THE EFFECT OF DEEP AND SURFACE MANURING ON THE TEMPERATURE AND WATER CONTENT OF SAND SOILS

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A new basis for the amelioration of loose sand soils has been laid down in Hungary by S. *E g e r s z e g i* when he worked out the deep-manuring method in soil cultivation. The principles of this procedure were outlined in a separate paper (3) published in 1953.

E g e r s z e g i pointed out that the poor productivity of the Hungarian loose sand soils is due to their insufficient water and nutrient regime. A layer of organic manure applied in different depth of the soil prevents the soaking in of the precipitation into the subsoil and serves also as a »water depot« which provides the top soil with moisture for a rather long time. The water content of this manure layer is 10 to 20 times higher than that of the adjacent soil. If deep manured, the soil profile looses its water content considerably slower durring the vegetation period than the a surface fertilized or untreated area.

In Germany, at the beginning of the 40th years a method similar to deep manuring was tested by F. *H e i n r i c h*. The essential difference, however, between the two kinds of experimental work was that instead of organic manure ground basalt and limy marl was used by *H e i n r i c h*. From these fertilizers on sand soils a 3 mm thick layer was put into a depth of 15 cm. But the water regime of the soil showed no remarkable changes (6). On the basis of the investigations of A. *K l i m e s - S z m i k* this failure can easily be understood. He disclosed that beside inorganic colloids also organic ones are necessary in the subsoil; as to the water reigme only in this case a favourable effect can be expected (8).

To improve the water regime of the soil chemical weed control is suggested by *H e i n r i c h* (7). He proved that mechanical procedures applied against weeds increase the evaporation losses of the soil surface (1). The sample plots treated for 19 months with chemicals had a water content 15 per cent higher than the untreated ones.

The deep manuring method of E g e r s z e g i causes a considerably better water regime in loose sand soils and — as a further advantage — by creating a favourable nutrient supply it ensures high crops.

This fact turned in the last years the attention of many scientists to the problem. Due to their work the new cultural practice of deep manuring became widely known in a relatively short time.

The investigations of *Klimes-Szmik* deal with the influence of deep manuring on the water regime of sand soils. By detailed work in the laboratory and in the field he revealed *that deep manuring changes qualitatively the profile of loose sand soil and furnishes it with properties similar to those of light clay soils.* He also underlined that stable manure is the most advantageous material for deep fertilizing and the most convenient thickness of its layer is 1 cm. By deep manuring also the water storage of the soil in winter is affected very favourably (8).

Besides, deep manuring improves also the nutrient regime of the soil; this was proved by the works of *L. Varga* and *P. Gyurkó,* demonstrating the activity of soil microorganisms (12).

Deep manuring was considered and worked out by *Egerszegi* as a method suitable for permanent amelioration of sand soils utilized by agriculture. The favourable effect of this method, however, caught the eye also of the foresters in a little while.

In the Soviet Union forest experiments with similar purpose have been started in 1935. They were suggested by *G. N. Wyssocki* as a convenient meassure for the afforestation of the shifting sand areas along the banks of the Lower--Dnjepr (11). But these experiments brought only partial results.

In the course of experiments carried on by *I. Babos* on loose sand soils near Kunadacs in order to find out the best method of afforestation for that area, also deep manuring was applied succesfully (2). It could be established that even a single manure layer may exert the desired effect. Furthermore, it was noticed as a great adventage that by this measure also the length of the roots can be regulated.

L. Papp applied deep manuring in the nursery of Máriabesnyő, where seedlings of the Scots and Austrian pine (*Pinus silvestris L.* and *P. nigra var. austriaca Hoess*) were grown on a loose poor sand soil. His aim was: to raise stocky, abundantly rooted seedlings, suitable for the afforestation of the extremely unfavourable sand soils of the Hungarian Great Plain (ALFÖLD). As to a satisfactory solution of the problem these experiments showed promising results (9, 10).

Beside causing changes in the water and nutrient regime of the soil, deep manuring also affects its temperature. In a paper published already in 1953 (4) *Egerszegi* drew attention also to the agrometeorological influence of deep manuring.

While the effect of deep manuring on the water regime of the soil is — as shown above — a thoroughly examined question, *its influence on the soil temperature has not been studied intensively.*

Although *L. Papp* gives some interesting data on soil temperature, the figures published do not cover the whole problem, because they refer only to two observations made in summer of the year mentioned. No data on surveys at night are available, therefore neither the daily changes of the temperature at different levels of the soil nor their extreme values can be established. The fundamental microclimatological researches of *R. Wagner* (13, 14) revealed, however, the high importance of these characteristics, without which the temperature conditions of a given soil cannot be judged properly.

In the course of experimental raising Scots pine seedlings also the influence of deep manuring was studied by the author. For one year and a half the temperatures and (in one vegetation period) also the water content of the soil were measured.

On the basis of the survey results obtained not only the effect of deep manuring on the temperature of the soil is characterized in this paper, but also a brief report on its water regime will be given.

