TESTING DRAINAGE METHODS AND DRAIN SPACING FOR THE KESZTHELY—HÉVÍZ MARSHLAND

by

M. Fahmy
Soils Dept. Agr. College, Alexandria Univ., Egypt,

and

L. Szabó
Chair for Water Resources Development, Budapest Technical Univ.

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Drainage of marshlands, as one of the ways for controlling excess water and for agricultural utilization of such areas, has long been applied in many countries [1, 2, 3, 4, 5, 6, 7].

Variations in permeability of marshy soils

It is a well-known fact that marshy soils — after an adequate control of groundwater table by means of a canalisation network — may effectively be utilized in agriculture. In the course of this utilization the soil with an originally fibrous structure will be decomposed and mineralized relatively quickly, owing both to the effect of soil cultivation, and to the lowering of groundwater table for the purpose of utilization. While the physico-chemical properties of the soil change, the structure of soil is decomposed, the soil becomes denser and thus its *permeability* is considerably reduced [7]. Since in this case the groundwater table cannot be controlled any more by a canalisation network developed for the marshland so as to meet demands and tolerance of plants, and for this purpose the creation of a denser canalisation network would be uneconomical, there is no other solution than drainage of the area.

The described process affected the marshland of the Keszthely–Hévíz region. The canalisation network shown in Fig.1 covering an area of about 30 sq.km has a threefold function: excludes external waters, serves both for drainage of the area at high groundwater level and for irrigation at low groundwater level. The most advantageous depth of groundwater table to favour plant growth [8] is as follows:

grass cultures	40 to 50 cm
other agricultural plants	60 to 65 cm.

Decrease in the permeability of soil has appeared in the Keszthely moorland after some years of agricultural cultivation. In order to determine the extent and characteristics of this change, in 1965 field experiments and laboratory tests were carried out by the *Department of Water Resources Development, Budapest Technical University*, and by the *Keszthely College of Agricultural Sciences*, as a common research project of both institutions. In the course of experiments 72 samples were taken on three occasions with a sampler of 721 cu.cm size at two sampling places shown in Fig.1.

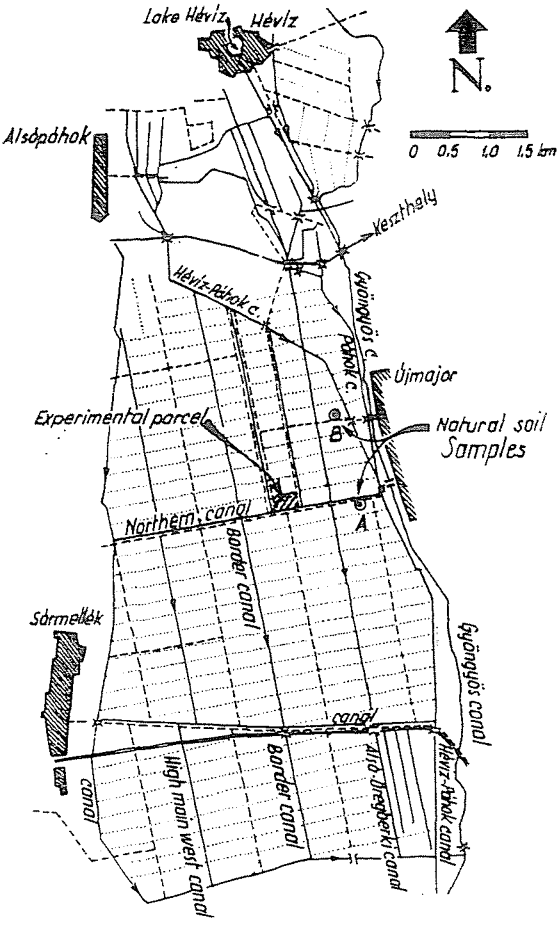

Fig. 1 Canalisation network of the Keszthely—Hévíz marshland.

