

ON THE ANALYSIS OF SALT DYNAMICS ABOVE THE CRITICAL GROUND WATER LEVEL

by

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Adatok a kritikus talajvízszint feletti sómozgás vizsgálatához. A szerzők helyszíni megfigyeléseiket a száraz és öntözött viszonyok között a Tiszántúl északkeleti részén a szolnoki löszhát peremén végezték. Közlelebből az előbbieK Karcag, az utóbbiak pedig Kisújszállás városok határában folytak.

Száraz gazdálkodás esetében a „kritikus mélység” körüli talajvízszint-állás körülményei között — mint általában éghajlatunk alatt — kísérleti területünkön is a talajsóK vándorlása az évszakonkénti szakaszosságot — a téli kimosodási és a nyári felhalmozódási irányzatot — követte.

Az elszikesedés veszélye nélkül öntözni lehet akkor is, ha a talajvíz a kritikus szint körül van, amennyiben gondoskodás történik arról, hogy a felesleges víz — talaj- vagy öntözővíz — elvezetést nyerjen. A dréneket ilyenkor megfelelő kiképzés esetén öntözésre és vízelvezetésre, lecsapolásra — tehát reverzibilisen — is fel lehet használni.

The authors field studies were made under dry and irrigation conditions in the northeastern part of Tiszántúl at the edge of the loessial plain of Szolnok. More exactly the first conditions were studied in the vicinity of Karcag, the latter in the vicinity of Kisújszállás.

In the case of dry farming, under conditions of ground water level around the “critical depth”, as is usual in our climate, the migration of the soil salts followed the periodicity of the seasons — the trends of leaching in winter and accumulation in summer also in the area investigated.

It is possible to irrigate without risk of alkalization also when the ground water level is near the critical level if we make sure that the superfluous water — ground water or irrigation water — can drain off. In such circumstances the drains can be used in case of suitable transformation, for irrigation and drainage, i. e. also reversibly.

Depending on the mechanical structure of the soil and the salt content of the ground water, evaporation can be fed already from the water table between 1 and 3.5 depth. In this case concentration of the salts dissolved in the water may alkalize the soil and cause accumulation of the salts (c, d, e).

The depth, from which the water-soluble salts can reach or approach the soil surface by capillary lift and can accumulate causing alkalization of the soil as a result of evaporation, is called “critical ground water level”.

Our field studies were made under dry and irrigation conditions in the northeastern part of Tiszántúl, at the edge of the loessial plain of Szolnok (a). More exactly, the first conditions were studied in the vicinity of Karcag, the latter in the vicinity of Kisújszállás.

The observation dealt with

1. the influence of climatic factors (precipitation, evaporation, irradiation, etc.) on the migration of the soil salts;
2. movements of the ground water as a factor of the migration of the salts;
3. the influence of human activity, such as irrigation.

Investigation Strategy

The investigations were carried out at two locations: one of them was unirrigated virgin grassland, the other irrigated plowland; the first had acidic alkali soil, the latter meadow soil, saline in depth. At different times — chiefly in spring, summer and fall — soil samples were taken from every 10 cm of the soil profiles. Profile sampling was repeated 3—8 times and the total salt percentage content of the samples was determined. The natural factors (precipitation, evaporation, ground water level) and human interference were evaluated mathematically and statistically.

With the aid of observation wells correlations were sought between the periodical variations of the water level and the migration of the soil salts.

Analysis of the total salt on the basis of electric conductivity was made according to our methodological manual.

As we have mentioned, the area investigated lies in the northeastern sector of Hungary. It is uniform both geographically and climatically, and it represents the regions with the most extremely continental climate in this country.

In the evaluation of the climatic elements we generally took periods of 25 years into consideration.

The area receives an average annual total of 2000 *sunshine* hours, and occasionally more. Farther north in the region, the annual total sunshine hours is already under 2000. Thus the average of the sunshine hours in the southern parts of the area is slightly higher than the average of the whole country. The average annual *total solar radiation* in the area is around 100 Kcal cm⁻².

The temperature conditions of the area are very extreme: the winter is cold, the summer is — except on the northeastern edges of the area — warmer than the national average. In winter severe frosts are frequent here, as the mean temperature in January varies between -2.5 and -4.0 °C.