The experiments and investigations were carried on from the autumn of 1954 til the fall of 1956 in the Biological Station (ALSÓGÖD) of the Eötvös Lóránt University (BUDAPEST).

Material and method

For the first experiment performed in 1955 the tract was prepared in October 1954. This area has not been manured for a long time. In the course of the researches the following three variations were examined:

1. *Deep manuring of 2 layers, 20 and 40 cm. below the surface.*
2. *Deep manuring of one layer only, in a depth of 40 cm.*
3. *Untreated.*

As fertilizer stable manure was used in a 2 cm. thick layer.

For each variation a 5 × 5 m. plot was prepared and in March 1955 all plots were divided into 3 subplots which measured 1 × 2 m. and were planted with seeds and one-year seedlings of Scots pine.

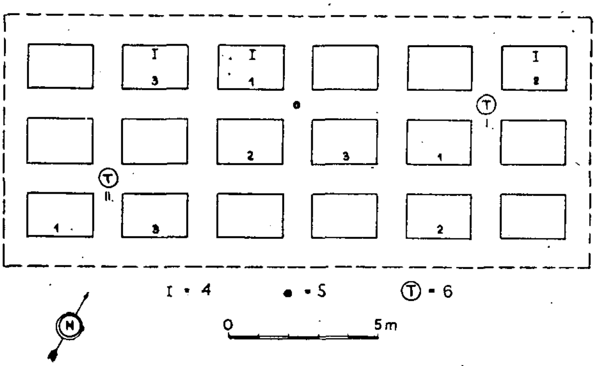


Fig. 1. The location of the plots.
1 = deep manuring, 2 = surface fertilizing, 3 = untreated control, 4 = mercurial thermometers 5 = ohmmeters, 6 = the place of the soil sample.

Gaining necessary experience in this preliminary experiment, for the actual investigation the plot was prepared in October 1955. Three variations were applied again:

1. *Deep manuring of one layer 20 cm. below the surface.*
2. *Surface fertilizing.*
3. *Untreated.*

For deep fertilizing also in this case a stable manure layer of 2 cm tickness was applied. For surface fertilizing the same quantity of manure was mixed uniformly into the top soil which was 20 cm. thick. On the untreated plots the soil was turned over. In order to ensure higher effectiveness for manuring, the plots were isolated to a depth of 50 cm. with bituminized cardboards.

Previously, in spring 1953, the experimental area was slightly fertilized with stable manure.

The experiment was carried on in three replications; the location of the plots are shown by Fig. 1.

From the 18 plots of the whole area 9 belonged to this experiment and were numbered. On the other 9 plots the deep manuring experiments were combined iwth irrigation. The results of this part of the investigations will be published in a separate paper.

The plots measured 1,5 × 2,2 m. and were separated by paths 1 m. broad.

In choosing suitable experimental plots uniformity of the area was looked upon as the main precondition. Furthermore, because microclimatological investigations were also planned, the disturbing influence of the neighbouring trees had to be eliminated as far as possible. This requirement could be met satisfactorily, only the shade of a single tree 10 m. apart reached the plot in the early forenoon. A south-west running line of low trees shadowed the plot in the late afternoon and exerted, therefore, no considerable influence.

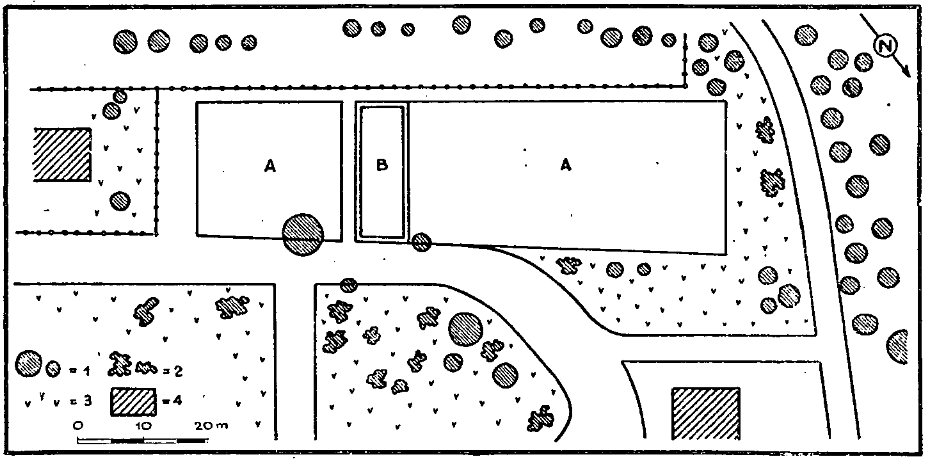


Fig. 2. The experimental area and are shown.
A—B = experimental field, B = the place of the experiment, 1 = trees, 2 = bushes, 3 = grassland, 4 = buildings.

The surroundings of the experimental area are shown by Fig. 2.

The soil of the experimental area is light coloured loose sand. It was analysed by *P. Stefanovits* (Chief of Division, Agrochemical Research Institute, BUDAPEST) whom the author thanks sincerely for his help.