Permeability tests at a soil state not fully saturated, extended over several hundreds of hours, have yielded the following mean values (reduced to a water temperature of 10°C) [9]:

		Permeability 10^{-4} cm/s
vertically	for primary marsh	16.4
	for cultivated marsh	9.1
horizontally	for primary marsh	31.0
	for cultivated marsh	1.4

The above data immediately show a considerable decrease in horizontal permeability. With reference to this fact B. SZEKRÉNYI and L. SZABÓ made a proposal for draining the marshland and for executing drainage experiments. On the basis of this suggestion an experimental area for drainage has been established in a central parcel of land (Fig.1) by the *Keszthely Region Company for Marsh Utilization and Water Management* in co-operation with the *Research Institute of Agricultural Machines.*

Objectives of drainage experiments

On the basis of data obtained from the relevant special literature, of preliminary studies, as well as of field investigations [10], it could be stated that two procedures might be considered as most economical for a final water control of the area, i.e. either application of mole drains, or of mole drains lined with plastic pipe (to be termed below briefly mole pipe drains, made simply in a drain-drawing equipment, forming plastic – generally PVC – strips into slotted pipe fitting into the soil [10, 11. 12]).

In connection with the development of a mole drain or plastic drain network it should be decided first, what drain spacing is the most suitable in the given local conditions. Because of the complex influencing factors, this problem could not be solved merely theoretically [13]. Hence, *the primary aim of the investigations in the experimental parcel of land had been to decide on the applicable drain system and to determine the optimum drain spacing.*

An arrangement with seven stripes has been applied on the experimental parcel of land. The layout of drains is shown in Fig.2. On the left side of the field the first stripe is undrained. Then parallel mole drains and PVC plastic drains have been drawn, spaced apart 5, 10, 15 m and 10, 20 m, respectively. The row is confined by a second undrained (control) stripe. In order to check the regulating effect of the drains on groundwater level, observation wells, spaced at 20 m have been located axially in each experimental stripe.

Mole drains 200 mm in diameter were drawn by a *Scholz*-type mole draining equipment with cleaning chain, mounted on a deep-loosening machine type *FA*–1 [10]. The effective drain diameter is but 10 to 12 cm because of the elastic properties of the marshy soil. To protect the throat of drain against erosion a 1 m long plastic pipe was pushed in the inlet of galleries. The draining equipment was pulled by a tractor type D4K–B and the mole drains were set out alternately from canals bordering the plot in longitudinal direction. Thus each second mole drain discharges into the same canal. The structural length of the drain drawing equipment being about 18 m and a curve being needed for turning round, as well as there being a dumping-ground near the canal, the drain ends are at a distance of about 40 m from the canals.

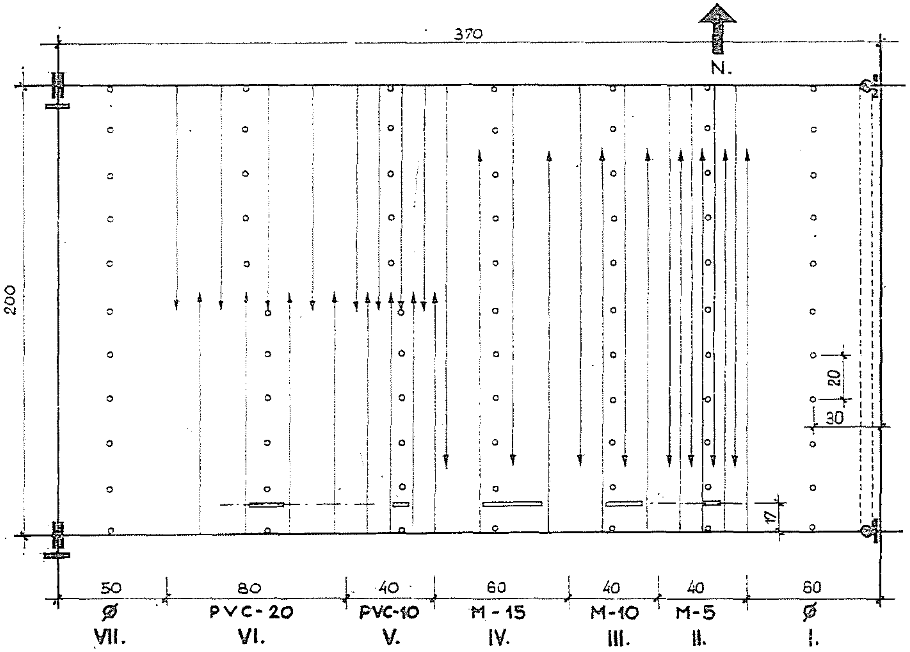

Fig. 2 Layout sketch of the parcel for drainage experiments.