The average of the annual temperature minima varies between -19.0 °C and -22.0 °C, but occasionally 10 degrees lower temperature also occur. The summer is moderately warm. The average mean temperature in July is 20—22 °C. In spite of this, warming up is intense in places, especially in the area investigated, where the average of the annual temperature maxima is around 35 °C.

The wind conditions of the area are very changeable. The annual average wind velocity is 2—3 m/sec. The annual average of windstorm hours varies between 145—180. In the southern parts of the area only 20—25 stormy days are likely to occur on average.

Fog formation is fairly frequent in the region, especially in its northeastern parts. In its southern parts, however, only 30—40 foggy days are likely to occur in a year.

Precipitation in the area is scanty. The average annual total precipitation varies between 500—550 mm. Near to this area lie the driest regions of the country: the area of the Hortobágy, the area between Szolnok and Szarvas, and the environs of Kunszentmárton. In these areas the amount of precipitation often does not reach even an annual 500 mm average.

The annual average number of rainfall hours is 1300—1800 in the area investigated. On the basis of the average of 50 years (1901—1950) — considering the monthly and annual amounts of precipitation at any one of the observation stations near to our area — we come to the conclusion that in the annual variation two waves can be observed: the maxima of May-June and October-November on the one hand, and the minima of January-February and August-September on the other. This regularity

does not appear in every year because the distribution of precipitation in time and space is unstable and there is considerable fluctuation in the extreme values.

The soil temperature are also very extreme. In winter they are very low, in summer very high. Frosts are common in the winter. The mean soil temperature in January varies between -3.0 and 0.1°C at 2 cm depth.

In summer, the surface of the soil is warm. The mean temperature in July at 2 cm depth under the soil surface is between the yearly average, 33.4°C and 29.8°C .

The migration of salts under dry conditions

The migration of the soil salts in the area under conditions without irrigation follows, as is usual in our climate, the seasonal periodicity of leaching out in the winter, and moving upward in the summer. In normal weather conditions these natural processes lead to washing down and sinking of the maximum salt accumulation in winter. As can be seen in *Fig. 1*, the maximum accumulation of salt in profiles 158 and 159 is at 70 cm, and in cores 158 and 159 at 80. (Sampling of 15 Dec. 1972. Continuous black line.)

Owing to the rise in temperature, evaporation of the ground water, and other causes, the direction of the migration of the salts changes and turns upward in the spring. As a result, the maximum accumulation of salts appears at 60 cm in the core samples (*Fig. 1*; observations on 5 April 1972 and 9 April 1973; dot-and-dash line and continuous line).

During the summer, the upward migration of the soil salts is more intense due to increased evaporation. It is generally at this time of the year that the migrating salts rise and come nearest to the soil surface. In the first core (156, 157) their distance from the surface is 50 cm. In the other, the maximal accumulation does not shift, but the salt curve (*Fig. 1*, 25 July 1972; dotted line) comes nearest to the soil surface at this time. The obstacle to further rising of the salts was that before sampling 70 mm rain fall in the area (*Fig. 2*), which caused the water-soluble salts of the different kinds of alkali soils to perform a different migration [f]. In fall, with the coming of steady rains, the prevailing direction of the salt migration changes: the salts begin to migrate downward, that is, the process of migration is repeated. The winter period begins again.

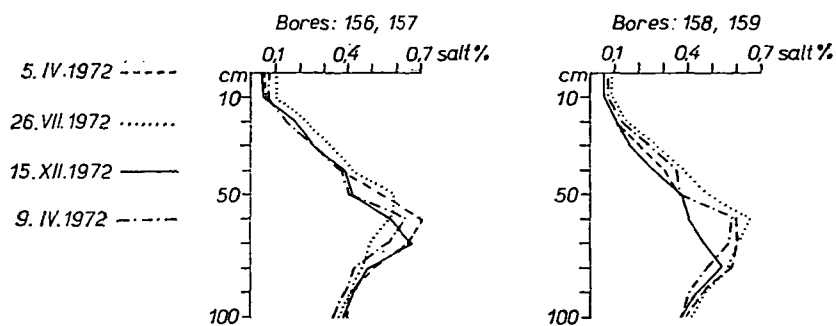
Under conditions without irrigation, the migration of the salts depends mainly on three factors: 1. precipitation, 2. evaporation, and 3. the depth of the water level. Naturally, the quality of the soil and the temperature are also important factors.

