in soil made up 16.9-18.9% from the sum of the absorbed bases (supplement, table 14). Alkalinization is going on due to Na bicarbonates and carbonates under washing regime of irrigation. In 1998 irrigation by the water from the river Shu, mineralization of which made up 0.32 $g.l^{-1}$ (SAR=1.06) caused decrease of the absorbed Na portion to 6.8-13.3% from the sum of the absorbed bases (supplement, table 14).

Density of soil structure during vegetation increased in upper layer 0....30 cm from 1.22 in spring to 1.48 in autumn. Deeper than 30 cm it changed slightly and was

within 1.48-1.54. Increase of soil structure density decreased the total porosity and aeration (supplement, table 9).
In 1996 during vegetation maize was developing normally. Differences in variants of N1 experiment were not observed. The content of nutrition elements in soil was enough for receiving of mean harvest without application of fertilizers. Humus level in arable horizon is 1.05-1.39%, mobile phosphorus (P_2O_5) - 21-29, mobile K (K_2O) - 342-410, hydrolised nitrogen (N) - 64-70 mg per 1000 g of soil (supplement, table 15,16). In 1997 differences in growth of plants were visible. In variants, where the seeds before sowing were subjected to treatment by 1.0% of $ZnSO_4$ solution, seedlings appeared earlier and the plants developed more quickly. The content of the main nutrition elements in comparison with the previous year changed slightly and made up in arable horizon: mobile phosphorus (P_2O_5) - 24-27, mobile potassium (K_2O) - 368-405, hydrolized nitrogen (N) - 57-61 mg per 1000 g of soil.

2.2. Experiment N2

Drainage water used for irrigation is useful for it by it's parameters. Mineralization of water for vegetation period 1996 gradually increased from 1.1 to 1.3 $g.l^{-1}$, and in 1997 from 1.03 to 1.06 $g.l^{-1}$.
The type of salinization in spring and summer was sulphate-hydrocarbonate, and in autumn became hydrocarbonate-sulphate. SAR index in 1996 ranged from 2.6 to 3.06, and in 1997 from 4.03 to 5,4. Total alkalinity for the first year made up 6.5-7.2 mg-equ/l, and for the second year became two times lower (3.2-4.1 mg-equ/l). Content of Na cations Na+ increased from 5.6 to 9.2 mg-equ/l. The ratio Na/Ca was within 2.57-2.93, the ratio Na/Ca+Mg - 1.11-1.22. Irrigation rate for each year was 4500 m^3.ha. For vegetation period of 1996, intake of salts from irrigation water was 9 ton per 1 ha including 0.72 t of Ca and 0.9 t of Na (supplement, table 4). Content of watersoluble salts in 0-100 cm layer of soil increased by 4 t/ha, and in 0-150 cm layer by 5 t/ha. For the first year changes in composition of the absorbed bases didn't take place. The portion of the absorbed Na made up 1.8-2.9% from the sum of the absorbed bases.
In spring 1997 the content of watersoluble salts in 0-150 cm layer of soil was larger, than in autumn of the previous year. Further washing regime of irrigation was supported by vegetational irrigations causing decrease of salinization. The salts were removed to ground waters and their nmneralization increased from 1.12 to 1.54 $g.l^{-1}$. Balance of salts in soil for 1997 was negative, but for two years as a whole it was positive (2.63 t/ha). Here $SO4^{-2}$ (0.37-0.48 mg-equ) prevails among anions, Na÷(0.2-0.23 mg-equ) among cations, but the sum of cations $Ca^{+2}+Mg^{+2}$ is two times higher than the sum of cations Na+K= (supplement, table 11).
Cations Na+ from irrigation water came into exchageable reactions with soil-absorbing complex and removed a part of Ca and Mg cations. By autumn the portion of the absorbed Na+ from the sum of the absorbed bases made up in arable horizon 12.5-17%, and in subarable horizon - 23-24%. Here the process of alkalinization goes on due to Na sulphates and Na bicarbonates. (supplement, table 12,14).
Yielding ability of maize in experiment N2 was lower, than in other experiments, as fertilizers were not applied here and the content of nutrition elements for plants was lower (supplement, table 15).
Treatment of seeds before sowing by humate and Zn sulphate solutions for the first year didn't give any effect, and for the second year it gave the following effect: in variant 2 - 27, in variant 3 - 11.5 c/ha (supplement, table 17).
In 1998 vegetables were cultivated on this area and irrigation was performed by river water, mineralization of which was 0.324 $g.l^{-1}$. Analyses of soil samples showed

decrease of the absorbed Na from the sum of the absorbed bases in arable horizon to 6.5-7.0%, and in subarable horizon to 9.5-12.5% (supplement, table 14).

2.3. Experiment N3

Earlier this plot wasn't used for irrigation. The soil here is sierozemic-meadow, and it refers to nonsaline soils by the total content of watersoluble salts, but it is highly alkaline soil by the content of anions HCO_2 and pH index. A large quantity of manure (40t/ha) was applied previous year before the establishment of experiments, so chemical analyses showed non typical high level of humus (4.43%) and high provision of soil by nutrition elements: mobile phosphorus (P_2O_5) made up 70-130, mobile potassium (K_2O) - 1371-1641, hydrolysed nitrogen (N) - 81-98 mg per 1000 g of soil. Thus yielding ability of maize in experiment N3 was higher than in other experiments. For irrigation, water was pumped from drainage holl of closed type, mineralization of which was in 1996 within 4.4-4.45 $g.l^{-1}$ and in 1997 within 4.24-4.59 $g.l^{-1}$, the type of salinization was chloride-hydrocarbonate-sulphate. According to O.A.Alyokin irrigation water refers to II hydrochemical type, and irrigational coefficient according to Priklonskiy is 9.57.

SO_4^{-2} (26.2-41.7 mg-equ/l) prevailed among anions, among cations - Na+ (32.6-43.8 mg.equ/l). Total alkalinity in 1996 was higher (20-23 mg-equ/l) than in 1997 (9.2 mg-equ/l), in return alkalinity from normal carbonates appeared (1.27 mg-equ/l). Total alkalinity in HCO_3 began to increase in the process of irrigation from spring to autumn from 9.2 to 18 mg-equ/l, and alkalinity from normal carbonates in CO_3^{-2} began to decrease from 1.27 to 0.17 mg-equ/l.

Irrigation rate made up for 1996 - 4600 and for 1997 - 4900 $m^3.ha^{-1}$. For 1997 salt intake into the soil from irrigation water was 2 2039.6 per 1 m (20.396 t/ha), including HCO_3 - 611.4; Cl - 201.3; SO_4 - 646.5; Ca - 90; Mg - 53.7; Na - 403.8 g.

Washing regime of irrigation caused salt removal from soil profile into ground water. Mineralization of ground water increased from 7.5 to 8.2 $g.l^{-1}$. In a meter layer of soil salt increase made up 1.67 t/ha, deeper than 1 meter salt balance was negative. In composition of the absorbed bases for the first year of the experiment essential changes were not observed.

After ceasing of irrigation and washing regime of irrigation ascending flows of moisture prevailed. The salts from closely depositing (150-160 cm) ground water moved through soil profile to the surface. In spring 1997 the salt content in soil was two times higher than in autumn 1996, and ground water mineralization was two times lower (4.157 $g.l^{-1}$) (supplement, table 10,13).

After deep loosening and corrugation, sowing of maize seeds was performed (19.05.97). Seedlings in variant 1 appeared on 7-8 day, in variant 2 and 3 - in 5-6 days after sowing. Salt intake into soil from irrigation water for vegetation period was 21.115 t/ha, including the sums of alkaline anions HCO_3+CO_3-3.548; cations Ca - 0.25; cations Na - 4.438 t/ha (supplement, table 4).

The salts were gradually removing from soil profile into ground water when irrigations resumed. Mineralization of ground water increased from 4.1 to 4.4 $g.l^{-1}$. Calculation of

the balance for the averageweighed content of ions shows that sulphates mainly were removed from soil into ground water (supplement, table 12). The content of sulphate-ions in ground water increased from 7.76 in spring to 34.47 mg-equ.l^{-1} in autumn. (supplement, table 13). About 6 t/ha of salts were removed from a meter layer of soil for the vegetation period in 1997, and about 8 t/ha of salts from a meter and a half

layer. As whole for two years salt balance in a meter layer is positive (÷6.38 t/ha), lower than 1 meter it is negative (supplement,table 11).

For two years of irrigation by mineralization water the total sum of salts didn't reach the threshold of toxicity, but increase of total alkalinity and appearance of alkalinity from normal carbonates, increase of pH (8.9-9.1) values, speak about the increase of toxic salts.

Irrigation by mineralised drainage waters of hydrocarbonate-sulphate type of salinization where the salts $NaHCO_3$ and Na_2SO_4 dominate and gypsum is practically absent led to intensive alkalinization of soil along the whole profile on the second year. If in spring before the beginnig of irrigation the content of the absorbed Na÷ from the sum of the absorbed bases made up from 2 to 6.7% along the profile, in autumn after ceasing of irrigation it was within 19.8-35.9% (supplement, table 14). Cations Ca^{+2} were removed by cations Na+ from soil-absorbing complex to greater degree and cations Mg^{+2} to the smaller degree. Under washing regime of irrigation the products of exchangeable reactions were removed to the depth of soil profile and into ground water. PH volumes of soil profile and ground waters increased to 9.0-9.2. In the upper arable horizon the process of illuviation and formation of firm horizon began. Compactness of soil structure increased to 1.49 $g.cm^{-3}$, waterpermeability decreased to 56 mm/min.

The process of alkalinization, for the first time , goes on due to Na bicarbonates, it is observed from the sharp increase of medium pH values.

As the intensity of alkalinization process increased from spring to autumn, it didn't greatly influenced on yield formation. Average yielding ability in variants of experiments ranged from 52.7 to 68.7 c/ha.

Treatment of seeds by 0.01% solution of HA:VEE gave yield gain relative to control 12.3 c/ha, treatment of seeds by 1.0% of sulphate zink solution - 16 c/ha. But the mass of the formed corn-cobs was different and ranged from 300 to 1.5 kg. Those crops that undergone toxic influence of salts had small corn-cobs.

In 1998 vegetables were cultivated at this plot and irrigation was performed by the water from the channel, mineralization of which made up 0.567 $g.l^{-1}$ (SAR = 1.42, hydrocarbonate-sulphate type of salinization).At the end of vegetatation decrease of the absorbed Na by two times was observed in comparison with autumn of the previous year. (Supplement, table 14).

3. Discussion of the results.

Researches showed that mineralization of the drainage (and ground) waters depends on the location of the dtainage holls. In the zone of the river Shu influence, mineralization ranges within 1.0-2.5 $g.l^{-1}$ (SAR = 4-6) and in the zone of the river Kuragaty influence - 3.5-4.5 $g.l^{-1}$ (SAR = 11.5). Prevailing type of salinization of drainage water is chloride-hydrocarbonate-sulphate, SO_4^{-2} prevails among anions, Na^+ prevails among cations. In drainage water, used for our experiments for irrigation content of Na^+ ions was more than Ca^+ ions in experiment N1 - by 2.8-3.3 times, in experiment N2 - by 2.6-2.9 times, in experiment N3 - by 13.3-15.6 times. Ground waters are located closely to the surface (1.6-1.8 m) and influence on soil processes. Typical pecularity of sierozemic-meadow soils used in our experiments is high content of carbonates beginning from the surface (5.5-20%) and low content of gypsum (0.03-0.1%), high alkalinity of soil solution (pH=8-9) and weak humus level (1.1-1.3%).