M—5	Mole drains, 5 m spacing
M—10	Mole drains, 10 m spacing
M—15	Mole drains, 15 m spacing
PVC—10	PVC drains, 10 m spacing
PVC—20	PVC drains, 20 m spacing
○	Control
◦	Piezometer
▭	7 piezometers
●	Pumping station

PVC drains have also been drawn by a tractor type D4K–B, using a plastic-draining machine type *B*–750, made in the German Democratic Republic [10]. Length of the drains of about 40 mm size extends to the half width of the field parcel (Fig.2).

On the experimental parcel a series of experiments of subsurface irrigation by rising water table and of drainage were carried out in September 1966. From data of the observation wells it could be stated that in the cases of both irrigation and drainage an optimum groundwater level control might be achieved by mole drains spaced at 5 m. While these produced in the middle of the lot a groundwater level variation of 50 cm for subsurface irrigation, drainage during 9 days could produce but 40 cm. As against this, in the undrained (control) stripe, similarly during 9 days, irrigation changed groundwater level by 25 cm only, and drainage even by as low as 16 cm [10]. It should be noted that values observed with mole drains spaced at 10 m were but some centimetres less favourable. (Detailed data processing is going on.)

These experiments furnished encouraging answers to the question, how groundwater table level develops in the median line of drains, i.e. parallel to them, during irrigation and drainage. Several important problems, however, have still remained uncleared, such as:

a) Whether in the marshy soil, much fissured in dry condition and swelling when saturated, a *regular level* corresponding to the given conditions *can form at all*, or whether water is moving only to and fro, in galleries and fissures?

b) How do the drawdown and rising levels develop *in time* in a plane perpendicular to the drains, for each drain type?

c) To what extent do the lowest and highest point of the drawdown and rising water table level *deviate from the average depth?*

d) Taking the above statements and the construction costs into consideration, *what kind of draining method* and *what drain spacing* would provide optimum solution?

To clear the above problems considered essential both theoretically and practically, (and also to control results of the quoted September experiments), field investigations with subsurface irrigation and drainage were started in the last quarter of 1966. These experiments were carried out within the framework of research performed by the *Department of Water Resources Development of the Budapest Technical University*, with the active co-operation and support of technical managers of the *Keszthely Region Company for Marsh Utilization and Water Management.*

Materials and methods involved in the marshland draining experiments

Field experiments were performed from 5th to 16th October 1966. During this period, as indicated by data of the Meteorological Station operating in the marshland at a distance of hardly 0.5 km from the experimental parcel of land, no considerable atmospherical precipitation could be observed. Surface of the area investigated was covered with grass.

The section to be examined was set out at right angles to the line of drains in a distance of not more than 17 m from the canal AT/1 (Fig.2).

As already mentioned, the mole drains lead alternately into the northern and southern canal of the parcel, and their ends are about 35 m away from the other canal. Therefore, in the line of their section, for the mole drain stripe of 5 m distance actually a drain type of 10 m spacing (with no intermediate drain), and for the mole drain stripe of 10 m distance a drain type of 20 m spacing were tested. Since drain spacings of 10 and 20 m are applied even in the case of PVC drains, this solution has facilitated to compare the results.

The object of our investigations was to observe the formation of groundwater table in the section perpendicular to the line of drains, while executing several days' subsurface irrigation and drainage for the parcel with mole and PVC drains of 10 and 20 m spacing. Measurements were anticipated to be executed by electric measuring sounds to be driven at any optional point. This method, however, has proved to be inadequate, owing to the long time needed for the water table to reach a constant state, the phenomenon being of