If the level of the ground water is lower, then the leaching effect of precipitation prevails. In the contrary case, however, when the ground water level is high, the situation is reversed. The high ground water level is summer, owing to increased evaporation, favors the migration of the salts upward.

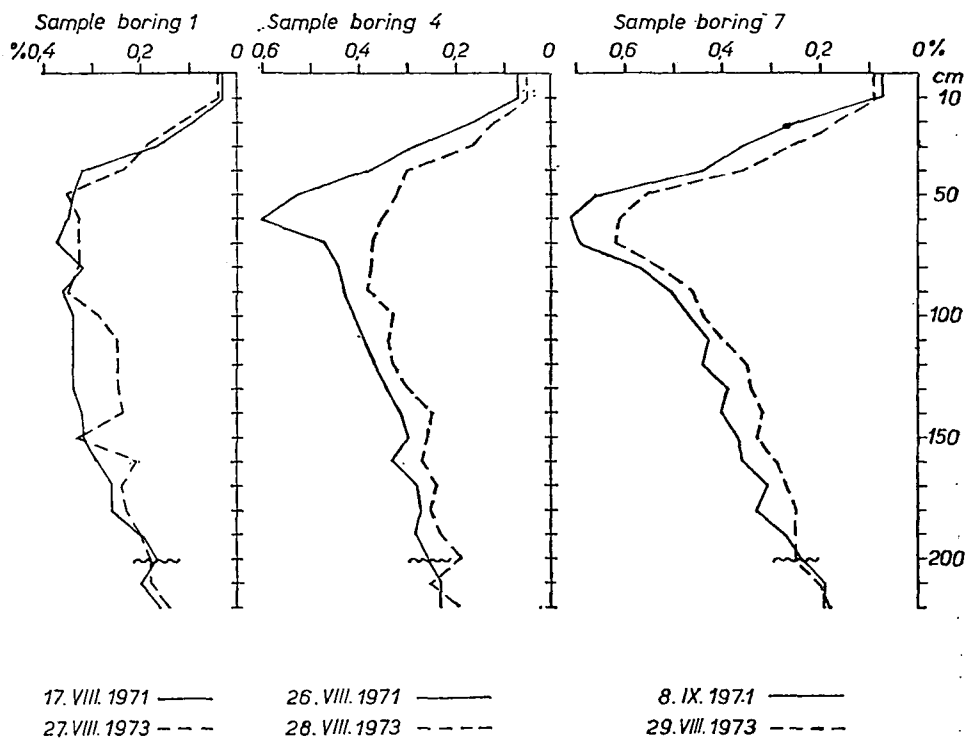
With a view to studying the salt migration, we made three wells for the observation of the ground water level at Karcag, near to the area of the investigation, in the vicinity of borings 156—159. Besides these, on two occasions, in the summers of 1971 and 1973, we made three parallel borings down to the ground water level. The percentage of the total salt content of the soil samples was evaluated, and the data are shown in *Fig. 1*.

In these wells the water level was around 2 m depth during the five years of observation. The seasonal variation and the large amount of precipitation were regularly observed. Small differences were observed in the height of the water levels,