In experiment N1 where drainage water with mineralization 1.7-2.0 $g.l^{-1}$ (SAR=3.5-5) was used for irrigation, the content of soil calcit ($CaCO_3$) in arable horizon makes

80

up 8-9%, maximum of calcit is located at the depth 50-100 cm - 18%. Gypsum content along the profile ranges within 0.021-0.082% with minimum in upper horizons (supplement, table 10).

Before establishment of experiments (in autumn 1995) 10 $t.ha^{-1}$ of manure was incorporated here, further it promoted increase of humus level by 0.2-0.3% and the main nutrition elements for crops by 1.5-2 times.

In experiment N2, where irrigation was performed by drainage waters with mineralization 0.9-1.1 $g.l^{-1}$, organic and mineral fertilizers were not used. Before experiments this plot was intensively used for cultivation of vegetables, thus humus and nutrition elements content was the lowest, it influenced on yielding ability of maize.

In experiment N3, where drainage waters with mineralization 4.2-4.5 g.l-1 were used, the highest doze of manure - 40 t/ha (autumn 1995) was applied before establishment of the experiments.

Humus level, determined by total carbon analysis (method of Tyurin), made up in arable horizon (1996) 2.5-4.4%, in 1997 it decreased by 2.3-3.5%. Content of nitrogen and phosphorus mobile forms increased by 2-2.5 times, and potassium - by 4-5 times. Thus in experiment N3, despite the high mineralization of irrigation water, yielding ability of maize was higher than at other plots as the salt content in soil didn't reach the threshold of toxicity under the washing regime of irrigation.Content of humus and mobile nutrition elements sharply decreases after 2 years (supplement, table 15). Decomposition of organic matter leads to enriching of soil solution by carbonic acid promoting dissolubility of soil calcit according to the scheme:

1. $CO_2 + H_2O = 2H^+ + CO_3^{-2}$
2. $CaCO_3$ (solid state) $+ 2H^+ + CO_3^{-2} = Ca^{+2} + 2HCO_3^-$

In our experiments, analysis of water extraction shows that in experiment N2 where manure wasn't applied, the values of HCO_3^- ions are less than in other experiments and changed from 0.36 to 0.66 mg-equ in experiment N1 with application of 10 t/ha manure in soil. The values of HCO_3^- ions are a little bit higher - 0.42-0.72 mg-equ, in experiment N3 with application of 40 t/ha manure in soil the content of HCO_3^- ions is higher and the values increased from 0.67 to 0.82 mg-equ per 100 g of soil (supplement, table 10 and 12).

Alkalinity occurence from normal carbonates (CO_3^{-2}) is observed between the irrigations and speaks about normal soda (Na_2CO_3) (the most toxic salt for crops) presence in soil solution. Soda appearance is possible under exchangeable reactions of soil calcit and soil-absorbing complex according to Gedroyts reaction:

$$CEC\,\}\,\overset{Na}{}\,ads + CaCO_3 \text{ --------- } CEC\}\,Ca\,ads + Na_2CO_3$$

After recurrence of irrigations, the content of CO_3^{-2} anions is gradually decreases and isn't observed in water extraction by autumn. At this time increase of becarbonate alkalinity in HCO_3^- is observed along the whole profile with maximum in upper horizons. Anions of HCO_3^- are formed under dissolution of soil calcit, and they get into soil with irrigation water. During transportation of irrigation water to the irrigation plot in summer the water becomes warmer and shifting of carbonate-calcium equilibrium is going on as dissolved carbon acid (CO_2) decreases in water. It leads to increase of water alkalinity, as carbonate-ion isolation into solution causes deficit of protones. In our experiment disturbance of equlibrium in carbonate-calcium system caused increase of pH in irrigation water to 9-9.2 (supplement, table 2).

Irrigation by mineralized waters with high alkalinity leads to increase on carbonate-ions in soil and increase of pH in soil solution.
Anions HCO_3^- in soil solution join the dominated cation of Na, which constantly increased with each irrigation. According to our calculations for two years per 1 ha Na cations intake into soil in experiment N1 - 2157 kg, in experiment N2 - 1356 kg, in experiment N3 - 8581 kg. The amount of Ca cations intake is less in experiment N1 - by 2 times (1092 kg), in experiment N2 - by 524 kg, in experiment N3 - by 8 times (1170 kg).

Under each irrigation concentration of soil solution increased and salt composition changed. Energy (rate) of soil alkalinization (intrusion of Na into CEC) is promoted either by solution concentration or it's composition and increases according to the following :

$NaCl < Na_2SO_4 < NaHCO_3 < Na_2CO_3$

Na cations from soil solution joined the exchange reactions with soil-absorbing complex, removing mainly cations Ca^{+2} and partially cations Mg^{+2} into solution.

As $NaHCO_3$ and Na_2SO_4 are the prevailing salts in soil of our experiments, exchange reactions went on in the following two ways:

1. $CEC\}Ca + 2NaHCO_3 \text{ ---- } CEC\}\underset{Na}{Na} + Ca(HCO_3)^2$

2. $CEC\}Ca + Na_2SO_4 \text{ ---- } CEC\}\underset{Na}{Na} + CaSO_4$

The products of exchange, formed under the washing regime of irrigation, removed into ground waters, thus the reaction shifted to the right. Sharp increase of anions SO_4^{-2} and cations Mg^{+2} and a slight increase of cations Ca^{+2} were observed in ground waters by the autumn whereas the content of cations Na^+ decreased (supplement, table 13).

Calculation of the salt balance (supplement, table 11) shows that the salts in soil solution coming from irrigation waters weren't accumulated, they filled up ground waters but still a small part of them delayed in soil. For two years of experiment the content of salts in a meter layer of soil increased in experiment N1 by 2.19, and in experiment N2 - 1.29 and in experiment N3 - by 6.38 t/ha. In ground waters (experiment N1) the content of anions SO_4^{-2} increased from 6.23 to 9.9 mg-equ.l^{-1}, the content of cations Ca^{+2} - from 2.0 to 3.0 mg-equ.l-1 and cations Mg^{+2} - from 1.82 to 9.86 mg-equ.l^{-1}, and cations Na^+ decreased from 9.76 to 4.5 mg-equ.l^{-1} (supplement, table 13).

The same situation is observed in experiment N2 but with smaller values. In experiment N3 irrigation was performed by more mineralized water with high content of cations Na^+ and presence of alkalinity from normal carbonates (CO_3^{-2}), so the exchange reactions here went on more intensively and in some other way. It is indicated by decrease of anions HCO_3- (from 34 to 17.5 mg-equ.l-1) by autumn in ground waters almostly by two times and cations Na^+ (from 34.1 to 18.8 mg-equ.l^{-1}) and sharp increase of anions SO_4^{-2}. Increase of cations K^+ from spring to autumn (from 1.03 to 13.8 mg-equ.l^{-1}), which is explained by soil enriching with cations K^+ under manure decomposition, is observed here in ground waters (supplement,table 13).

Determination of the absorbed bases composition showed that in 1996 the content of the absorbed Na was low as the balance of salts in soil was positive and exchange reactions of soil solution with soil-absorbing complex didn't shift to the right and the salts of Na in soil solution didn't reach critical concentration yet. In 1997 the processes of alkalinization were going on under washing regime of irrigation in all three experiments, i.e. intrusion of cations Na^+ into soil-absorbing complex. In experiment N1 the absorbed Na cations make up 21-24%, in spring they made up only 1.6-2.7% from the sum of bases.

In experiment N2 the absorbed Na^+ by autumn was in different variants from 13.2 to 2.07% from the sum of bases. The greatest value of the Na+ reached in experiment N3, where it's part from the sum of the absorbed bases increased up to 24.7-33.3% (supplement, table 14). Increase of soil alkalinity in arable horizon provided increase of absorbing capacity CEC from 11.8 -13.47 to 19.48-21.29 mg-equ per 100 g of soil (supplement, table 14).

Intensity of the washing regime of irrigation influenced on the salt balance in soil and on the content of the absorbing Na in CEC. Washing regime of irrigation by mineralized waters on sierozemic-meadow carbonate soils influences in two ways. From one side it leads to weakening of salt accumulation and negative salt balance, so it enables to use waters with higher mineralization for irrigation, from the other side - it makes exchange processes more intensive and promotes increase of soil alkalinization processes under unfavourable chemical composition of irrigation water.

Thus under irrigation by mineralized waters where among anions HCO_3- prevails, among cations Na^+ dominates, the solonetzization process is going on in carbonate soils. Under washing regime of irrigation it increases, after ceasing of washimg regime of irrigation it decreases and it goes back with increase of soil calcit solubility. Dealkalinization of soils can be achieved by substitution of mineralized water by fresh one.

4. Conclusion.

1. High alkalinity and prevailance of Na cations over Ca independently on the level of mineralization are typical for drainage waters of Tasotkel massif, it complicates their use for irrigation.
2. Washing regime of irrigation by mineralized waters removes salts into ground waters but it intensifies the process of alkalinization. A part of salts returns to soil profile with ascending moisture flows in the period between irrigations and close bedding of ground waters.
3. Irrigation by drainage waters of different mineralization with alkaline reaction (pH=8-9) inevitably leads to increase of soil alkalinity and intensive alkalinization. Their use for irrigation is possible under decrease of their alkalinity to neutral. It is possible to use drainage waters for irrigation with higher mineralization (3-4 $g.l^{-1}$) but with neutral reaction pH in sierozemic-meadow carbonate soils.
4. It is possible to get rather high yields of maize green mass and grain without damage to their quality under irrigation by mineralized drainage waters, owing to application of organic and mineral fertilizers, well-timed agrotechnical measures during 2-3 years (up to the full alkalinization of soils).
5. Preseeding treatment of seeds by 0.01% of humate solution and 1.0% solution of zink sulphate gives a positive effect under increase of salinization of soil and irrigation water.

6. Exploitation of drainage-waste waters for irrigation at Tasotkel massif requires ameliorative measures for improvement of their quality and protection from soil salinization and alkalinization.

Supplement

Table 1. Complex method for estimation of irrigational water quality.