From December 1955 to October 1956 the soil temperature was measured on the deep and surface manureed as well as on the untreated plots in six levels each: *2, 10, 15, 20, 25 and 30 cm.* below the surface. As far as it was possible the principles established by *R. Wagner* (13) concerning the measurement of soil temperatures (with respect to the characteristics of microclimatology) were also taken into consideration. In the depths of 15 and 25 cm. the temperature was examined, because it is an important task to investigate the effect of a layer of manure put 20 cm. below the surface. Unfortunately, in the survey period temperature could be measured regularly only twice a day in the fixed moments every morning and at noon.

But in this area from 15 June to 1 July 1956 *R. Wagner,* Professor of University, has led microclimatological measurements and in connection with this work the temperatures on the experimental plots were also established by observations carried out day and night hourly

Within the scope of the microclimatological investigations in the experimental area also the air temperature was registered in two altitudes and every 15 minutes.

During the whole time mercurial thermometers were used for controlling the soil temperature and air temperature was measured by ohmmeters.

From 1 May to 1 October 1956 the water content of the soil was stated six times.

On every occasion from all plots and from each plot respectively 2 to 3 soil samples were taken, weighing about 100—100 g each. Sampling was carried out partly by a soil borer partly by digging small pits. Samples were taken at every turn from 15 and 25 cm depth.

From the deep manured layer samples were taken twice for comparison; their moisture content surpassed nearly 10 times that of the samples taken from the untreated plots. This result corresponds entirely with the data of the literature (5).

Results and conclusions

First of all the characteristics of the soil of the experimental area are given below.

From two spots of the area soil samples were taken and their analysis showed that the soil of the plots is uniform.

In the soil profile following layers can be seen

0 to 20 cm. light greyish-brown sand, rich in humus
20 to 35 cm. yellowish brown sand with a small humus content
35 to 80 cm. yellow sand (particle size about 0,1 mm.).

The type of the profile is that of a sand with only a small amount of humus and containing many pieces of muscovite of about 1 mm. diameter. The quantity of the coloured particles is of medium degree. In the cultivated layer remnants of stable manure, applied 3 years ago are to be found. The chemical reaction of

TABLE 1.

The place of the soil sample		hy	humus %	$CaCO_3$ %
I.	0—20 cm.	0,47	1,32	12,81
I.	20—35 cm.	0,29	0,46	13,86
I.	35—80 cm.	0,28	0,34	15,54
II.	0—20 cm.	0,44	1,40	14,49
II.	20—50 cm.	0,32	0,58	16,80

the profile is neutral on the whole cross section, calcium carbonate appears in every layer.

The results of soil analysis are given in Table 1.

The relatively low value of the hygroscopicity (hy) which amounts not even in the humus containing layer to 0,5 shows that the soil is poor in elutriatable particles (silt), accordingly its water retaining capacity is low. The content on calcium carbonate is abotu 15 percent, this is for sand soils a very high proportion.

Having low water holding capacity, this soil seemed to be suitable for deep manuring experiments.

In the course of the preliminary experiments performed in 1954 and 1955 soil temperature could be measured (at the levels of 5, 20 and 40 cm below the surface) only on some occasions. Water contents had not been meassured. The data thus obtained showed differences of some tenths to 2° C between the deep manured and untreated plost. As the measurements were not carried out systematically and have only an informative character, further accounts are omitted.

In the volume increment and especially in the morphology of the roots considerable differences could be observed. On the plots which were deep manured in two layers (at the 20 and 40 cm. level) the seedlings developed far more abundant root system than those of the untreated plots.

Deep fertilizing with only one layer of manure (at the 40 cm. level) did not change noticeably the morphology of the roots, but — due to the influence of the influence of the treatment — they grew longer.

On the basis of these results the experiments in 1955/56. were carried out only with one manure layer applied 20 cm. below the surface, because this is the most suitable treatment to develop a root system which meets the requirements. L. Papp also pointed out that one layer of manure is entirely satisfactory, but he applied it at the 30 cm. level. *In the opinion of the author a deep fertilizing at the 20 cm. level is more convenient, because it results in seedlings with bushy, 25 cm long roots, while from manuring in 30 cm. depth plants with about 35 cm long roots can be expected.* Theoretically the latter treatment may be more favourable, but the customary methods of the practice are not satisfactory — in the opinion of the author — for saving the full root system when seedlings with extremely long roots should be lifted.

The results of the investigation carried on in 1956 and concerning the water content of the soil are summarized in Table 2.

TABLE 2.

Method of manuring	4 may		31 may		13 july		26 july		26 sept.		1 october	
cm.	15	25	15	25	15	25	15	25	15	25	15	25
deep manuring	13,4	10,0	8,6	10,0	8,1	9,8	7,6	9,5	6,3	8,4	6,1	7,9
surface fertilizing	10,5	10,1	9,3	9,4	10,0	6,3	7,6	5,4	6,9	5,8	8,5	6,1
untreated control	10,3	8,8	7,8	6,6	6,1	6,6	6,1	5,0	6,0	5,0	5,6	4,6

The water content is expressed in percentage of the fresh weight of the soil. The data prove that the deep manured soil has stored much more moisture during the winter than the surface manured and untreated soil. In the vegetation period the soil of all variants of the experiment showed a successive decrease of their water content, but this was the leaston the deep manured plots. At the end of the vegetation period the moisture of these plots was nearly twice as much as that of the untreated ones.