Times and designations of borings



Mean values of total salt % in 3 bores at each boring



ground water level ~~~~~

Fig. 1. Mean values of total salt percentage

Rainfall in the area of Karcag in 1971-1975

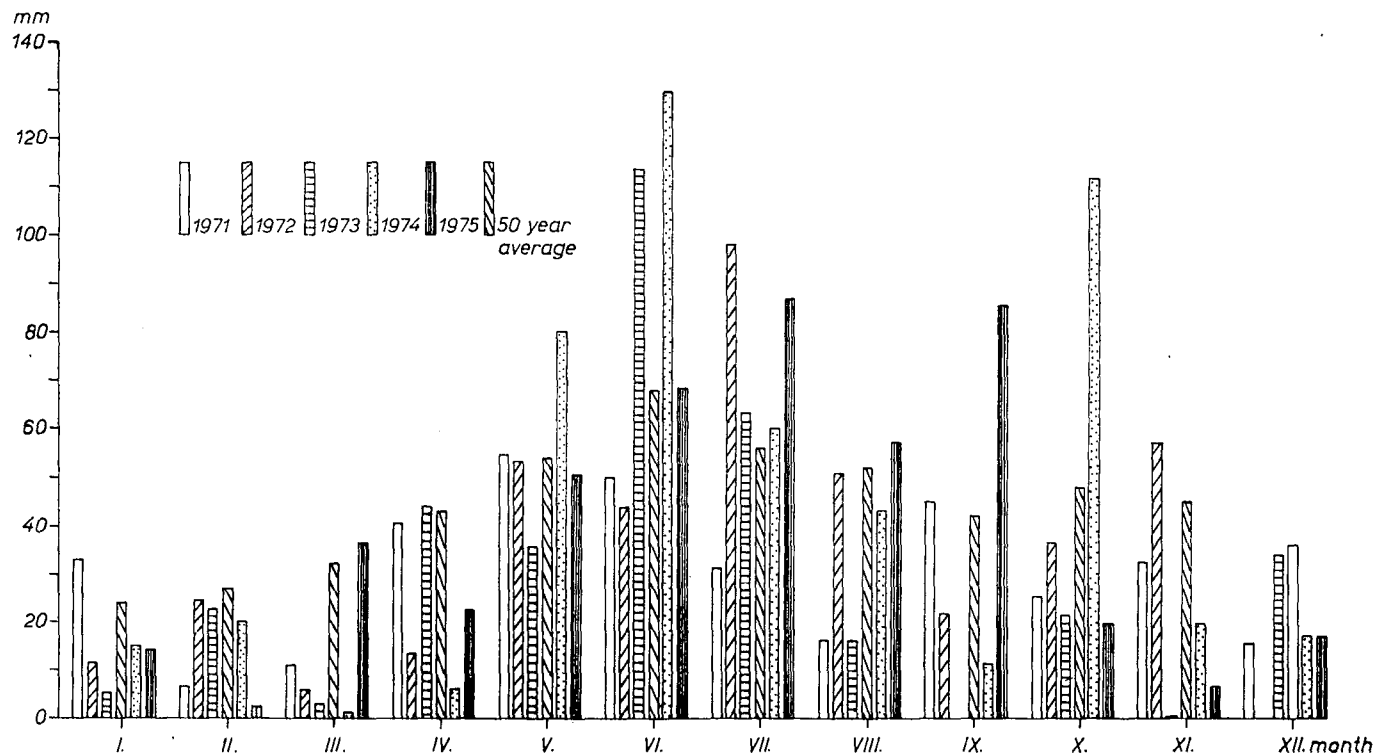


Fig. 2. Rainfall in the area of Karcag in the years 1971-1975

which can be explained by the different mechanical structures of the soil layers feeding the wells.

We noted the following correlations between the salt migration shown by the upper line in *Fig. 1* (bore 156—159) and the variation of the water level in the observation wells: On 26 July 1972, at the time of high water level in the wells [f], the salts were at a high level (dotted line) in the soil profiles (156, 157, 158, 159). In winter, on 15 December at the time of low water level, the salts were at a greater depth (continuous line in *Fig. 1*). In spring, on 5 April 1972 and 9 April 1973, the salts were at mid height between the two water levels previously mentioned. (*Fig. 1*, dot-and-dash line and continuous line.) From this it is clear that the seeping of the water in the wells and the maximum accumulation of the soil salts are synchronal.

On two occasions we made three borings down to the ground water level beside each one of the wells (*Fig. 1*). Soil samples were taken from the boring at every 10 cm and from the total water-soluble salt content was determined. The mean values of the comparable data were calculated and are shown in *Fig. 1*. In the course of the statistical calculations we found significant leaching of the salts only in one case, beside well 4, above the capillary zone. Near the other two wells we found only salt migration, a leaching tendency in the profile (well 7), or not even that (well 1). We emphasize this because between the mean salt values in the case of the tendencies the statistical standard deviation of the heterogeneity of the soil and the analysis is greater than the differences between the samples taken at two different times. Yet a definite decrease can be seen.

Salt migration under conditions with irrigation

In this case the migration of the soil salts during the irrigation period is influenced — depending on the method of irrigation — first of all by the irrigation water. However, in this case, too, the natural conditions, such as precipitation, temperature, the chemical and physical structure of the soil, play an important role. We can see this in the following.

We carried out investigations of these factors in the vicinity of Kisújszállás. The soil of the area is saline in depth, with a moderately thick humus layer, and in depth carbonate-containing meadow clay. The 0—60 cm top layer was analyzed. The plant cultivation experiment of J. Kapocsi [g, h] was going on in the area. He was using modified furrow irrigation.