Possible negative manifistations	Quantative indices	Conditions of exploitation	Resource
Salinization	$K1=\frac{M(mg/l).0,03x}{Ca+2 + Mg+2}$	If K1<4, the water is useful for irrigation of any soil, if K1=4 –5, the water is useful for irrigation of loamy sands, and if K1>5 – 6 - for irrigation of sandy soils.	M.F. Budanov (1956)
Sodaformation	$K2=(HCO3- + CO3-2) - (Ca+2 + Mg+2)$	If K2 <1,25 mg-equ/l water isn't considered harmful for irrigation, if K2= 1,25 - 2,5 mg-equ/l, it is useful for irrigation of asid soils, if K2>2,5 mg-equ/l, wotera isn't useful for irrigation.	Manual of Central Asia Research Institute of Crop Science and Irrigation
Natrium alkalinization	$K3=\frac{Na+ + Mg+2 \quad Ca+2}{Ca+2 + Mg+2}$	If K3 >4 alkalinization is possible for irrigation of moderate and heavy loamy soils, if K3>5-6, so alkalinization is possible for irrigation of light loams and loamy sands.	A.M. Mozhayko and etd. (1966)
Magnesium alkalinization	$K4=\frac{Mg+2 \times 100\%}{Ca+2 + Mg+2}$	Ghb K4>50% manifistation of magnezium alkalinization.	I. Sabolch (1961)
Chloride salinization	$K5=\frac{2Cl- + SO4-2}{2}$	If K5= 3-7 mg-equ/l it is possible to irrigate soils with low water permeability, if K5= 7-15 mg-eqy/l – soils with mean water permeability , if K5 =15-20 – soils with good water permeability.	Danein (USA)

Table 2. Mineralization of drainage water, used for irrigation in field experiments, in 1996-1997 and irrigation water from channel in 1998 .

Date of sampling	Ionic composition % per 1 l mg-equ								Sum of salts, g/l	pH	Type of salinization	SAR
	Alkalinity		Cl-	SO4-2	Ca+2	Mg+2	Na+	K+				
	Total in HCO3-	In CO3-2										
1	2	3	4	5	6	7	8	9	10	11	12	13
Experiment №1 V. Enbek												
7.06.96 г.	0,68 11,19	-	0,25 7,04	0,55 11,43	0,24 12,00	0,11 8,87	0,175 7,60	0,05 1,19	2,06	8,4	hydrocarbonate-sulphate	2,35
2.07.96	0,73 12,00	-	0,28 7,89	0,49 10,24	0,12 6,00	0,17 13,96	0,216 9,40	0,032 0,83	2,04	8,4	sulphate-hydrocarbonate	2,97
20.10.96	0,63 10,39	-	0,28 7,89	0,54 11,25	0,18 9,00	0,16 13,00	0,161 7,00	0,020 0,53	1,971	8,3	hydrocarbonate-sulphate	2,11
14.02.97	0,40 8,03	-	0,25 7,04	0,69 14,37	0,20 10,00	0,13 11,00	0,182 7,93	0,019 0,51	1.961	8,2	Hydrocarbonate-Sulphate	2,45

20,05.97	0,293 / 4,80	0,029 / 0,97	0,224 / 6,31	0,695 / 14,47	0,07 / 3,50	0,140 / 11,50	0,225 / 9,76	0,070 / 1,79	1,746	8,96	Hydrocarbonate-chloride-sulphate	3,56
17.07.97	0,353 / 5,78	0,010 / 0,33	0,301 / 8,48	0,637 / 13,27	0,080 / 4,00	0,118 / 9,80	0,303 / 13,16	0,035 / 0,90	1,837	8,91	Hydrocarbonate-chloride-Sulphate	5,00
29.09.97	0,417 / 6.84	0,005 / 0,17	0,369 / 10,40	0,553 / 11,53	0,10 / 5,00	0,097 / 8,10	0,351 / 15,28	0,022 / 0,56	1,914	8,89	Hydrocarbonate-chloride-Sulphate	5,97
Experiment № 2 V. Enbek.												
11.06.96	0,44 / 7,21	-	0,06 / 1,60	0,31 / 6,35	0,12 / 6,00	0,04 / 3,34	0,13 / 5,62	0,008 / 0,20	1,108	8,2	Sulphate-Hydrocarbonate	2,6
2.07.96	0,44 / 7,21	-	0,08 / 2,39	0,31 / 6,35	0,12 / 6,00	0,06 / 5,02	0,108 / 4,71	0,009 / 0,22	1,127	8,2	Sulphate-hidrocarbonate	2,09
20.10.96	0,34 / 6,51	-	0,14 / 3,94	0,42 / 8,75	0,12 / 6,00	0,06 / 5,00	0,16 / 6,96	0,009 / 0,24	1,230	8,3	Hydrocarbonate-Sulphate	3,06
14.02.97	0,44 / 7,21	-	0,11 / 3,10	0,42 / 8,75	0,16 / 8,00	0,005 / 4,00	0,158 / 6,86	0,008 / 0,20	1,418	8,3	Hydrocarbonate-csulphate	2,87
19.05.97	0,195 / 3,20	0,010 / 0,33	0,079 / 2,23	0,403 / 8,39	0,05 / 2,5	0,05 / 4,11	0,169 / 7,33	0,008 / 0,21	1,036	8,58	Hydrocarbonate-Sulphate	4.03
17.07.97	0,251 / 4,12	0,005 / 0,15	0,13 / 3,65	0,34 / 7,08	0,07 / 3,50	0,038 / 3,15	0,187 / 8,11	0,009 / 0.24	1,030	8,37	Hydrocarbonate-sulphate	4,45
20.09.97	0,273 / 4,48	-	0,193 / 5,44	0,262 / 5,45	0,10 / 5,0	0,010 / 0,82	0,214 / 9,28	0,010 / 0,27	1,062	8,14	Chloride-sulphate	5,44
Experiment № 3 V. Sautbek.												
11.06.96	1,22 / 19,99	-	0,43 / 12,11	1,48 / 30,74	0,20 / 10,00	0,11 / 8,87	1,009 / 43,87	0,004 / 0,10	4,453	8,7	Chloride-hydrocarbonate-sulphate	14,28
2.07.96	1,38 / 22,56	-	0,45 / 12,70	1,39 / 29,88	0,20 / 10,00	0,13 / 16,90	0,877 / 38,14	0,004 / 0,10	4,431	8,9	Chloride-hydrocarbonate-Sulphate	10,40
21.10.96	1,42 / 23,19	-	0,51 / 14,37	1,26 / 26,24	0,20 / 10,00	0,256 / 21,10	0,75 / 32,60	0,004 / 0,10	4,40	8,9	Cloride-hydrocarbonate-sulphate	8,27
15.02.97	1,102 / 18,06	-	0,57 / 16,06	1,92 / 36,90	0,20 / 10,00	0,27 / 22,20	0,891 / 38,74	0,003 / 0,008	4,956	9,1	Chloride-hydrocarbonate-sulphate	9,65
19.05.97	0,561 / 9,20	0,038 / 1,27	0,412 / 11,61	2,002 / 41,71	0,05 / 2,50	0,27 / 22,20	0,900 / 39,00	0,003 / 0,09	4,236	8,79	Hydrocarbonate-chloride-sulphate	11,1
18.07.97	0,810 / 13,28	0,029 / 0,97	0,425 / 11,96	1,857 / 38,69	0,05 / 2,50	0,274 / 22,80	0,909 / 39,50	0,004 / 0,10	4,358	8,86	Chloride-hydrocarbonate-Sulphate	11,57
20.09.97	1,098 / 18,00	0,005 / 0,17	0,436 / 12,28	1,764 / 36,76	0,06 / 3,00	0,29 / 23,80	0,93 / 40,3	0,004 / 0,10	4,587	8,68	Chloride-hydrocarbonate-sulphate	11,01
Irrigation water from the cannel of the v. Enbek - experiment № 1 and № 2.												
24.05.98	0,109 / 1,78	-	0,027 / 0,75	0,102 / 2,13	0,05 / 2,50	0,017 / 1,37	0,017 / 0,74	0,002 / 0,005	0,324	7,09	Hydrocarbonate-Sulphate	1,06
Irrigation water from the cannel of the v. Sautbek – experiment № 3 .												
25.05.98	0,176 / 2,89	0,005 / 0,17	0,037 / 1,05	0,20 / 4,17	0,05 / 2,50	0,04 / 3,28	0,056 / 2,42	0,003 / 0,08	0,567	8,81	Hydrocarbonate-sulphate	1,42

Table 3. Estimation of irrigation water quality of experiments

Date of sampling	Possible negative manifistations					Estimation
	Salinization K1	Sodaformation K2	Natrium alkalinization K3	Magnium alkalinization K4	Chloride salinization K5	
Experiment № 1						
7.06.1996	2.96	-	1,36	42,5	12,75	Limited useful, possible magnesium
2.07.1996	3,07	-	1,47	69,94	13,0	
20.10.1996	2,69	-	1,32	59,09	13,51	
14.02.1997	2,80	-	1,38	52,38	14,22	

20.05.1997	3,49	-	1,65	76,67	13,54	alkalinization
17.07.1997	3,99	-	1,95	71,01	15,11	
29.091997	4,38	-	2,17	61,83	16,16	
Experiment № 2						
11.06.1996	3,56	-	1,60	35,76	4,77	Useful for irrigation
02.07.1996	3.07	-	1,43	45,55	5,56	
20.10.1996	3,63	-	1,63	45,45	8,31	
14.02.1997	3,55	-	1,57	33,33	7,47	
19.05.1997	4,70	-	2,11	62,18	6,42	
17.07.1997	4,65	-	2,22	47,37	7,19	
20.09.1997	5.47	-	2,29	14,09	8,14	
Experiment № 3						
11.06.1996	7,08	1,12	3,32	47,01	27,48	For irrigation isn't useful Salinization and alcalinization are possible.
2.07.1996	4,94	-	2,38	62,8	27,64	
21.10.1996	4,24	-	2,05	67,85	27,49	
15.02.1997	4,62	-	2,20	68,94	34,51	
19.05.1997	5,15	-	2,58	89,88	32,46	
18.07.1997	5,17	–	2,56	90,12	31,3	
20.09.1997	5,14	–	2,50	88,81	30,66	

Table 4. Salt intake into soil with irrigation water per 1 ha.