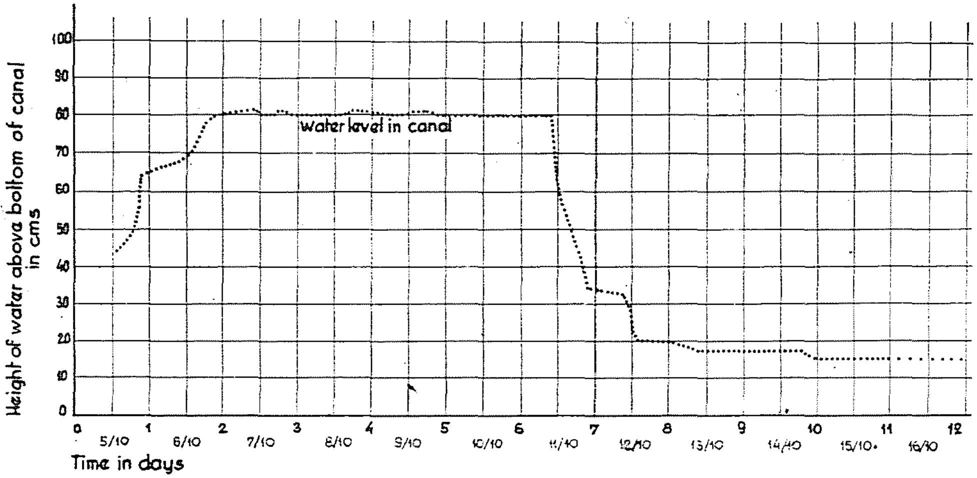

Fig. 3 Water levels in canals in the course of subsurface irrigation and drainage experiments.

unsteady character. For this reason a series of observation wells was established for the period of experiments even in the section examined (whereas possibility to test at an arbitrary point has been given up). This well series consisted of 7 wells for each drain spacing of the types investigated, i.e. of a total of 28 wells.

During investigation, for the sake of subsurface irrigation first a nearly constant water level was ensured by pumping water in canals AT/1 and AT/3 bordering the parcel longitudinally, then for drainage, the water level of canals was lowered. Average water level measured in the canals from the bottom has been indicated in Fig.3. As shown here, the high water level required to irrigation could be ensured for about 4.5 days at a level fluctuation of as little as 1 cm. In the course of drainage a low level was maintained for 3.5 days varying by no more than 2 cm.

It is mentioned here that in the irrigation stage of investigations round 2900 cu.m of water were lifted by two pumps for filling the canals. When it came to drainage, totally 2611 cu.m of water was withdrawn from the longitudinal canals bordering the lot.

Water levels both in observation wells and in canals were recorded four times a day: at 10 h a.m., 2, 6 and 10 h p.m.

Results of field experiments and discussion

Data of groundwater table level, obtained in the course of subsurface irrigation and drainage between the mole drains at 2 p.m. every day have been indicated in Figs. 4 and 5. Water levels measured between the mole drains lined with PVC pipes are shown in a similar way in Figs. 6 and 7.

The above figures demonstrate that sections of groundwater level between the drains during irrigation and drainage may be considered as *regular curves*. This is also apparent from mole drain alternating (Figs.4 and 5).

To facilitate comparison of measurement results, for each drain type both groundwater levels observed in the midline of drain spacing during subsurface irrigation, and average water levels in the canals have been indicated in Fig.8. As it appears from Fig.8, water levels in the canals closable by locks were very low before experimental irrigation. Thus, under nearly the whole experimental parcel of land a relatively deep groundwater table level of about 66 cm could be observed. In the stripe of mole drains lined with PVC pipe spaced at 20 m —as shown by the September experiments completed four days before— a groundwater table level 10 cm higher than that was measured.

In the course of experimental irrigation extremely high water levels (hardly 20 cm deeper than average ground level) were maintained in the canals. From