In the study area, during two vegetation periods (1974, 1975), on two occasions in each, before and after irrigation, among the furrows and beside them, we made 16 soil borings 60 cm deep in each place. The soil samples were taken from each 10 cm. After this, the total water-soluble salt percentage was determined on the basis of electric conductivity in our laboratory. The samples taken parallelly were suitably grouped and statistically evaluated. The results are shown graphically in *Figs. 4. and 5.*

The area was drained at right angles to the furrows 45—50 cm deep at 60 cm intervals. The drain diameters were 8 cm [h].

We must mention that in the period studied, during the vegetation periods of 1974 and 1975, the weather was not very favorable for the analysis because of heavy rains (*Fig. 3*); in fact it disturbed our analysis because it caused strong leaching of the soil with humid conditions, which were very different from the average conditions of many years.

Rainfall in the area of Kisújszállás in 1973-1975

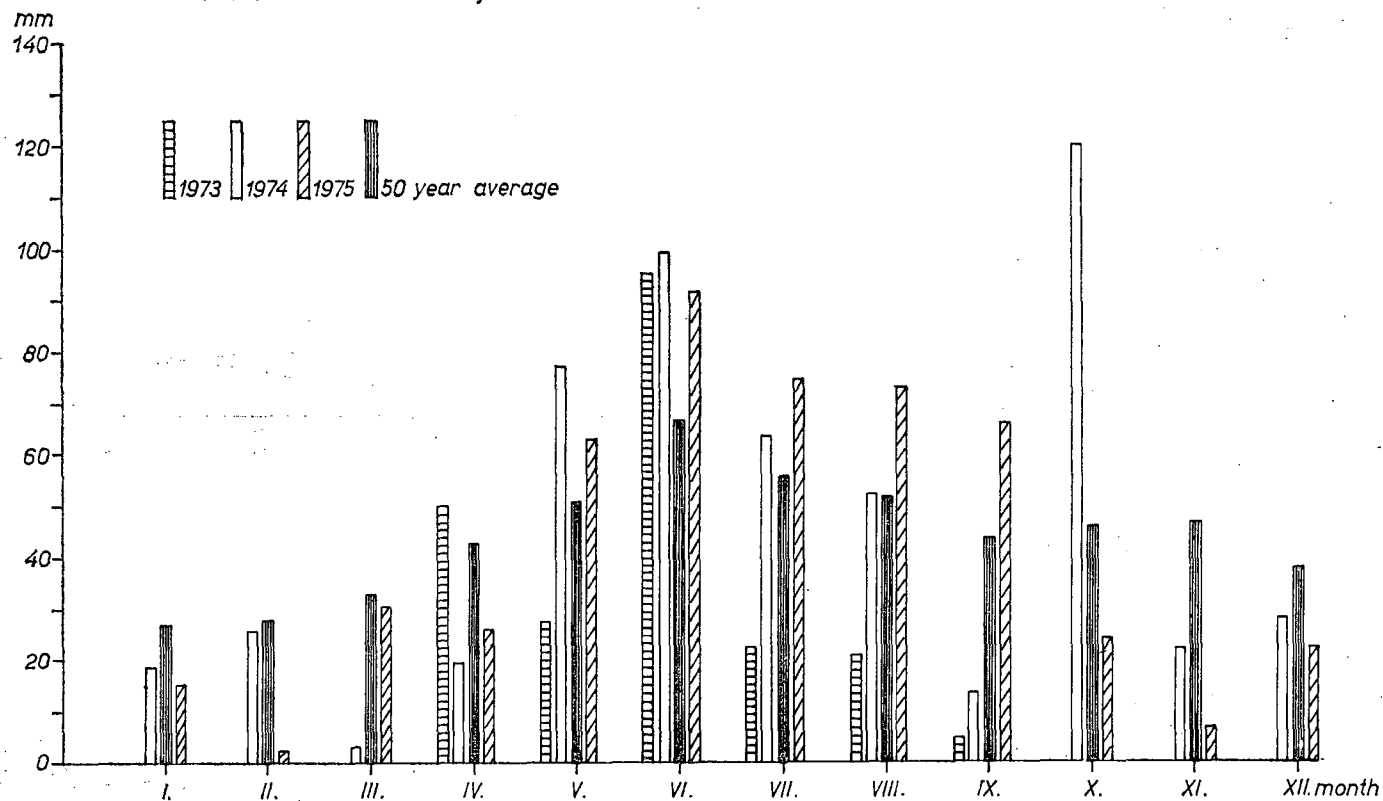


Fig. 3. Rainfall in the area of Kisújszállás in the years 1973—1975

In the course of 1974 the disturbance was first of all due to the extreme amount of rainfall in October (Fig. 3). Under normal weather conditions the downward migration of the soil salts usually only just starts in this month. In this case, however, the intensive and significant downward migration of the soil salts, usually to 40 cm