Despite the fact that water content measurings were made on few occasions and in two layers (at the 15 and 25 cm. level) only, from the data which could be gathered water content isophlets were constructed. Altough these lines are sketched arbitrarily, they demonstrate clearly the differences among the three variants (Fig. 3.).

The column graphs below the isopleths show the quantity of precipitation in the period concerned; the connection between these values and those of the water content of the soil can be judged easily.

The course of the isopleths in the examined layers (at the 15 and 25 cm. level) of the deep manured and untreated soil is opposite. It can be seen clearly that the untreated soil dries up successively from below, while the moisture content of the drying top layer of the deep manured soil is supplemented obviously by the reserves of the manure layer and and had, therefore, at the time of controlling a considerably higher water content than the untreated soil.

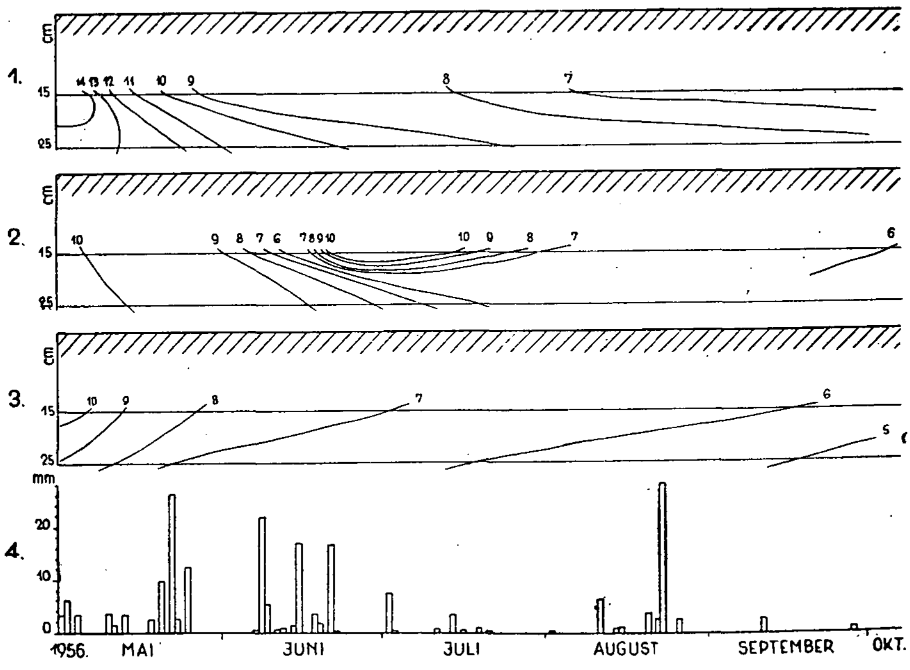


Fig. 3.

The water content of the soil profil and the quantity of precipitation in the experimental time.
1 = deep manuring, 2 = surface fertilizing, 3 = untreated control, 4 = precipitation.

The entirely different trend of the isopleths in the surface manured soil is probably due to the fact, that surface manuring promotes the percolation of larger amounts of summer precipitation to a greater depth. Therefore, the higher water content at the beginning of July may be the consequence of the considerable quantity of precipitation falling down in the middle of June.

Certainly the important masses of rain falling about the 20th of August also drenched the surface manured soil more than 15 cm deep, but at that time the water content was not established. However, the relatively high moisture content which could be observed 15 cm. below the surface at the end of September may be ascribed also to the effect of surface fertilizing and drenching respectively.

The curve of the isopleths in the surface manured soils is much more steep than in the other two variants. From this fact the conclusion may be drawn, that although the upper layers of the surface fertilized soil drench quicker and in a higher degree, they on the other hand, desiccate faster.

Before discussing and evaluating the data of soil temperature it must be stressed, that by measurements performed twice daily only the temperature differences observed in the three variants at a given moment could be ascertained. However, from these differences some conclusions as to the daily fluctuation of the temperature may be drawn.

From the records of nearly one year's observations the data for 10 days are separated in Table 3.

In choosing these example days for Table 6 to the requirements of microclimatological researches proper attention was given: *bright, dry, and as far as possible calm days were selected.* Furthermore the Table contains also the data of one the coldest winter and hottest summer days.

From the results of the measurements following establishments could be drawn.

1. In the winter months in the profile of the deep and surface manured and untreated plots no differences of stead character can be observed. It could be noticed only, that on very cold days (10 February) the temperature of the untreated soil is by 0,5 to 1,5° C higher than that of the fertilized plots. This result seems to be a contradiction especially if we suppose that the water content of both manured variants is higher than that of the untreated one.