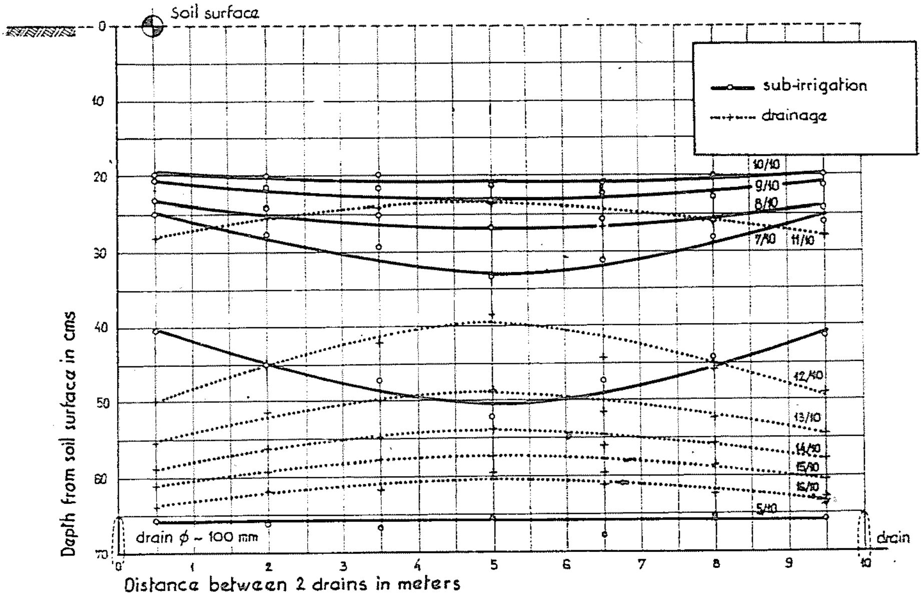

Fig. 4 Variations in groundwater table level between mole drains with 10 m spacing.

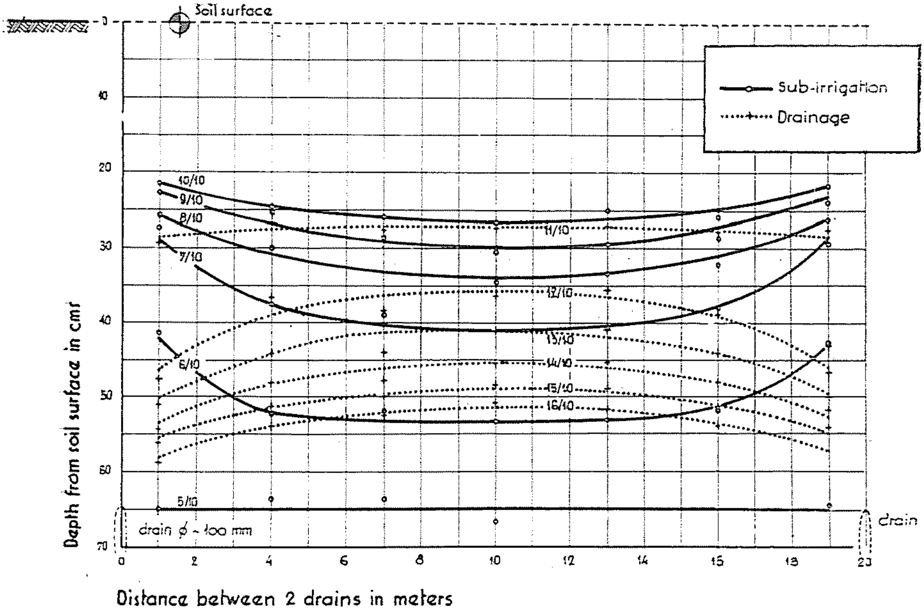

Fig. 5 Variations in groundwater table level between mole drains with 20 m spacing.

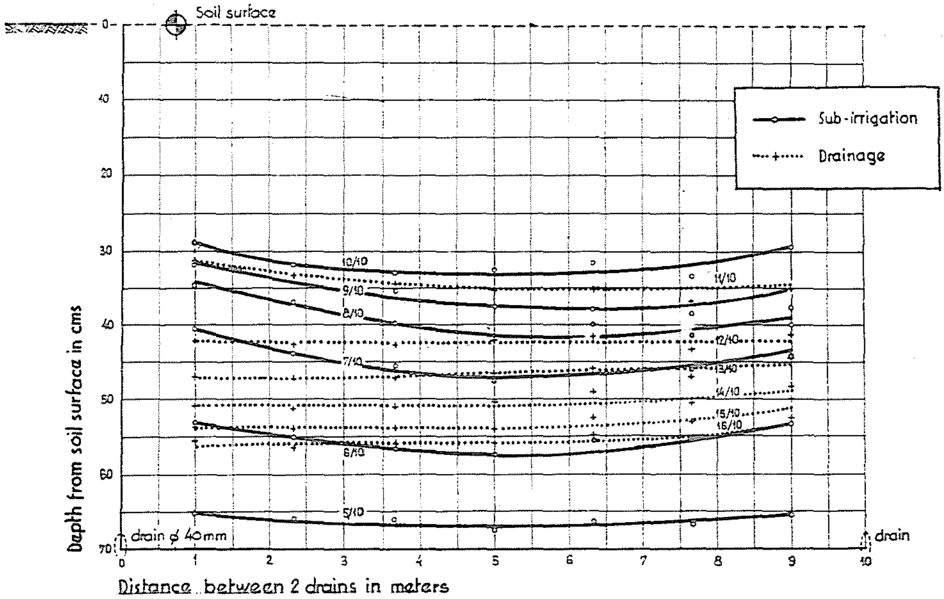

Fig. 6 Variations in groundwater table level between PVC drains with 10 m spacing.