Year	Water intake in m 2 per 1 ha.	Sum. of salts in t/ha	Sum of alkaline anions (HCO3- + CO3-2)		Cations Ca+2		Cations Na+	
			t/ha	kg-equ	t/ha	kg-equ	t/ha	kg-equ
1	2	3	4	5	6	7	8	9
Experiment № 1								
1996	Saturation capacity – 600	1,236	0,408	6,714	0,144	7,200	0,105	4,560
	1-st irrigation – 700	1,442	0,476	7,833	0,168	8,400	0,122	5,320
	For 2,3,4,5 irrigations - 2800	5,712	2,044	33,600	0,336	16,80	0,605	26,32
	For 6-th irrigation - 400	0,788	0,252	4,156	0,072	3,600	0,064	2,80
For 1996г.	4500	9,178	3,18	52,303	0,720	36,0	0,896	39,0
1997	1-3 irrigations - 2200	3,841	0,708	12,694	0,154	7,700	0,495	17,446
	4-5 irrigations – 1600	2,939	0,581	9,776	0,128	6,400	0,485	21,056
	6-th irrigation – 800	1,531	0,338	5,608	0,080	4,00	0,281	12,224
For 1997	4600	8,311	1,627	28,078	0,362	18,10	1,261	50,726
For 2 years	9100	17,489	4,807	80,381	1,082	54,10	2,157	89,726
Experiment № 2								
1996	Saturration capacity – 600 и +							
	1-st irrigation – 700	1,440	0,572	9,373	0,156	7,800	0,169	7,306
	2-5 irrigations– 2800	3,156	1,232	20,188	0,336	16,800	0,302	13,188

	6-th irrigations - 400	0,532	0,136	2,604	0,048	2,400	0,064	2,784
For 1996	4500	5,128	1,94	32,165	0,54	17,0	0,535	23,278
1	2	3	4	5	6	7	8	9
	Experiment № 2							
1997	1-3 irrigations – 2200	2,279	0,451	7,766	0,110	5,50	0,372	16,126
	4-5 irrigations– 1600	1,648	0,410	6,832	0,112	5,60	0,299	12,976
	6-th irrigations – 700	0,743	0,191	3,136	0,070	3,50	0,150	6,496
For 1997	4500	4,67	1,052	17,734	0,292	14.60	0,821	35,598
For 2 years	9000	9,798	2,992	49,899	0,832	41,6	1,356	58,876
	Experiment № 3							
1996	Suturation capacity – 600 and +							
	1-st irrigation – 700	5,789	1,586	25,987	0,260	13,00	1,312	57,031
	2-5 irrigations-- 2800	12,407	3,864	63,168	0,560	28,00	2,456	106,792
	6-th irrigations - 500	2,200	0,710	11,595	0,100	5,00	0,375	16,300
For 1996	4600	20,396	6,16	100,75	0,92	46,00	4,143	180,123
1997	1-4 irrigations – 2 900	12,284	1,737	30,363	0,145	7,25	2,61	113,100
	5-6 irrigations -- 1500	6,537	1,259	21,375	0,075	3,75	1,363	59,25
	7-th irrigations- 500	2,294	0,552	9,085	0,030	1,50	0,465	20,150
For 1997	4900	21,115	3,548	60,823	0,25	12,5	4,438	192,50
For 2 years	9500	41,511	9,708	161,573	1,17	58,5	8,581	372,623

Table 5. Granulometric composition of sierozemic-meadow soils in field experiments.

Depth of sampling, cm	Content of fractions (mm) in %, in absolutely - dry soil.							Classification of soils according to granulometric composition (according to Katchinskiy N.A.)
	SAND		SILT			SILT	Physical clay	
			coarse	medium	fine			
	1-0,25	0,25--0,05	0,05-0,01	0,01-0,005	0,005-0,001	< 0,001	< 0,01	
1	2	3	4	5	6	7	8	9
				Experiment № 1				
0-10	7,6	41,0	22,2	5,5	11,6	12,0	29,1	Light coarse silty-sandy loam
10-20	6,6	43,9	21,1	5,8	12,6	10,0	28,4	Light coarse silty-sandy loam
20-30	7,1	37,9	28,8	5,3	8,5	12,4	26,2	Light coarse silty-sandy loam
30-50	5,1	33,3	22,9	6,9	12,6	19,2	38,7	Medium coarse silty-sandy loam
50-75	2,3	29,5	29,8	9,0	11,8	17,6	38,4	Medium-sandy –silty loam
75-100	5,0	36,2	26,8	6,5	12,9	12,6	32,0	Medium coarse-silty-sandy loam.
100-125	1,7	32,5	32,8	4,2	14,4	14,4	33,0	Medium sandy-silty loam
125-150	1,4	51,3	25,4	5,8	6,2	9,9	21,9	Light coarse-silty-sandy loam
150-175	2,7	38,0	26,6	9,4	8,1	15,2	32,7	Medium coarse-silty-sandy loam.
				Experiment № 2				
0-10	9,1	44,8	21,3	6,1	8,5	10,2	24,8	Light coarse-silty-sandy loam
10-20	10,1	44,0	18,4	7,1	7,4	13,0	27,5	Medium coarse-silty-sandy loam
20-30	8,0	51,5	13,8	7,2	6,1	13,4	26,7	Medium coarse-silty-sandy loam
30-50	6,8	41,7	22,4	8,6	9,3	11,2	29,1	Light coarse-silty sandi loam.

50-75	7,4	32,6	25,6	10,1	11,6	12,7	34,4	Medium coarse – silty-sandy loam.
75-100	3,2	51,8	19,5	6,3	7,7	11,5	25,5	Light coarse-silty-sandy loam
100-125	2,5	34,0	31,0	7,8	10,3	14,4	32,5	Medium cjarse-silty-sandy loam
125-150	2,2	46,7	26,7	4,1	7,8	12,5	24,4	Light coarse-silty-sandy loam
15-=175	6,1	64,3	14,6	3,9	4,0	7,1	15,0	Silty loamy sand
Experiment № 3								
0-10	5,2	45,7	27,0	5,5	8,6	8,0	22,1	Light silty-sandy loam.
10-20	4,9	47,4	27,5	6,7	6,7	6,8	20,2	Light silty-sandy loam.
20-30	4,8	47,1	23,9	6,2	6,9	11,1	24,2	Light silty-sandy loam.
30-50	3,5	45,3	26,2	5,8	7,3	11,9	25,0	Light silty-sandy loam.
50-75	1,0	66,7	18,7	4,4	3,2	6,0	13,6	Silty loamy sand.
75-100	9,0	51,7	22,6	5,5	3,9	7,3	16,7	Silty loamy sand.
100-125	1,7	38,5	34,9	7,0	5,7	12,2	24,9	Medium coarse-silty-sandy loam.
125-150	9,2	32,2	17,3	10,1	12,6	18,6	41,3	Heavy silty – sandy loam.
150-175	6,0	58,9	16,4	6,1	5,7	6,9	18,7	Silty loamy sand .

Table 6. Microaggregate composition of sierozemic-meadow soils in field experiments.

Depth of sampling, cm	Content of fractions (mm) in %, in absolutely-dry soil.								
	SAND		SILT			SILT	0,25-0,01	> 0,05	<0,01
			coarse	medium	fine				
	1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	< 0,001			
1	2	3	4	5	6	7	8	9	10
Experiment № 1									
0-10	8,5	54,4	24,7	5,7	4,8	1,9	79,1	62,9	12,4
10-20	8,2	56,7	20,6	4,6	4,8	5,1	77,3	64,9	14,5
20-30	7,4	56,4	22,0	3,7	4,6	5,9	78,4	63,8	14,2
30-50	5,8	55,5	25,1	4,9	5,3	3,4	80,6	61,3	13,6
50-75	2,5	46,3	34,6	5,9	6,9	3,8	80,9	48,8	16,6
75-100	2,9	47,7	30,1	9,7	6,3	3,3	77,8	50,6	19,3
100-125	1,8	50,4	29,3	9,1	6,2	3,2	79,7	52,2	18,5
125-150	1,9	75,6	12,2	5,1	3,8	1,4	87,8	77,5	10,3
150-175	2,4	79,4	8,4	3,2	3,1	3,5	87,8	81,8	9,8
Experiment № 2									
0-10	10,0	59,6	20,1	3,2	5,5	1,6	79,7	69,6	10,3
10-20	8,1	60,6	19,7	4,8	4,4	2,4	80,3	68,7	11,6
20-30	8,3	59,5	20,6	5,0	4,9	1,7	80,1	67,8	11,6
30-50	10,5	50,3	26,6	5,8	4,9	1,9	76,9	60,8	12,6
50-75	7,2	47,6	32,7	5,1	5,3	2,1	80,3	54,8	12,5
75-100	3,3	59,6	25,5	3,5	5,5	2,6	85,1	62,9	11,6
100-125	2,4	45,7	25,5	15,3	7,7	1,0	71,2	48,1	24,0
125-150	2,2	49,3	37,2	5,1	2,8	3,4	86,5	51,5	11,3
150-175	6,2	72,9	12,8	5,1	2,0	1,0	85,7	79,1	8,1
Experiment № 3									
0-10	7,7	61,0	22,9	4,0	3,0	1,4	83,9	68,7	8,4

10-20	6,5	56,8	26,7	5,5	2,7	1,8	83,5	63,3	10,0
20-30	6,0	57,6	26,5	4,0	3,7	2,2	84,1	63,6	9,9
30-50	4,2	55,1	25,2	7,8	4,8	2,9	80,3	59,3	15,5
50-75	0,7	66,4	16,6	3,0	9,8	3,5	83,0	67,1	16,3
75-100	9,9	64,4	18,7	3,6	1,9	1,5	83,1	74,3	7,0
100-125	0,6	56,7	30,3	7,8	2,7	1,9	87,0	57,3	12,4
125-150	18,6	52,1	15,6	7,3	4,0	2,4	67,7	70,7	13,7
150-175	0,6	95,1	1,7	1,1	1,1	0,4	96,8	95,7	2,6
									coagulation

Table 7 . Data estimation of granulometric and microaggregate composition of sierozemic-meadow soils in field experiments.

Depth of sampling, cm	Factor of dispersion according to Kachinskiy N. A.	Factor of structure condition according to Fageler	Level of aggregation condition according to Bevern and Roades	Granulometric index of structure condition according to A.F. Vadyunina
Experiment № 1				
0-10	15,8	84,2	22,7	30,5
10-20	51,0	49,0	22,2	25,3
20-30	47,6	52,4	29,5	29,1
30-50	17.7	82,2	37,3	45,3
50-75	21,6	78,4	34,8	34,8
75-100	26,2	73,8	18,6	27,3
Experiment № 2				
0-10	15,7	84,3	22,6	28,4
10-20	18,5	81,5	21,2	39,5
20-30	12,7	87,3	12,2	49,4
30-50	17,0	83,0	20,2	27,8
50-75	16,5	83,4	27,0	26,8
75-100	22,6	77,4	12,6	34,3
Experiment № 3				
0-10	17,5	82,5	25,9	19,5
10-20	26,5	73,5	17,4	16,6
20-30	19,8	80,2	18,4	30,0
30-50	24,4	75,6	17,7	30,3
50-75	58,3	41,7	-	22,8
75-100	20,5	79,4	18,3	22,8

Table 8 . Hydrophysical indices of a meter soil layer in experiments.