This contradiction may probably be eliminated by a displacement which eventually occurs in the daily course of the temperature, but the temperature data available showed no signs of it.

2. In spring the deep manured soil warms up first. This can be understood easily: the manure layer exerts an isolating effect and precents the penetration of the heat downward in the soil. Therefore, the insolation heat absorbed by the soil warms the layers above the manure level first. The warming up of the surface fertilized soil proceeds most slowly. In comparison to the other two variants its temperature is during the whole summer lower, but in dry periods it may be higher than that of the deep manured soil.

3. The temperature data of the untreated plots have a wider amplitude, and conversely, both manuring methods lessen the extremities of soil temperature. In the upper layers the difference — as compared with the values of the fertilized and in the first place of the deep manured soil — may score 2 to 4° C and 30 cm. below the surface 1,5° C.

4. In autumn the untreated soil shows the lowest temperature, it turns cold considerably quicker than the manured plots. In this season in the layers below the 20 cm. level of the deep manured soil the daily fluctuation of the temperature is only of a minimum degree; this phenomenon may also be attributed to the isolation influence of the deep manure layer.

From the data of soil temperature measurings performed hourly the daily

TABLE 3.

Date		time		deep manuring						surface fertilizing						untreated control					
				cm.																	
		hour	mi- nute	5*	10	15	20	25	30	5*	10	15	20	25	30	5*	10	15	20	25	30
		6	43	0,6	0,0	0,6	—	—	—	0,5	0,9	1,2	—	—	—	0,8	1,0	1,2	—	—	—
1 january	1956	13	43	3,2	2,4	1,9	—	—	—	3,4	2,6	2,9	—	—	—	3,3	2,4	1,7	—	—	—
		6	43	-0,8	-0,1	-0,1	—	—	—	-0,7	-0,2	-0,1	—	—	—	-0,6	-0,1	-0,1	—	—	—
8 january	1956	13	43	-0,2	-0,1	0,0	—	—	—	-0,3	-0,2	-0,2	—	—	—	-0,1	-0,1	0,0	—	—	—
		6	43	0,7	1,3	1,1	—	—	—	1,0	1,1	1,0	—	—	—	1,0	1,1	1,5	—	—	—
16 january	1956	13	43	4,9	3,3	2,4	—	—	—	4,8	3,6	2,4	—	—	—	4,0	3,4	2,3	—	—	—
		6	43	-7,4	-6,2	-5,6	—	—	—	-7,1	-6,8	-5,8	—	—	—	-6,4	-5,6	-5,1	—	—	—
10 february	1956	13	43	-5,9	-5,5	-5,4	—	—	—	-5,5	-5,9	-5,7	—	—	—	-5,5	-5,2	-5,1	—	—	—
		6	43	5,4	5,8	6,7	—	—	—	4,9	5,4	6,5	—	—	—	5,0	6,3	6,6	—	—	—
4 april	1956	13	43	15,1	11,9	10,0	—	—	—	14,7	12,3	9,5	—	—	—	14,6	12,3	10,1	—	—	—
		6	43	10,9	11,5	12,2	12,0	12,6	12,6	10,7	—	12,1	12,2	12,4	11,9	10,6	11,2	12,1	11,7	12,3	12,3
17 april	1956	13	43	19,6	15,7	14,3	12,4	12,6	12,2	19,3	—	13,5	12,6	12,2	11,3	19,5	15,8	14,1	12,8	12,3	12,3
		6	43	16,0	16,7	17,8	18,3	18,6	18,4	15,5	—	17,9	18,3	18,6	17,9	16,1	17,2	18,5	18,4	18,9	19,1
30 may	1956	13	43	33,8	26,9	23,4	20,0	18,8	18,4	32,5	—	20,7	19,2	18,6	17,6	32,6	27,4	23,1	19,8	19,3	18,9
		6	43	22,0	22,3	23,3	23,8	24,0	23,6	21,9	21,7	—	23,4	23,7	23,3	21,2	22,2	23,3	24,2	23,7	23,7
22 july	1956	13	43	42,2	27,3	25,6	24,1	23,6	23,0	40,2	26,5	—	23,4	23,4	22,8	43,9	26,6	25,6	24,7	23,6	23,3
		6	43	22,7	22,4	23,0	23,9	23,5	23,1	22,0	22,4	—	23,3	22,2	23,0	20,9	21,7	22,8	23,5	22,9	22,8
21 august	1956	13	43	36,4	26,3	24,6	23,0	22,6	22,2	35,8	26,3	—	22,7	22,7	22,1	37,3	26,8	24,3	23,6	22,5	22,3
		6	43	11,0	14,1	14,2	15,6	16,3	16,0	11,1	14,2	—	16,2	16,8	16,3	10,5	13,7	14,9	15,9	15,8	15,9
30 september	1956	13	43	30,1	20,5	18,4	16,6	16,4	16,5	31,0	19,9	—	16,6	16,6	16,1	29,3	20,2	18,2	17,0	16,3	15,9

* in 2 cm. deep from 22 july 1956.

course and the extreme values of the temperature can be obtained; these data give a rather complete picture of the temperature conditions of the soil profiles.