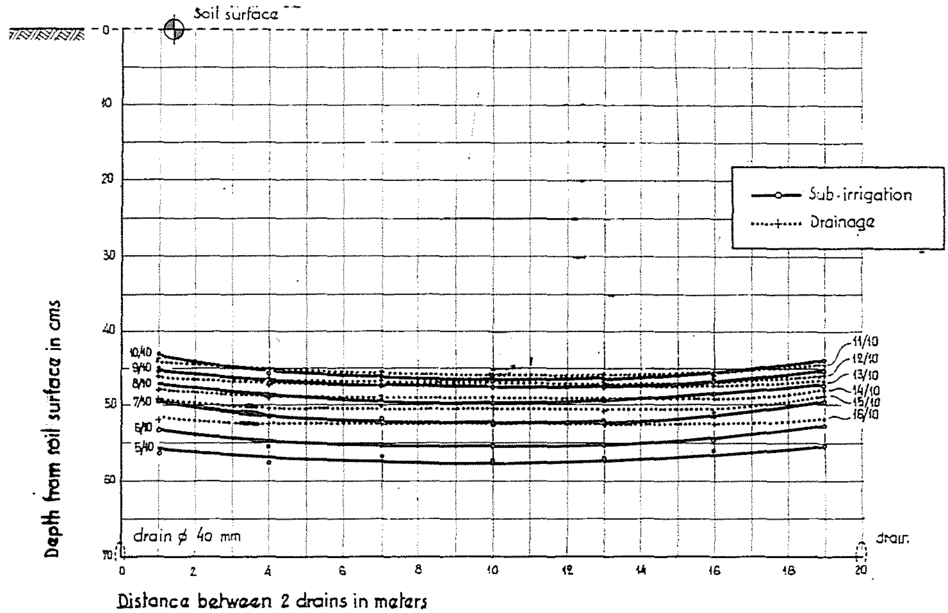

Fig. 7 Variations in groundwater table level between PVC drains with 20 m spacing.

the beginning of experiment a time of 24 hours was needed to reach this level (Fig.3). During 5 days (from 2 p.m. October 5 to 2 p.m. October 10) — according to data in Fig.8 — in the midline of drain spacings for each drain type the following absolute variations in water level had been recorded:

	row spacing	*rise in water level*
	m	cm
mole drains	10	44.1
	20	39.9
PVC drains	10	32.4
	20	11.4

(It is noted that the data in the observation well of the control parcel near the pumps, pertaining to the experimental section, had also been recorded. These data, however, have been omitted, partly because of seepage losses in the supply canal longitudinally bordering the stripe, and because of water conduction of the test drains drawn with the draining equipment at the end of stripe.)