Depth of sampling	Maximum hydroscopy		Humidity of deposition		Maximum and field capacity		Maximum productive moisture		Maximum moisture, solving salts		Water permeability from the surface mm/ min
	%	M3/ra	%	M3/ra	. %	M3/ra	%	M3/ra	%	M3/ra	
Experiment № 1											
0-10	3,16	4,1	4,23	55	16,9	218	12,67	163	13,74	177	0,61
10-20	3,13	43	4,19	58	17,3	239	13,11	181	14,17	196	

20-30	3,14	45	4,21	61	16,8	245	12,59	184	13,66	200	
30-50	3,80	114	5,09	153	17,1	513	12,01	360	13,30	399	
50-100	3,41	259	4,57	347	16,8	1277	12,23	930	13,39	1018	
0-100	-	502	-	674	-	2492	-	1818	-	1990	
Experiment № 2											
0-10	3,0	39,0	4,02	52,0	16,3	212	12,28	160	13,30	173	0,67
10-20	2,96	40,0	3,97	54,0	16,3	223	12,33	169	13,34	183	
20-30	3,67	53,0	4,92	71,0	17,0	247	12,08	176	13,33	194	
30-50	3,33	100	4,46	134	16,5	495	12,04	361	13,17	395	
50-100	3,31	253	4,44	340	16,2	1239	11,76	899	12,89	986	
0-100	-	485	-	651	-	2416	-	1765	-	1931	
Experiment № 3											
0-10	3,84	49,0	5,15	66,0	17,0	218,0	11,85	152	13,16	169	0,56
10-20	2,97	39,0	3,98	53,0	16,5	221	12,52	168	13,53	182	
20-30	2,83	41,0	3,79	56,0	16,3	238	12,51	182	13,47	197	
30-50	2,64	80,0	3,54	108	16,2	493	12,66	385	13,56	413	
50-100	2,60	200	3,48	268	16,2	1247	12,72	979	13,6	1047	
0-100	-	409	-	551	-	2417	-	1866	-	2008	

Table 9. Dynamics of density and total porosity of a meter layer in experiments .

Depth of sampling, cm	Density of solid phase, g/cm -3	Density of structure g/cm-3					Total porosity, %				
		1996		1997		1998	1996		1997		1998
		spring	autumn	spring	autumn	summer	spring	autumn	spring	autumn	summer
Experiment № 1											
0-10	2,67	1,22	1,33	1,23	1,34	1,29	54,3	50,2	53,9	49,8	51,7
10-20	2,87	1,36	1,42	1,35	1,47	1,38	52,6	50,5	53,0	48,8	51,9
20-30	2,71	1,42	1,46	1,41	1,48	1,46	47,6	46,1	48,0	45,4	46,1
30-50	2,79	1,48	1,48	1,46	1,51	1,50	46,9	46,9	47,6	45,9	46,2
50-100	2,88	1,51	1,52	1,51	1,54	1,52	47,6	47,2	47,6	46,5	47,2
Experiment № 2											
0-10	2,56	1,24	1,30	1,24	1,36	1,30	51,6	49,2	51,6	46,9	49,2
10-20	2,75	1,34	1,40	1,35	1,44	1,37	51,3	49,0	50,9	47,6	50,2
20-30	2,86	1,41	1,45	1,42	1,48	1,45	50,7	49,3	50,3	48,2	49,3
30-50	2,77	1,46	1,47	1,48	1,52	1,50	47,3	46,9	46,6	45,1	45,8
50-100	2,72	1,50	1,49	1,52	1,54	1,53	44,8	45,2	44,1	43,4	43,7
Experiment № 3											
0-10	2,55	1,20	1,29	1,27	1,36	1,28	52,9	49,4	50,2	46,7	49,8
10-20	2,76	1,32	1,40	1,33	1,49	1,34	52,2	49,3	51,8	46,0	51,4
20-30	2,65	1,44	1,46	1,45	1,49	1,46	45,7	44,9	45,3	43,8	44,9
30-50	2,68	1,52	1,52	1,53	1,54	1,52	43,3	43,3	42,9	42,5	43,3
50-100	2,70	1,53	1,53	1,54	1,55	1,54	43,3	43,3	42,6	43,0	43,0

Table 10. Salt content in sierozemic- meadow soils of field experiments.

Depth of sampling , cm	Water extraction, mg-equ per 100 g of absolutely –dry soil									PH	calcit CaCO3, %	gypsum CaSO4. 2H2O,%	Type of salinisation
	alkalinity		Cl-	SO4-2	Ca+2	Mg+2	Na+	K+	Sum of salts ,%				
	total in HCO3-	From the Rate of carbonates in CO3-2											
1	2	3	4	5	6	7	8	9	10	11	12	13	14

Experiment № 1 7.06.96 Before irrigations.													
0-10	0,39	-	0,22	0,20	0,40	0,25	0,14	0,02	0,057	8,59	8,23	0,114	S-Ch-H
10-20	0,43	-	0,22	0,25	0,40	0,33	0,12	0,01	0,061	8,55	8,89	0,073	Ch-S-H
20-30	0,43	-	0,17	0,18	0,40	0,25	0,12	0,01	0,055	8,64	7,50	0,073	Ch-S-H
30-50	0,43	-	0,31	0,25	0,50	0,33	0,14	0,02	0,067	8,64	13,34	0,125	S-Ch-H
50-75	0,43	-	0,17	0,28	0,40	0,20	0,26	0,02	0,061	8,70	14,91	0,112	S-H
75-100	0,39	-	0,22	0,22	0,40	0,25	0,16	0,02	0,057	8,67	7,36	0,089	Ch-S-H
100-125	0,31	-	0,17	0,34	0,30	0,33	0,15	0,01	0,055	-	13,00	0,184	H-S
125-150	0,28	-	0,20	0,37	0,30	0,33	0,20	0,02	0,057	-	9,89	0,152	H-S
150-175	0,36	-	0,11	0,49	0,35	0,33	0,25	0,03	0,067	-	16,78	0,139	H-S
Experiment № 1 20.10.96 After irrigations.													
0-10	0,46	-	0,16	0,23	0.40	0,24	0,17	0,03	0,61	8,85	7,20	0,042	S-H
10-20	0,43	-	0,13	0,33	0,40	0,20	0,33	0,02	0,66	8,77	7,55	0,106	S-H
20-30	0,44	-	0,13	0,32	0,37	0,24	0,26	0,02	0,065	8,78	7,55	0,081	S-H
30-50	0,55	-	0,15	0,34	0,42	0,24	0,35	0,03	0,076	8,88	12,38	0,097	S-H
50-75	0,51		0,11	0,30	0,35	0,22	0,32	0,03	0,068	9,00	17,23	0,135	S-H
75-100	0,47	-	0,13	0,31	0,35	0,30	0,24	0,02	0,065	8,85	16,37	0,080	S-H
100-125	0,47	-	0,11	0,29	0,35	0,15	0,34	0,03	0,064	-	14,17	0,092	S-H
125-150	0,47	-	0,14	0,27	0,37	0,17	0,34	0,02	0,064	-	13,42	0,108	S-H
150-175	0,42	-	0,14	0,32	0,33	0,20	0,33	0,02	0,064	-	7,64	0,040	S-H
Experiment № 1 20.05.97 Before irrigations.													
0-10	0,82	-	0,22	0,41	0,55	0,33	0,39	0,18	0,108	8,84	8,57	0,023	S-HГ
10-20	0,67	-	0,17	0,36	0,55	0,33	0,22	0,10	0,088	8,76	8,25	0,021	S-H
20-30	0,67	-	0,11	0,50	0,55	0,33	0,35	0,05	0,090	8,87	9,37	0,040	S-H
30-50	0,62	-	0,11	0,45	0,55	0,25	0,35	0,03	0,085	9,05	15,75	0,082	S-H
50-75	0,62	-	0,08	0,60	0,55	0,33	0,39	0,03	0,086	9,30	18,76	0,072	S-H
75-100	0,59	0,07	0,08	0,40	0,50	0,25	0,35	0,04	0,073	9,18	18,15	0,088	S-H
100-125	0,59	0,07	0,08	0,40	0,50	0,25	0,35	0,04	0,073	9,11	16,64	0,18	S-H
125-150	0,59	0,07	0,08	0,25	0,40	0,25	0,30	0,04	0,070	9,23	10,42	0,148	S-H
150-175	0,56	0,07	0,11	0.30	0,40	0,25	0,35	0,04	0,070	9,20	9,55	0,139	S-H
Experiment № 1 29.09.97 After irrigations.													
0-10	0,72	-	0,15	0,14	0,45	0,32	0,22	0,02	0,075	8,85	9,15	0,045	Ch-H
10-20	0,65	-	0,15	0,23	0,43	0,30	0,25	0,05	0,076	8,75	8,59	0,045	S-H
20-30	0,66	-	0,15	0,24	0,45	0,30	0,25	0,05	0,075	8,80	10,12	0,049	S-H
30-50	0,56	-	0,16	0,34	0,47	0,30	0,27	0,02	0,073	8,91	16,73	0,088	S-H
50-75	0,60	-	0,13	0,30	0,45	0,33	0,23	0,02	0,073	-	20,62	0,087	S-H
75-100	0,56	-	0,11	0,27	0,43	0,30	0,20	0,01	0,068	-	20,02	0,097	S-H
100-125	0,66	-	0,16	0,10	0,40	0,30	0,20	0,02	0,068	-	18,35	0,109	Ch-H
125-150	0,53	-	0,15	0,19	0,37	0,28	0,18	0,04	0,063	-	11,25	0,058	S-H
150-170	0,49	-	0,15	0,12	0,38	0,22	0,14	0,02	0,054	-	9,86	0,043	Ch-H
Experiment № 2 7.06.96 Before irrigations.													
0-10	0,36	-	0,20	0,35	0,60	0,20	0,10	0.01	0,061	8,60	7,52	0,060	H-S
10-20	0,36	-	0,23	0,34	0,50	0,20	0,22	0,01	0,065	8,45	7,04	0,078	H-S
20-30	0,36	-	0,22	0,44	0,40	0,33	0,28	0,01	0,069	8,60	7,52	0,084	H-S