The observation data taken from 10, 20 and 30 cm. depth on the relatively brightest day of a fortnight period are shown in Fig. 4.

The daily course of the soil temperature 2 cm. below the surface is not demonstrated, because in this layer — as it can be established from the data of other days — the development of the temperature does not depend chiefly on the manner of fertilizing, but is influenced in the first place by the factors connected with the insolation (shade, clouds, etc.).

To present a comparison, also the data of air temperature measured 10 and 180 cm.

Above the experimental plots are shown in Fig. 4.; the graphs permit the establishment of further differences characterizing the three variants:

1. In 10 cm. depth the maximum amplitude of the daily temperature can be observed in the untreated, and the minimum in the surface manured soil. The temperature amplitude of the untreated soil surpasses that of the deep manured soil by 1° C and that of the surface fertilized soil by 1,5° C.

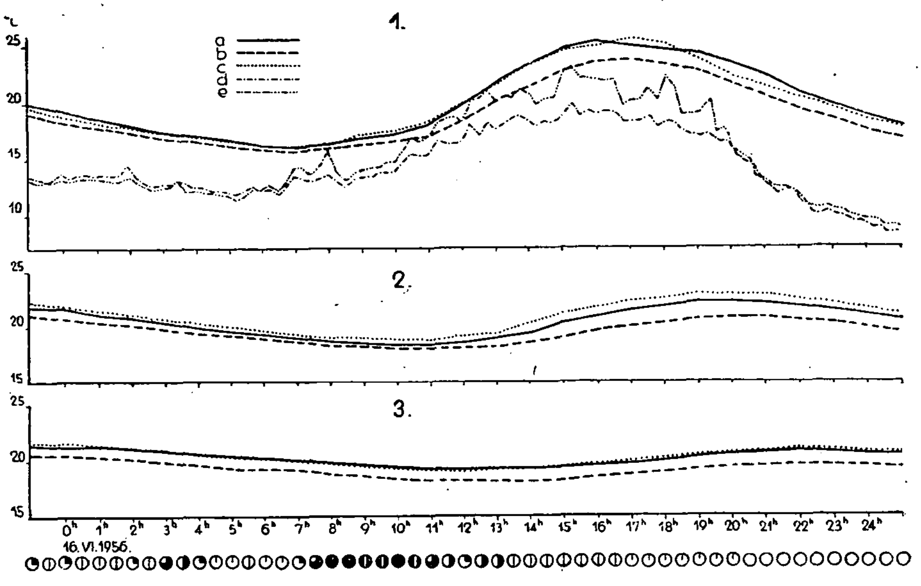


Fig. 4. The daily course of the soil and air temperature.
1 = the soil temperature in 10 cm. deep and the air temperature, 2 = the soil temperature in 20 cm. deep, 3 = the soil temperature in 30 cm. deep, a = deep manuring, b = surface fertilizing, c = untreated control, d = the air temperature measured 180 cm., e = the air temperature measured 10 cm.

In teh surface manured and untreated soil the temperature reaches its maximum at 16 h, in the deep manured soil at 15 h. In the soil of all variants the time of the minimum was 6 h (Middle-European standard time).

2. In 20 cm. depth the temperature amplitudes of the three variants relate to each other with differences similar to those found at the 10 cm. level. The

moderating effect of deep manuring is clearly proved partly by the fact that the amplitude of the daily temperature of the plots treated thus is by 0,5° C lesser than in the untreated soil and partly by the lower temperature (0,5° to 1,0° C). In the soil of all three variants the temperature maximum takes place at 18 h and the minimum about 10 h.

3. In 30 cm. depth there is no remarkable difference in the amplitudes of the daily temperature, its values are about 2,5° C in each variant.

The temperature has its maximum at 21 h, its minimum about 11 h.

4. The surface manured soil shows in every layer the lowest temperature. At 10 cm. level it is by 0,5° to 2,0° C, in 30 cm. depth by about 1,0° C lower than the temperature of the untreated soil.

5. In 10 and 30 cm. depths of the untreated and deep manured soils the thermometer shows — except all but extreme values — identical degrees. At 20 cm. level (in the layer of the manure), however, the temperature of the deep manured soil is nearly by 1,0° C lower than that of the untreated soil.