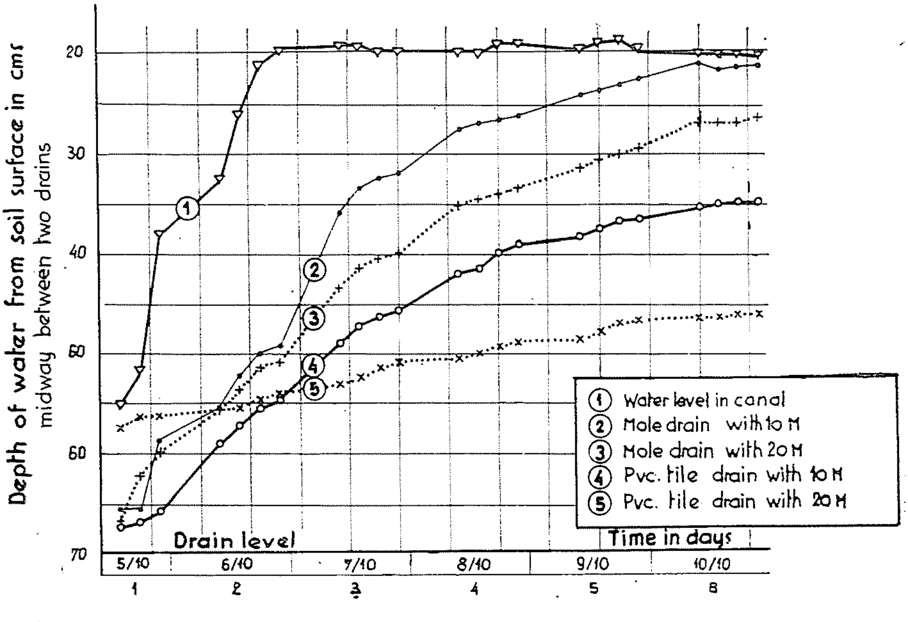

Fig. 8 Water level measured in the canals and in the midline between drains during subsurface irrigation tests.

During the drainage experiment of 6.5 days (from 10 p.m. October 10 to 10 a.m. October 17), water level of the canals reached the required minimum likewise after one day (Fig.3). Under the effect of drawdown, in the midline of drains the following absolute variations in groundwater level could be observed (Fig.9):

	row spacing m	*lowering in water level* cm
mole drains	10	41.4
	20	27.2
PVC drains	10	22.0
	20	7.8

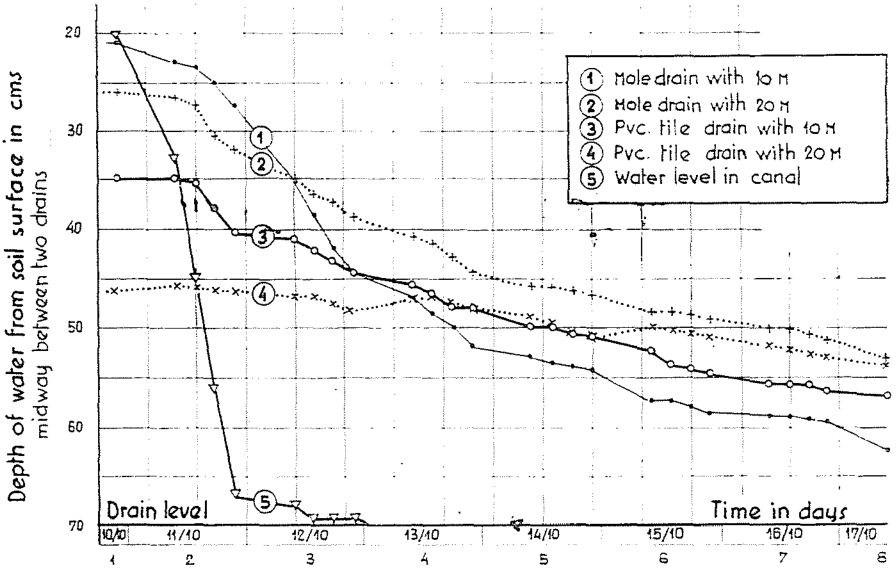

Fig. 9 Water level measured in the canals and in the midline between drains during drainage tests.

From the presented results, the following conclusions could be drawn:

a) Water conduction of the swelling marsh-soil of fibrous structure is likely to be similar to the seepage in granular soils. During irrigation and drainage, equipotential surfaces produced by drains may be considered as regular. As a consequence, in a marshland with nearly constant coefficient of permeability and hydraulic features, groundwater table between drains of the same type and dimensions, develops in the same way. In other words: *in this marshland the optimum drain depth and optimum drain spacing may be predetermined.*

b) It follows from the foregoing that during the unsteady process of groundwater rise and drawdown the sections of water surface observed in a perpendicular plane to the drains regularly vary in time.

The groundwater table follows the surface level of canals most quickly *between the mole drains of 10 m spacing*. As already mentioned before, the average depth of groundwater table optimum for plants is 40 cm. It should be added that to maintain a lower level of groundwater than that in the drains is not justified, neither in the interest of plant cultivation nor for the stability of drains. Thus in an extreme case, i.e. when the groundwater table is flush with that in the drains, hence at a depth of about 70 cm, within the section investigated the required *water level rise of 30 cm can be produced*, in one and a half day at a high water level in the canal (at about 80 cm from the bottom), while *in the full parcel of land in 2,5 days*. (The latter statement has been based on data obtained in the September investigations.)