depth, had already occurred in the immediate vicinity of the irrigation furrows and among them as well in the whole experimental area. Significant leaching down to 30 cm depth at a 0,1 or 1 % level was recorded only on one occasion (Fig. 4, last graph). Then the effect of irrigation or of the summer soil humidity manifested itself only as a tendency in evaporation, in the upward salt migration, in the higher water-soluble salt content, especially in the 50—60 cm layer (Fig. 4).

The salt migration data are generally significant at 0,1 and 1 % levels. The most unfavorable significant difference is 5%, when its value is 0,04 total salt per cent (Fig. 4).

In 1975 the amount of rainfall in the period of April through October was about 5% less, and its distribution more even than in the previous year (Fig. 3). This mani-

Investigation of salt dynamics in the area of Kisújszállás in 1974

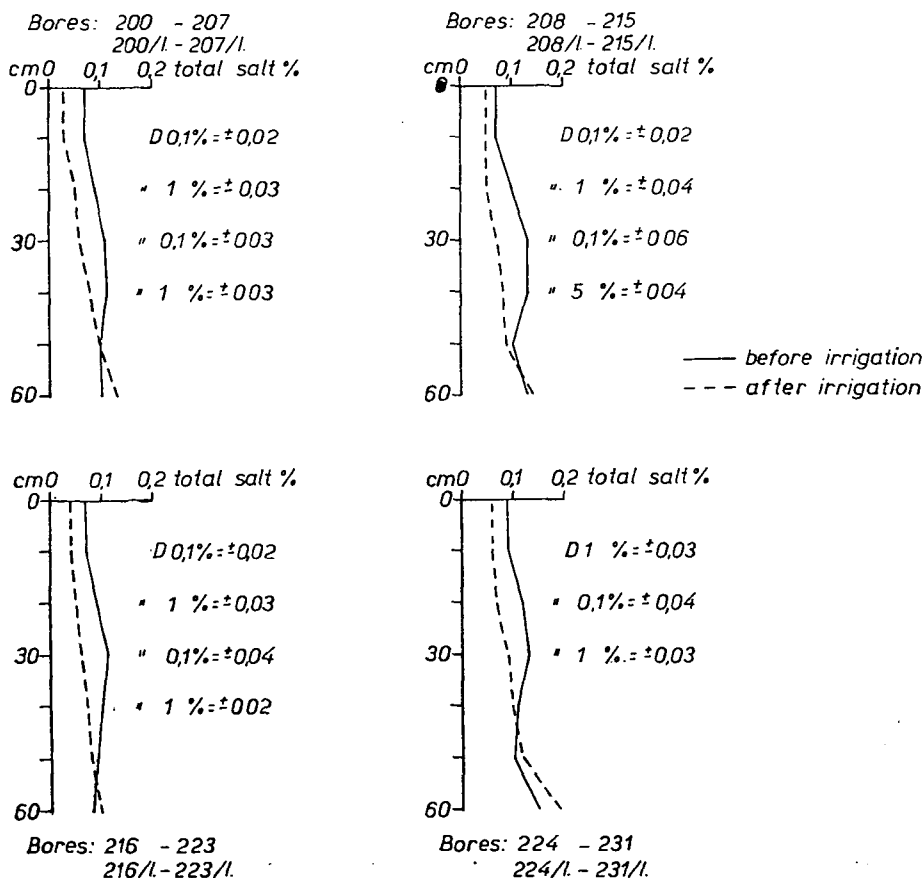


Fig. 4. Investigation of salt dynamics in the area of Kisújszállás in 1974. D = difference significant

fested itself in leaching and a higher salt content of the soil profiles (Figs. 4 and 5). In comparison with the situation before irrigation, the data were significant less frequently and to a lesser degree (Fig. 5). This phenomenon (the significance) can be explained by the considerably more humid March of 1975 (Fig. 3) and the higher degree of leaching of the soil profiles which served as the basis of comparison (Fig. 5; continuous line).