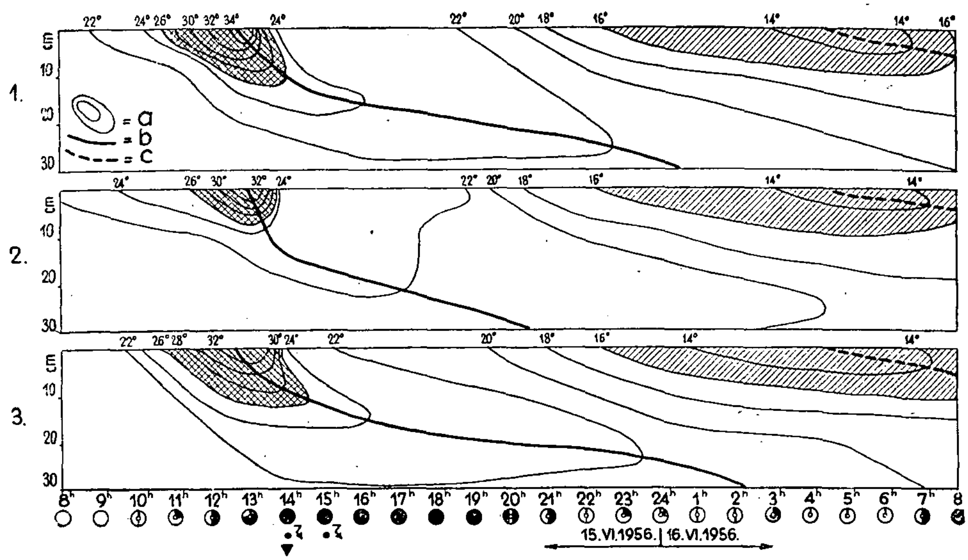
Still more complete picture on the temperature conditions of the whole soil profile are given by the temperature isopleths.

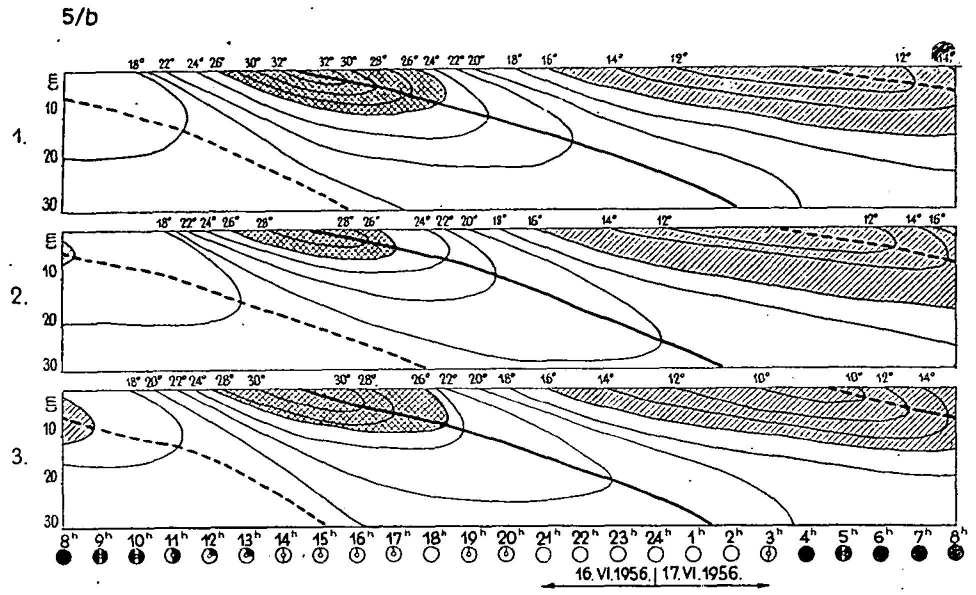
Fig. 5/a—c. shows the temperature isopleths of all three variants based on the records of three days and a half.

Unfortunately, in the fortnight when the microclimatic observations were carried out, the clouding cover was nearly uninterrupted and disturbed the characteristic temperature conditions. The relatively brightest day was 16 June, therefore the conclusions concerning the soil profile of each variant are chiefly drawn from the isopleths of this day. But even the values of this day are disturbed by an event: on the preceding day 16,9 mm. precipitation has fallen down and increased the moisture content of the upper soil layers considerably.

Analysing the temperature isopleths of the three variants, following establishments may be fixed:

5/a





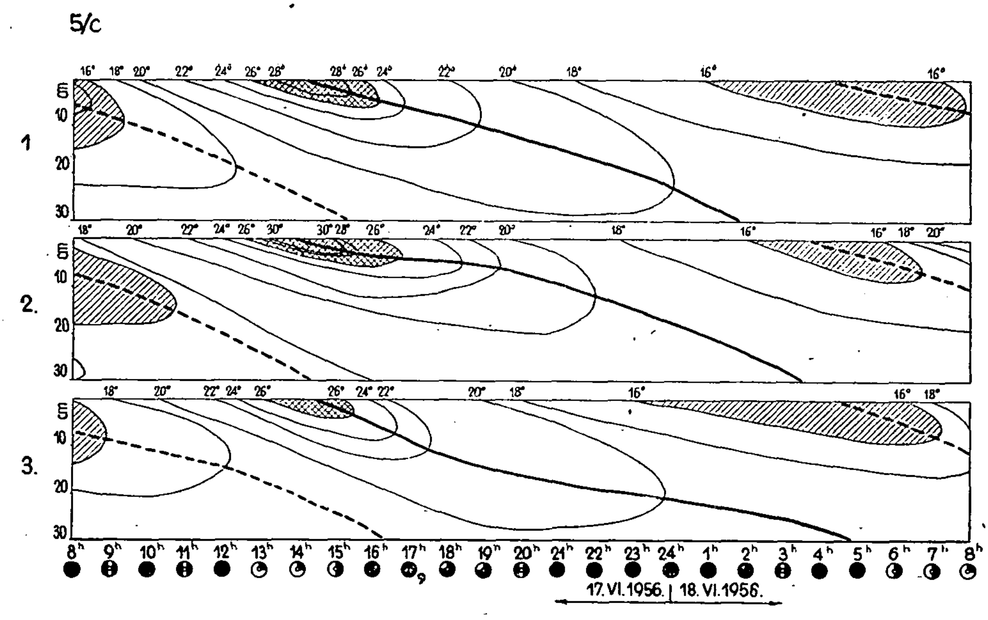


Fig. 5/a—c. Isopleths of the soil temperature.
1 = deep manuring, 2 = surface fertilizing, 3 = untreated control, a = isopleths, b = »warm level«, c = »cold level«.

1. The soil temperature of the surface manured plots is lower and more balanced: the curve of the isopleths is less steep than that of the other two variants.

2. In the uppermost 2 cm. layer of the surface fertilized soil the low temperature lasts for the shortest time. At about 5,30 h the temperature of this layer exceeds already 14° C. In the soil of the two other variants the temperature in the same layer reaches 14° C at about 6,15 h only. Moreover between their temperature considerable differences can be observed. The uppermost layer of the deep manured soil cools to 14° C only at about 2,0 h, but the same layer of the untreated soil shows that temperature elready at 23,30 h and also the cooling down penetrates deeper in it.

3. Remarkable differences can be noticed also in the warming up of the soil of the three variants. The surface manured soil gets warm moderately: the temperature of the uppermost 2 cm. layer surpasses 28,0° C only between 12,30 and 15,30 h while in the same laye of the deep manured soil a temperature over 28,0° C can be observed from 12,0 to 16,30 h. In this respect the untreated and deep manured plots display a similar behaviour with a postponement of half an hour only. The essential difference between these two variants is, that the deep manured soil has a higher temperature gradient and, as a consequence, its temperature maximum is by about 1,0° C higher (due to the checking effect of the deep manure layer on temperature penetration).

4. The »cold level« and »warm level« defined by *Wagner* (14) has nearly the same angle; this fact indicates a good change of the heat in both direction. The slope of the cold level — esperially in the deeper layers of the untreated soil — is rather steep, showing that the temperature changes quicker here than in manured soils. This phenomenon verifies indirectly also the heat isolation effect of the manure and we may conclude from it that the accumualtion of heat in the lower layers of the untreated soil is less than in the manured ones.

On the following days the warming up of the soil assummed a rather different countenance. The temperature of the surface fertilized soil was higher than that of the untreated plots. This is by all means directly due to the greater clouding over on those days. The heat reserve accumlated in the deeper layer of the manured soils together with the insolation resulted in higher temperatures in the upper layers of these soils.

It is worth to analyse the effect of the stormy hail which occurred on 15 June about 13 h. The relatively considerable amount (16,9 mm.) of cold precipitation falling down very fast changed decidedly the course of the temperature isopleths. The greatest difference can be observed in the profile of the surface fertilized soil. This corroborates the establishment given above that the surface manuring facilitates faster penetration of the precipitation to a relatively greater depth, where the layers are more cooled down.

Summary

In connection with growing seedlings of Scots pine, for one year and a half investigations were performed on loose sand soils in order to examine the effect of deep and surface manuring on the heat and water regime of the soil. Following facts could be ascertained:

2. The results pertaining to the latter problem essentially correspond with

From the two procedures tested the effect of deep manuring seems to be more favourable, especially as to the water regime of the soil.

2. The results peratining to the latter problem essentially correspond with those obtained by *A. Klimes-Szmik* (8), revealing that in the vegetation period the desiccation of the fertilized soil is in its entire profile slower than that of the untreated soil (the manure layer serves as a water depot) and, therefore, the former ensures better water supply for the plants.

3. It should be underlined, that surface fertilizing contributes to quicker and deeper penetration of summer precipitation, but, on the other hand, the soil thus treated dries faster.

4. Surface manuring decreases the extreme changes of temperature of sandy areas: the warming up and cooling down of the soil is equally slower. But, on the other hand, the soil thus treated grows colder, chiefly in rainy periods.

5. The deep manure layer delays the expansion of heat to the layers beneath it. Moreover, due to its high moisture content, it may also store heat, despite the fact, that its temperature is slightly lower than that of a layer in the same depth in untreated soils. The advantage of deep manuring manifests itself chiefly in decreasing the extremeties of temperature and in ensuring higher temperature in sand soils. However, in case of heavy insolation this effect may become damageous, because the »heat isolation« of the deep manure layer may cause too high temperatures in the layers near the surface. This danger threatens far less if the manure layer is placed into greater.

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