For mole drains spaced at 20 m the times given above should be increased by about two days. These periods for subsurface irrigation have been calculated also for the PVC drain type. In the following table only effective times valid for the whole parcel of land have been indicated.

Times needed to rise groundwater table by 30 cm (from 70 cm to 40 cm):

for mole drains with 10 m spacing	2.5 days
for mole drains with 20 m spacing	3.0 days
for PVC drains with 10 m spacing	4.5 days
for PVC drains with 20 m spacing	8.5 days

In the Keszthely–Hévíz marshland, since the canalisation no higher average groundwater level than at a depth of 20 cm from ground level, has occurred during growth seasons. Therefore, in drainage calculations, the groundwater table depth of 20 cm is taken for an upper limit value. If this groundwater table is to be lowered by 40 cm to an average depth of 60 cm (from ground level) throughout the lot of land, then, according to our test data, this process will last for each drain type:

for mole drains with 10 m spacing	6.0 days
for mole drains with 20 m spacing	8.5 days
for PVC drains with 10 m spacing	13.0 days
for PVC drains with 20 m spacing	21.0 days

It should be noted that it is but seldom necessary to lower groundwater table by so much, if not at the beginning of the growth season, or in an extremely rainy period.

c) Deviation of the highest and lowest point of the drawdown and rising equipotential surfaces of groundwater table from the average depth in a given soil depends in addition to the depth and spacing of drains, primarily on the discharge drained and on the recharge. In our examinations, the maximum deviation from average water table level amounted, on the basis of data in Figs.4 through 7, to the following values:

for mole drains with 10 m spacing	5.5 cm
for mole drains with 20 m spacing	6.5 cm
for PVC drains with 10 m spacing	3.5 cm
for PVC drains with 20 m spacing	3.5 cm

Based on the above, it may be stated that *the extent of deviation is unimportant from the aspect of plants.*

d) As already mentioned, in the course of field experiments executed in September 1966 the most favourable irrigation and drainage values were obtained in the area of mole drains with 5 m spacing. Rise and drawdown situation for mole drains with 10 m spacing, however, was but by a few centimetres less advantageous. According to results of the investigations described here, an optimum solution has been provided by the drain type of 10 m spacing, although even that with 20 m spacing provides an advantageous water control.

In addition to technical-economical considerations discussed in the foregoing, even the problem of economy in itself should be studied. According to computations performed at the Reserarch Institute for Agricultural Machines [10], overall costs of 1 linear metre of PVC drains applied in this marshland amount to Ft 4.12, whereas those of mole drains only to Ft 0.17.

Durability of a PVC drain is defined first of all by its blocking-off time. In this respect no sufficient experience is available. Approximately, an operation period of 10 years may be reckoned with. According to durability tests of the mole drains, these have still been in good condition one year after their drawing. Their beneficial effect may be estimated to at least 3 years. In spite of this, in areas where soil conditions are favourable, *mole drainage is more economical, even if it must be remade every year.*

According to CHERKASSOW [7], permeability of marsh-soils may decrease during the years after drainage to one-tenth of the original value, then, after the peat has fairly been mineralized and has become granular or crumbly in structure, permeability may increase again and even exceed the original state. Accordingly, *in Keszthely–Hévíz bay a further decrease in permeability of the fostering soil may be expected.*

All aspects considered and data of experiments compared, *in the area investigated, application of mole drains with 10 m spacing has been found to be most advantageous.*

Summary

Subsequent to the drainage of the Keszthely—Hévíz marshland in the vicinity of Lake Balaton, during a mineralization process of the peat, permeability of the soil has decreased to such an extent as to require drainage, in order to control groundwater.

Based on preliminary studies, in an experimental parcel of land, stripes with mole drain and PVC drain types, at different spacings, have been constructed. In this parcel subsurface irrigation and drainage experiments were carried out, in order to investigate time-dependent variations in equipotential surface level between the drains. Test results, economy studies and literature data showed mole drains spaced at 10 m to be the optimum solution.

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