30-50	0,36	-	0,22	0,27	0,40	0,33	0,10	0,02	0,057	8,76	8,78	0,103	S-H
50-75	0,36	-	0,22	0,44	0,35	0,33	0,33	0,01	0,069	-	11,12	0,224	H-S
75-100	0,36	-	0,08	0,53	0,40	0,39	0,17	0,01	0,067	-	16,30	0,160	H-S
100-125	0,33	-	0,11	0,40	0,40	0,33	0,10	0,01	0,057	-	16,78	0,026	H-S
125-150	0,31	-	0,11	0,27	0,25	0,20	0,22	0,02	0,048	-	10,41	0,109	S-H
150-175	0,31	-	0,10	0,25	0,20	0,10	0,34	0,02	0,048	-	7,36	0,069	S-H
Experiment № 2 20.10.96. After irrigations.													
0-10	0,59	-	0,11	0,27	0,35	0,25	0,35	0,02	0,071	9,10	7,48	0,093	S-H
10-20	0,47	-	0,12	0,28	0,45	0,25	0,15	0,02	0,089	8,93	6,45	0,053	S-H
20-30	0,47	-	0,17	0,50	0,45	0,33	0,35	0,01	0,080	8,85	6,06	0,071	H-S
30-50	1,08	-	0,12	0,47	0,40	0,33	0,92	0,02	0,163	8,99	8,96	0,090	S-H
50-75	0,59	-	0,11	0,31	0,40	0,33	0,27	0,01	0,073	9,12	12,93	0,193	S-H
75-100	0,59	-	0,08	0,28	0,35	0,33	0,26	0,01	0,070	9,10	16,96	0,159	S-H
100-125	0,51	-	0,08	0,31	0,35	0,33	0,21	0,01	0,065	-	16,66	0,060	S-H
125-150	0,51	-	0,08	0,31	0,30	0,33	0,25	0,02	0,065	-	12,90	0,082	S-H
150-175	0,43	-	0,08	0,25	0,25	0,25	0,25	0.01	0,055	-	8,25	0,079	S-H
Experiment № 2. 20.05.97 г. Before irrigations.													
0-10	0,67	0,07	0,11	0,65	0,45	0,66	0,30	0.09	0,105	9,10	7,82	0,020	S-H
10-20	0,67	0,07	0,11	0,27	0,45	0,25	0,26	0,15	0,084	9,16	8,09	0,105	S-H
20-30	0,67	0,07	0,11	0,13	0,45	0,25	0,17	0,10	0,073	9,08	7,82	0,107	S-H
30-50	0,75	-	0,11	0,04	0,45	0,16	0,26	0,03	0,069	9,22	11,44	0,100	Ch-H
50-75	0,79	0,07	0,17	0,06	0,45	0,25	0,35	0,03	0,079	9,24	14,16	0,177	Ch-H
75-100	0,79	0,07	0,17	0,24	0,55	0,33	0,35	0,03	0,090	9,20	18,40	0,158	S-H
100-125	0,69	0,07	0,20	0,55	0,55	0,33	0,48	0,04	0,092	9,00	18,40	0,028	S-H
125-150	0,63	0,06	0,20	0,47	0,55	0,33	0,43	0,04	0,093	8,88	15,80	0,100	S-H
150-175	0,59	-	0,11	0,30	0,45	0,25	0,26	0,04	0,069	9,17	9,12	0,071	S-H
Experiment № 2 29.09.97 г. After irrigations.													
0-10	0,70	-	0,13	0,14	0,42	0,35	0,17	0,03	0,072	-	8,56	0,067	S-H
10-20	0,64	-	0,15	0,10	0,40	0,30	0,17	0,02	0,067	-	8,50	0,072	Ch-H
20-30	0,64	-	0,16	0,16	0,43	0,30	0,21	0,02	0,070	-	8,70	0,044	Ch-S-H
30-50	0,58	-	0,18	0,26	0,42	0,30	0,28	0,02	0,066	-	11,04	0,087	S-H
50-75	0,60	-	0,18	0,36	0,42	0,36	0,33	0,03	0,078	-	13,53	0,090	S-H
75-100	0,58	-	0,19	0,25	0,40	0,33	0,27	0,02	0,069	-	17,87	0,101	S-H
100-125	0,58	-	0,16	0,30	0,40	0,38	0,24	0,02	0,072	-	16,53	0,100	S-H
125-150	0,52	-	0,18	0,26	0,35	0,36	0,23	0,02	0,066	-	12,93	0,092	S-H
150-175	0,44	-	0,18	0,19	0,33	0,28	0,17	0,03	0,056	-	9,70	0,073	Ch-H
Experiment № 3 7.06.96 г. Before irrigations.													
0-10	0,62	-	0,17	0,15	0,35	0,25	0,24	0,10	0,070	8,41	7,57	0,150	Ch-H
10-20	0,70	-	0,22	0,06	0,40	0,20	0,26	0,12	0,074	8,55	8,60	0,125	Ch-H
20-30	0,70	-	0,22	0,15	0,30	0,20	0,40	0,17	0,082	8,76	9,21	0,168	Ch-H
30-50	0,67	-	0,22	0,25	0,35	0,20	0,41	0,18	0,087	9,10	15,34	0,177	S-H
50-75	0,43	-	0,17	0,18	0,10	0,10	0,40	0,18	0,060	-	7,66	0,182	S-H
75-100	0,39	-	0,17	0,14	0,10	0,20	0,40	0,10	0,055	-	5,15	0,077	Ch-H

100-125	0,36	-	0,65	0,84	0,35	0,39	0,90	0,21	0,126	-	11,86	0,079	Ch-S
125-150	0,36	-	1,15	1,24	0,70	0,82	1,01	0,22	0,178	-	19,84	0,222	Ch-S
150-175	0,28	-	0,37	0,29	0,20	0,20	0,40	0,14	0,065	-	5,93	0,066	S-Ch
Experiment № 3. 21.10.96 г. After irrigations.													
0-10	0,78	-	0,18	0,14	0,45	0,36	0,19	0,10	0,082	8,73	8,27	0,114	Ch-H
10-20	0,71	-	0,12	0,23	0,42	0,29	0,22	0,13	0,081	8,93	9,07	0,145	S-H
20-30	0,72	-	0,12	0,30	0,36	0,25	0,40	0,13	0,087	9,11	9,40	0,123	S-H
30-50	0,70	-	0,11	0,35	0,37	0,20	0,45	0,14	0,079	9,28	12,27	0,093	S-H
50-75	0,68	-	0,13	0,22	0,31	0,17	0,42	0,13	0,080	9,39	9,36	0,132	S-H
75-100	0,59	-	0,13	0,25	0,30	0,23	0,33	0,11	0,073	9,41	9,31	0,115	S-H
100-125	0,58	-	0,22	0,27	0,45	0,32	0,20	0,10	0,070	-	12,36	0,134	S-H
125-150	0,51	-	0,21	0,24	0,38	0,28	0,20	0,10	0,070	-	7,23	0,090	S-H
150-175	0,47	-	0,14	0,18	0,30	0,25	0,16	0,08	0,058	-	3,78	0,090	S-H
Experiment № 3 19. 05. 97 г. Before irrigations.													
0-10	1,34	-	0,20	0,79	0,60	0,33	0,48	0,92	0,182	8,50	8,60	0,083	S-H
10-20	1,21	-	0,22	0,83	0,60	0,33	0,48	0,85	0,172	8,76	11,10	0,083	S-H
20-30	1,15	-	0,20	0,71	0,50	0,25	0,52	0,79	0,263	9,10	9,55	0,088	S-H
30-50	1,26	-	0,22	0,74	0,50	0,25	0,73	0,74	0,174	9,19	12,38	0,127	S-H
50-75	0,87	0,07	0,22	0,57	0,50	0,16	0,48	0,58	0,111	9,20	9,78	0,114	S-H
75-100	0,79	0,07	0,22	0,60	0,45	0,16	0,48	0,58	0,123	9,21	8,78	0,080	S-H
100-125	0,79	0,07	0,22	0,51	0,40	0,25	0,52	0,41	0,117	9,15	13,79	0,091	S-H
125-150	0,67	0,07	0,22	0,63	0,40	0,25	0,61	0,12	0,111	9,22	8,71	0,077	S-H
150-175	0,56	0,07	0,17	0,28	0,35	0,16	0,48	0,09	0,075	9,22	4,58	0,038	S-H
Experiment № 3 30.09.97. After irrigations.													
0-10	0,90	-	0,13	0,77	0,42	0,41	0,72	0,25	0,124	8,90	9,87	0,120	S-H
10-20	0,72	-	0,26	0,67	0,40	0,33	0,72	0,20	0,122	8,81	10,Ta83	0,145	S-H
20-30	0,69	-	0,16	0,84	0,43	0,30	0,72	0,24	0,126	8,76	10,04	0,100	H-S
30-50	0,68	-	0,17	0,68	0,45	0,30	0,63	0,15	0,113	8,77	10,33	0,118	H-S
50-75	0,55	0,07	0,20	0,62	0,33	0,22	0,48	0,41	0,109	9,05	9,58	0,042	H-S
75-100	0,44	-	0,19	0,50	0,25	0,19	0,35	0,34	0,086	9,01	7,58	0,047	H-S
100-125	0,56	-	0,15	0,50	0,35	0,25	0,37	0,24	0,091	-	11,81	0,046	S-H
125-150	0,54	0,07	0,12	0,42	0,30	0,30	0,36	0,19	0,085	-	9,57	0,090	S-H
150-175	0,40	0,07	0,10	0,28	0,23	0,19	0,28	0,15	0,056	-	5,22	0,062	S-H

Note : ch- chloride, s- sulphate, h – hydrocarbonate.

Table 11. Balance of watersoluble salts according to the water extraction data in soilgrounds under irrigation by drainage-waste waters with equal irrigation rate.

Calculated layers, cm	Time of determination, content and balance of salts, t/ha						
	1996 г		Balance for 1996	1997 г		Balance for 1997	Balance for 2 years
	spring	autumn		spring	autumn		
Experiment № 1 – mineralization of irrigation water							
in 1996 – 1,95-2,03, in 1997 – 1,75-1,91 g.l-1							
0-30	2,31	2,70	+0,39	3,79	3,29	- 0,50	+ 0,98

30-50	1,98	2,25	+0,27	2,48	2,21	- 0,27	+0,23
50-100	4,45	5,05	+0,60	6,00	5,43	- 0,57	+ 0,98
0-100	8,74	10,00	+1,26	12,27	10,93	- 1,34	+ 2,19
100-150	4,31	4,96	+0,65	5,50	5,08	-0,42	+ 0,77
0-150	13,05	14,96	+1,91	17,77	16,01	- 1,76	+ 2,96
Experiment № 2 – mineralization of irrigation water in 1996 – 1,1-1,34, in 1997 – 0,9-1,07 g/l							
0-30	2,60	3,33	+0,73	3,47	2,98	- 0,49	+ 38
30-50	1,66	4,79	+3,13	2,04	2,01	- 0,03	+ 0,35
50-100	5,10	5,33	+0,23	6,42	5,66	- 0 ,76	+ 0,56
0-100	9,36	13,45	+4,09	11,93	10,65	- 1,28	+ 1,29
100-150	3,99	4,97	+0,98	7,08	5,31	- 1,77	+ 1,32
0-150	13,35	18,42	+ 5,07	19,01	15,98	- 3,03	+ 2,63
Experiment № 3 – mineralization of irrigation water in 1996 – 4,29-4,45, in 1997 - 4,24-4,59 g.l-1.							
0-30	3,00	3,46	+ 0,46	8,41	5,38	- 3,03	+ 2,38
30-50	2,64	2,40	- 0,24	5,32	3,48	- 1,84	+ 0,84
50-100	4,40	5,85	+ 1,45	9,01	7,56	- 1,45	+ 3,16
0-100	10,04	11,71	+ 1,67	22,74	16,42	- 6,32	+ 6,38
100-150	11,93	5,81	- 6,12	8,95	6,95	- 2,00	- 4,98
0-150	21,97	17,52	- 4,45	31,69	23,37	- 8,32	+ 1,40

Table 12. Balance of average weighted content of the main ions in soils of field experiments under irrigation by mineralized drainage waters, mg-equ per 100 g of soil.