On the basis of the foregoing we can state that if during, before, or after the vegetation period there is more precipitation than the long-term average, irrigation (drains combined with irrigation furrows) causes no salt accumulation in the surface soil even when the stickiness of the meadow clay is 75—80.

Investigation of salt dynamics in the area of Kisújszállás in 1975

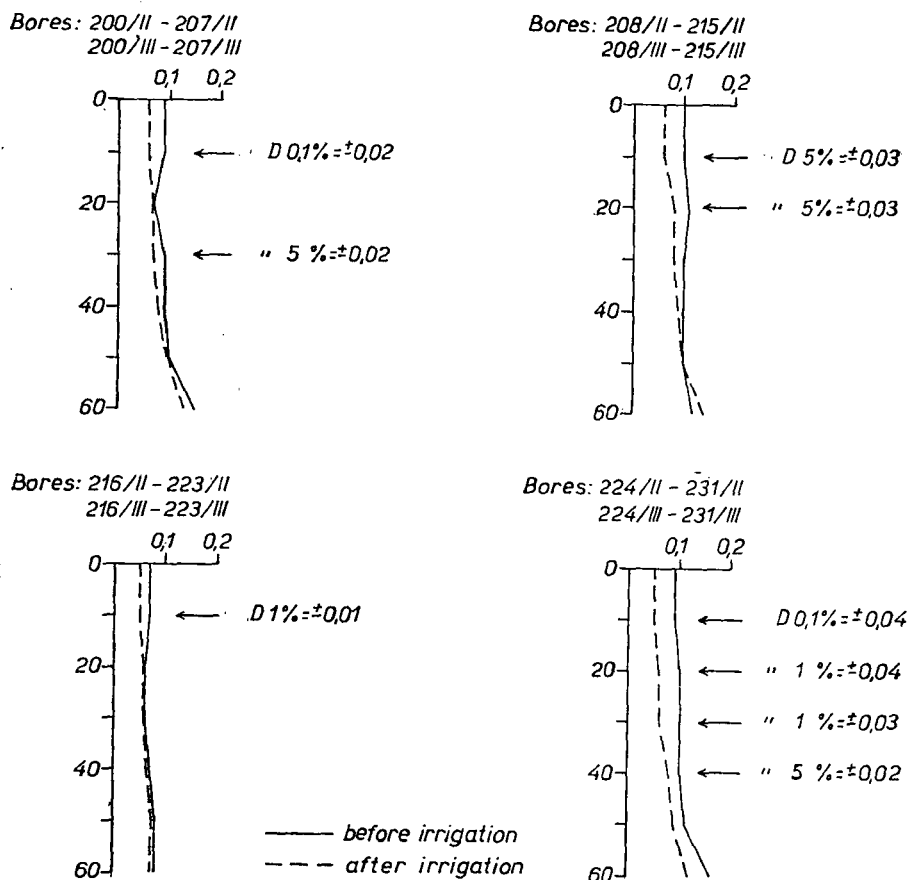


Fig. 5. Investigation of salt dynamics in the area of Kisújszállás in 1975. D =difference significant

Conclusions

In the case of dry farming, under conditions of ground water level around the "critical depth", as is usual in our climate, the migration of the soil salts followed the periodicity of the seasons — the trends of leaching in winter and accumulation in summer also in the area investigated. This regularity was the more apparent the deeper the ground water level lay or within certain limits the more alkalizable the soil was.

The water level near the "critical depth" controls the salt migration in the surface soil according to the rainfall and evaporation. Then the case of high ground water level, the maximal salt accumulation lies higher, in the case of low ground water level it lies lower.

Under conditions with irrigation on highly sticky, in the subsoil saline meadow clay, in the case of drain and furrow irrigation — if in the vegetation period the weather is more rainy than the long-term average — no salt accumulation takes place in the surface soil.

It is possible to irrigate without risk of alkalization also when the ground water is near the critical level if we make sure that the superfluous water (ground water or irrigation water) can drain off. In such circumstances the drains can be used in case of suitable transformation, for irrigation and drainage, i. e. also reversibly.

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