Calculated layer, cm	Initial content				Final content				Balance			
	HCO3-	SO4-2	Ca+2 + Mg+2	Na+ + K+	HCO3-	SO4-2	Ca+2 + Mg+2	Na+ + K+	HCO3-	SO4-2	Ca+2 + Mg+2	Na+ + K+
Field experiment № 1												
0-30	0,42	0,21	0,68	0,14	0,68	0,21	0,75	0,28	+ 0,26	+ 0,00	+ 0,07	+ 0,14
30-50	0,43	0,25	0,83	0,16	0,56	0,34	0,77	0,29	+ 0,13	+ 0,09	- 0,06	+ 0,13
50-100	0,41	0,25	0,62	0,23	0,58	0,30	0,76	0,23	+ 0,17	+ 0,05	+ 0,14	+ 0,00
0-100	0,42	0,24	0,68	0,19	0,61	0,28	0,76	0,26	+ 0,19	+ 0,04	+ 0,08	+ 0,07
100-150	0,30	0,36	0,63	0,19	0,60	0,15	0,66	0,22	+ 0.30	- 0,21	+ 0,03	+ 0,03
0-150	0,38	0,28	0,66	0,19	0,60	0,24	0,73	0,26	+ 0,22	- 0,04	+ 0,07	+ 0,07
Field experiment № 2												
0-30	0,36	0,37	0,74	0,21	0,66	0,13	0,77	0,21	+ 0,30	- 0,24	+ 0,03	0,00
30-50	0,36	0,27	0,73	0,12	0,58	0,26	0,72	0,30	+ 0,22	- 0,01	- 0,01	+ 0,18
50-100	0,36	0,48	0,73	0,26	0,59	0,31	0,76	0,33	+ 0,23	- 0,17	+ 0,03	+ 0,07
0-100	0,36	0,40	0,73	0,22	0,61	0,25	0,76	0,29	+ 0,25	- 0,15	+ 0,03	+ 0,07
100-150	0,32	0,33	0,59	0,17	0,55	0,28	0,75	0,26	+ 0,23	- 0,05	+ 0,16	+ 0,09
0-150	0,35	0,37	0,66	0,20	0,59	0,26	0,76	0,28	+ 0,24	- 0,11	+ 0,10	+ 0,08
Field experiment № 3												
0-30	0,67	0,12	0,57	0,43	0,77	0,76	0,76	0,94	+ 0,10	+ 0,64	+ 0,19	+ 0,51
30-50	0,67	0,25	0,55	0,59	0,68	0,68	0,75	0,78	+ 0,01	+ 0,43	+ 0,20	+ 0,19
50-100	0,41	0,16	0,25	0,54	0,50	0,56	0,50	0,79	+ 0,09	+ 0,40	+ 0,25	+ 0,25
0-100	0,54	0,17	0,41	0,52	0,62	0,64	0,63	0,83	+ 0,08	+ 0,47	+ 0,22	+ 0,31
100-150	0,36	1,04	1,13	1,17	0,55	0,46	0,60	0,58	+ 0,19	- 0,58	- 0,53	- 0,59

0-150	0,48	0,46	0,65	0,73	0,59	0,58	0,62	0,75	+ 0,11	+ 0,12	- 0,03	+ 0,02

Table 13. Mineralization level of ground water at experimental plots.

Data of sampling	Level of ground water	% per 1 litre of water / mg-equ								Sum of salts, g/l	pH	SAR
		Alkalinity		Cl-	SO4-2	Ca+2	Mg+2	Na+	K+			
		Total in HCO3-	From norm. carbonates CO3-2									
1	2	3	4	5	6	7	8	9	10	11	12	13
Experiment № 1												
7.06.96	170	0,54 8,85	-	0,06 1,60	0,854 17,80	0,20 10,0	0,108 8,87	0,213 9,25	0,005 0,13	1,98	8,87	3,01
20.10.96	190	0,55 8,95	-	0,085 2,39	1,02 21,25	0,16 8,00	0,106 8,70	0,362 15,74	0,006 0,15	2,29	8,90	5,44
21.05.97	164	0,366 6,00	0,029 0,97	0,088 2,48	0,299 6,23	0,04 2,00	0,022 1,82	0,27 11,71	0,006 0,15	1,12	8,85	8,47
17.07.97	179	0,415 6,80	0,024 0,80	0,102 2,87	0,32 6,67	0,05 2,50	0,044 3,64	0,25 10,85	0,006 0,15	1,21	8,80	6,19
29.09.97	208	0,42 6,89	0,005 0,17	0,082 2,31	0,47 9,90	0,06 3,00	0,12 9,86	0,144 6,26	0,006 0,15	1,31	8,37	2,47
Experiment № 2												
7.06.96	165	0,45 7,41	-	0,07 2,08	0,48 10,00	0,12 6,00	0,10 8,22	0,119 5,17	0,004 0,10	1,34	7,91	1,94
20.10.96	181	0,50 8,25	-	0,10 2,86	0,54 11,25	0,11 5,50	0,09 7,80	0,205 8,93	0,005 0,13	1,55	8,17	3,46
20.05.97	165	0,366 6,00	0,024 0,88	0,224 6,31	0,158 3,30	0,06 3,00	0,049 4,11	0,225 9,76	0,006 0,15	1,112	7,84	4,91
17.07.97	173	0,547 8,96	0,10 0,33	0,209 5,88	0,166 3,45	0,07 3,50	0,094 7,86	0,164 7,133	0,005 0,13	1,355	8,24	2,99
29.09.97	205	0,927 15,19	0,005 0,17	0,040 1,13	0,22 4,62	0,10 5,00	0,14 11,50	0,104 4,51	0,004 0,10	1,54	8,80	1,57
Experiment № 3												
7.06.96	150	1,22 19,99	-	1,62 45,68	2,56 53,80	0,60 30,00	0,63 51,80	0,842 36,60	0,042 1,07	7,556	9,10	3,20
20.10.96	162	1,37 22,39	-	1,45 40,84	2,97 61,86	0,49 24,50	0,51 42,10	1,249 54,30	0,163 4,19	8,202	9,12	9,41
21.05.97	164	2,078 34,06	0,082 2,73	0,494 13,92	0,377 7,86	0,04 2,00	0,26 21,37	0,785 34,16	0,041 1,04	4,157	8,87	9,96
18.07.97	160	1,754 28,75	0,100 3,34	0,377 10,62	0,857 17,86	0,04 2,00	0,297 24,80	0,659 28,67	0,199 5,10	4,283	9,02	7,83
30.09.97	157	1,068 17,50	0,125 4,12	0,224 6,31	1,65 34,47	0,02 1,00	0,35 28,78	0,435 18,87	0,54 13,80	4,412	9,25	4,89

Table 14. Composition of the absorbed bases in field experiments under irrigation by mineralized waters.

Depth of sampling, cm	Mg-equ per 100 g of soil					in % from the sum			
	Ca+2	Mg+2	Na+	K+	Сумма	Ca+2	Mg+2	Na+	K+
1	2	3	4	5	6	7	8	9	10
Experiment № 1 7.06.96 Before irrigations.									
0-10	7,0	2,5	0,85	0,38	10,73	65,2	23,3	7,9	3,6
10-20	6,0	3,0	0,75	0,38	10,13	59,2	29,6	7,4	3,8
20-30	6,5	1,5	0,80	0,30	9,70	71,4	16,5	8,8	3,3
30-50	5,5	3,0	0,80	0,34	9,64	57,1	31,1	8,3	3,5
50-75	6,0	3,0	0,76	0,29	10,05	59,7	29,8	7,6	2,9
75-100	5,5	3,0	0,76	0,27	9,53	57,7	31,5	8,0	2,8
20.10.96 After irrigations.									
0-10	5,3	4,2	0,79	0,21	10,50	50,5	40,0	7,5	2,0
10-20	5,6	3,2	0,82	0,19	9,81	57,1	32,6	8,4	1,9
20-30	5,5	2,5	0,74	0,16	8,90	61,8	28,1	8,3	1,8
30-50	5,0	4,0	0,79	0,15	9,94	50,3	40,2	8,0	1,5
50-75	5,5	3,8	0,78	0,14	10,22	53,8	37,2	7,6	1,4
75-100	5,0	4,0	0,75	0,17	9,92	50,4	40,3	7,6	1,7
20.05.97 Before irrigations.									
0-10	9,5	5,0	0,34	0,37	15,21	62,5	32,8	2,3	2,4
10-20	9,5	4,5	0,24	0,25	14,49	65,6	31,1	1,6	1,7
20-30	8,0	2,5	0,30	0,20	11,00	72,7	22,7	2,7	1,9
30-50	8,0	3,0	0,20	0,16	11,36	70,4	26,4	1,8	1,4
50-75	9,0	4,0	0,27	0,13	13,40	67,2	29,8	2,0	1,0
75-100	8,0	3,0	0,36	0,14	11,50	69,6	26,1	3,1	1,2
20.09.97 After irrigations.									
0-10	6,6	2,1	1,84	0,34	10,88	60,7	19,3	16,9	3,1
10-20	5,2	3,0	1,88	0,39	10,47	49,7	28,6	18,0	3,7
20-30	5,8	2,2	1,81	0,36	10,17	57,0	21,6	17,8	3,6
30-50	6,0	2,5	2,03	0,19	10,72	56,0	23,3	18,9	1,8
50-75	5,7	2,8	1,88	0,15	10,53	54,1	26,6	17,9	1,4
75-100	5,8	2,6	1,71	0,11	10,22	56,8	25,4	16,7	1,1
Experiment № 1 12.10.98									
0-10	7,0	3,0	0,75	0,35	11,10	63,1	27,0	6,8	3,1
10-20	5,5	4,1	0,80	0,38	10,78	51,0	38,0	7,5	3,5
20-30	6,0	2,5	1,21	0,35	10,06	59,6	24,9	12,0	3,5
30-50	5,7	3,0	1,37	0,21	10,28	55,4	29,2	13,3	2,0
50-75	6,5	3,0	0,92	0,20	10,62	61,2	28,2	8,7	1,9
75-100	5,5	2,8	0,86	0,17	9,33	59,0	30,0	9,2	1,8
Experiment № 2 7.06.96 Before irrigations.									
0-10	5,5	3,5	0,70	0,23	9,93	55,4	35,2	7,1	2,3

10-20	5,5	3,0	0,59	0,22	9,31	59,1	32,2	6,3	2,4
20-30	5,5	3,5	0,82	0,22	10,04	54,8	34,8	8,2	2,2
30-50	5,5	3,5	0,69	0,19	9,88	55,7	35,4	7,0	1,9
50-75	5,0	4,2	0,82	0,18	10,20	49,0	41,2	8,0	1,8
75-100	5,0	4,2	0,83	0,21	10,24	48,8	41,0	8,1	2,1
20.10.96 After irrigations.									
0-10	4,0	4,5	0,70	0,22	9,42	42,5	47,8	7,4	2,3
10-20	5,0	4,0	0,84	0,30	10,14	49,3	39,4	8,3	3,0
20-30	4,5	4,5	0,71	0,12	9,83	45,8	45,8	7,2	1,2
30-50	4,5	4,5	0,82	0,10	9,92	45,4	45,3	8,3	1,0
50-75	5,0	5,0	0,79	0,13	10,92	45,8	45,8	7,2	1,2
75-100	4,5	4,0	0,78	0,16	9,44	47,7	42,4	8,2	1,7
20.05.97 Before irrigations.									
0-10	7,5	3,25	0,22	0,28	11,25	66,7	28,9	1,9	2,5
10-20	9,0	4,25	0,25	0,33	13,83	65,1	30,7	1,8	1,4
20-30	8,0	3,0	0,26	0,25	11,51	69,5	26,0	2,3	2,2
30-50	9,0	3,5	0,23	0,15	12,88	69,9	27,2	1,8	1,1
50-75	9,0	3,75	0,29	0,12	13,16	68,4	28,5	2,2	0,9
75-100	8,0	3,5	0,35	0,15	12,00	66,7	29,2	2,9	1,2
20.09.97 After irrigations.									
0-10	6,0	2,8	1,31	0,33	10,44	57,5	26,8	12,5	3,2
10-20	5,2	3,2	1,51	0,28	10,19	51,0	31,4	14,8	2,8
20-30	5,2	3,5	1,82	0,24	10,76	48,3	32,5	17,0	2,2
30-50	4,6	3,7	2,54	0,16	11,00	41,8	33,6	23,1	1,5
50-75	4,7	4,0	2,80	0,14	11,64	40,4	34,4	24,0	1,2
75-100	4,5	4,3	2,46	0,13	11,39	39,5	37,8	21,6	1,1
12.10.98									
0-10	6,0	3,5	0,68	0,30	10,48	57,2	33,4	6,5	2,9
10-20	5,5	4,0	0,73	0,26	10,49	52,4	38,1	7,0	2,5
20-30	5,5	3,5	0,97	0,25	10,22	53,8	34,2	9,5	2,5
30-50	4,8	3,4	1,20	0,22	9,62	49,9	35,3	12,5	2,3
50-75	5,0	3,4	1,30	0,15	9,85	50,8	34,5	13,2	1,5
75-100	5,0	3,8	1,14	0,14	10,08	49,6	37,7	11,3	1,4
Experiment № 3 7.06 96 Before irrigations.									
0-10	5,5	5,7	0,93	1,29	13,47	40,8	42,7	6,9	9,6
10-20	6,5	3,0	0,91	1,39	11,80	55,1	25,4	7,7	11,8
20-30	5,5	3,0	0,80	1,25	10,55	52,1	28,4	7,6	11,9
30-50	4,0	3,0	0,70	0,99	8,69	46,0	34,5	8,1	11,4
50-75	2,5	2,0	0,66	0,58	5,74	43,6	34,8	11,5	10,1
75-100	2,5	2,0	0,86	0,57	5,93	42,2	33,7	14,5	9,6
20.10.96 After irrigations.									
0-10	8,5	5,7	1,16	1,00	16,36	52,0	34,8	7,1	6,1
10-20	5,7	5,7	1,01	1,02	13,43	42,4	42,4	7,6	7,6
20-30	4,0	4,5	0,93	1,06	10,49	38,1	42,9	8,9	10,1

30-50	4,2	3,7	1,00	1,33	10,23	41,0	36,2	9,8	13,0
50-75	3,5	3,5	0,88	1,19	9,07	38,6	38,6	9,7	13,1
75-100	4,0	3,0	0,77	0,72	8,49	47,1	35,3	9,1	8,5
19.05.97 Before irrigations.									
0-10	12,0	5,0	0,29	1,19	18,48	64,9	27,1	1,6	6,4
10-20	10,0	4,0	0,32	1,22	15,54	64,4	25,7	2,2	7,8
20-30	7,5	2,5	0,39	1,29	11,68	64,2	21,4	3,3	11,1
30-50	7,0	3,0	0,32	0,84	11,16	62,7	26,9	2,9	7,5
50-75	4,5	1,5	0,53	1,31	7,84	57,4	19,1	6,8	16,7
75-100	4,5	1,5	0,82	1,44	8,26	54,5	18,2	9,9	17,4
30.09.97. After irrigations.									
0-10	8,0	6,0	5,25	1,84	21,29	37,6	29,1	24,7	8,6
10-20	7,5	5,0	5,36	1,62	19,48	38,5	25,7	27,5	8,3
20-30	5,25	4,0	5,26	1,93	16,44	31,9	24,3	32,0	11,8
30-50	4,7	3,2	4,74	2,30	14,24	33,0	22,5	33,3	16,2
50-75	2,7	2,5	3,74	2,80	11,74	23,0	21,3	31,9	23,8
75-100	3,0	1,5	3,00	2,85	10,35	29,0	14,5	29,0	27,5
12.10.98.									
0-10	8,5	5,7	2,10	1,53	17,83	47,7	32,0	11,8	8,6
10-20	7,7	5,5	2,35	1,33	16,88	45,6	32,6	13,9	7,9
20-30	6,0	5,0	2,41	1,64	15,05	39,9	33,2	16,0	10,9
30-50	5,0	3,5	2,05	1,78	12,33	40,6	28,4	16,6	14,4
50-75	3,5	2,5	1,77	2,00	9,77	35,8	25,6	18,1	20,5
75-100	3,5	2,0	1,45	1,84	8,79	39,8	22,8	16,5	20,9

Table 15. Level of humus and the main nutrition elements in soils of field experiments.

Depth of sampling, cm	Macroelements						
	Humus, %	Total nitrogen, %	Bulk, %		Mobile, mg per 1000 g of soil		
			P2O5	K2O	Hydrolyzed nitrogen	P2O5	K2O
1	2	3	4	5	6	7	8
Experiment № 1 1996							
0-10	1,14	0,098	0,15	2,39	70,0	21,0	342,6
10-20	1,39	0,098	0,16	2,40	64,4	29,0	410,3
20-30	1,05	0,084	0,115	2,29	67,2	13,0	314,7
30-50	0,47	0,056	0,10	2,40	72,8	2,0	342,6
Experiment № 1 1997							
0-10	1,27	0,101	0,13	2,49	61,1	24,1	368,8
10-20	1,08	0,095	0,17	2,49	57,4	27,0	405,1
20-30	0,64	0,088	0,12	2,29	52,8	12,3	320,5
30-50	0,18	0.076	0,10	2,40	67,7	3,2	340,7
Experiment № 2 1996							
0-10	1,04	0,084	0,12	2,39	56,0	13,0	297,9
10-20	0,95	0,084	0,125	2,40	47,6	16,0	314,7

20-30	0,59	0,078	0,13	2,29	52,4	9,0	280,2
30-50	0,53	0,056	0,115	2,40	58,8	2,0	224,8
Experiment № 2 1997							
0-10	1,12	0,098	0,115	2,49	42,4	13,8	380,7
10-20	1,01	0,081	0,13	2,49	38,1	14,4	308,5
20-30	0,54	0,074	0,13	2,29	30,5	8,0	256,3
30-50	0,49	0,062	0,115	2,40	24,9	2,0	230,8
Experiment № 3 1996							
0-10	4,43	0,261	0,25	2,21	98,0	130,0	1371,3
10-20	2,53	0,177	0,22	2,04	81,2	70,0	1641,0
20-30	1,40	0,112	0,20	2,29	78,4	90,0	1568,0
30-50	0,74	0,098	0,15	2,30	67,2	27,0	1303,8
Experiment № 3 1997							
0-10	3,59	0,256	0,24	2,19	79,8	118,4	1167,8
10-20	2,30	0,164	0,185	2,01	78,4	66,8	1245,4
20-30	0,93	0,106	0,185	2,29	70,6	71,3	1301,6
30-50	0,40	0,077	0,115	2,29	71,0	25,5	1098,2

Table 16. Content of mobile forms of the main microelements in field experiments.

Depth of sampling, cm	Microelements in mg per 1000 g of soil.					
	Zn	Cu	Pb	Cd	Mn	Co
Experiment № 1						
0-10	2,0	0,8	6,0	0,7	100,0	1,3
10-20	2,0	0,8	6,0	0,6	95,0	1,3
Experiment № 2						
0-10	4,4	0,8	6,0	0,6	90,0	1,3
10-20	3,6	0,8	5,0	0,6	81,0	1,2
Experiment № 3						
0-10	4,4	0,5	6,0	0,7	53,0	1,3
10-20	3,8	0,6	6,0	0,6	50,0	1,3

Table 17. Yielding ability of maize grains in field experiments.

Variants	1996 Sort Kazakhstanskaya 40					1997 Sort Yugoslavskiy hybrid ZPSC599					For 2 years	
	Rep.. 1	Rep. 2	Rep.3	Average in kg per 10 m2.	In c/ha	Rep.1	Rep.2	Rep. 3	Average in kg per 10 m2.	In c/ha	In c/ha	Average.
Experiment № 1												
Variant 1 (control)	6,01	5,83	5,75	5,86	58,6	4,07	4,31	3,70	4,03	40,3	98,9	
Variant 2 (treatment by humate)	5,52	5,37	5,04	5,31	53,1	5,91	6,44	4,82	5,72	57,2	110,3	105,6
Variant 3 (tratment by ZnSO4)	5,15	4,86	4,58	4,86	48,6	5,83	6,57	5,36	5,92	59,2	107,8	
Experiment № 2												
Variant 1 (control)	7,11	6,34	6,08	6,51	65,1	3,66	3,10	3,85	3,54	35,4	100,5	
Variant 2 (treatment by humate)	6,25	5,77	5,59	5,87	58,7	4,50	3,36	3,58	3,81	38,1	96,8	99,2

Variant 3 (tratment by ZnSo4	6,00	5,18	5,46	5,55	55,5	4,52	3,55	5,40	4,49	44,9	100,4	
Experiment № 3												
Variant 1 (control)	5,21	4,63	5,35	5,06	50,6	5,30	5,5	5,0	5,27	52,7	103,3	
Variant 2 (treatment by humate)	5,37	6,25	5,75	5,79	57,9	8,50	5,4	5,6	6,50	65,0	122,9	119,7
Variant 3 (treatment by ZnSo4)	6,87	6,26	6,17	6,43	64,3	7,0	7,5	6,1	6,87	68,7	133,0	

Table 18. Results of plant samples analysis from maize (sort Yugoslavskiy hybrid ZPSC599).

Experiment №	Variants	Types of analyses						
		Total moisture, %	Raw protein, %	Starch, %	Ash , %	N , %	P2O5 , %	K2O, %
1 Grain	Var1 (control)	7,9	9,25	57,2	1,64	1,48	0,42	0,33
	Var. 2(treatment by humate)	7,9	9,25	56,8	1,49	1,48	0,48	0,33
	Var..3 (treatment by ZnSO4)	8,1	10,25	56,8	1,60	1,61	0,48	0,32
Stems	----------	5,7	No	no	3,8	0,72	0,20	0,90
2 Grain	Var. 1(control)	8,1	9,85	57,2	1,39	1,49	0,42	0,31
	Var.2 (treatment by humate)	8,1	10,25	57,0	1,29	1,64	0,42	0,29
	Var. (treatment by ZnSO4)	8,0	9,50	56,8	1,42	1,52	0,42	0,30
Stems	----------	5,6	no	No	3,9	0,73	0,22	0,90
3 Grain	Var. 1 (control)	8,3	9,81	56,8	1,93	1,57	0,50	0,30
	Var. 2 (treatment by humate)	8,3	9,88	56,8	1,50	1,58	0,48	0,28
	Var.3 (treatment by ZnSO4)	7,9	10,44	56,9	1,74	1,67	0,50	0,30
Stems	----------	5,8	no	No	3,8	0,78	0,28	0,92