CHANGES OF SOIL HUMIDITY AND ITS CORRELATION TO PHYTOMASS PRODUCTION IN SANDY MEADOW ASSOCIATIONS

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Received on 17th September, 1970

Comparative surveys in different parts of the world were started within the International Biological Program in order to establish exactly the phytomass production of various vegetation types. The evaluation of the results and the necessity of their comparability raised numerous methodological problems. These problems and the reference works on the subject are included in Handbook Nr. 6 of the IBP.

In Hungary, methodological problems were discussed in detail by Précsényi (1967) and Précsényi – Máthé (1969).

Most of the research workers did not limit their activities to the mere registration of the extent of phytomass productions, but tried to find a correlation between the phytomass production of different ecosystems, on one hand, and the values and changes of the ecological factors, on the other. (Weaver, 1958, Scott-Billings 1964, Dahlman – Kučera 1965, Bliss 1966, etc.).

The Department of Plant Taxonomy, of the Eötvös Loránd University has joined the work of IBP in 1967.

Sandy meadow associations were examined for their production conditions on the protected area of Csévharaszt where some interesting and valuable relicts of the original sandy wooded steppe vegetation of the Hungarian Lowland can be found and where complex bio-coenological examinations have been carried out for some years in co-operation with other institutions. According to our hypothesis the precipitation and the hydrological conditions of the sandy soil are, among the climatic conditions of the Lowlands, one of the most important influencing factors of the production of these meadows.

The present work is aimed therefore at the determination of soil humidity in different layers and of eventual relations to production.

Site and Methods

Prior to the present examinations on phytomass and soil humidity, research work has been done for some years in order to disclose the characteristic sandy plant associations as well as the ecological factors affecting their conditions (Simon — Kovács-Láng 1964, Simon — Kovács-Láng 1968, Kovács-Láng 1970, Simon — Batanouny 1971).

Based on the observation that the sand became overgrown with grass, weighings were carried out in 1968 on a one year old open meadow *(Brometum tectorum secaletosum)* and on the perennial open sandy meadow *(Festucetum vaginatae danubiale)*, in 1969 on the closing sandy steppe meadow *("Festucetum Wagneri")* and, as a control, on a rye field in the same area.

Weighing of phytomass: In the vegetation period from April to October 10 samples were taken from each of the aforesaid associations in form of 20×20×20 cm. monoliths; the overground part was cut off on the site, the floral and cryptogam material separated and weighed in air-dry condition together with the underground phytomass coming from the monoliths and cleaned from soil.

Simultaneously with the sampling, the soil humidity was measured in 3 bore holes in each of the marked plots of the associations.

Humidity was measured in natural meadow associations at dephts of 20, 40, 60, 100, 140, 200 cm, and in the rye field at 20, 40, 60, 80, 100, 120 and 140 cm. The average of three parallel humidity values was taken subsequently as a basis. There was but little difference between the parallel measurements.

A neutron-scattering moisture meter constructed by members of the Academic Research Institute for Agrochemistry and Soil Science, Hungarian Academy of Sciences was used. Measuring principle of measurement: The fast neutrons leaving the Pu — Be radiation source lose a considerable part of their energy through the collision with H atomic nuclei in the soil, and become thermic neutrons that can be detected by the G — M tube combined with the radiation source and covered with a silver foil. Since H atoms in mineral soils are directly proportional to soil humidity, the impulses proportional to humidity are measured with a ratemeter.

Prior to the examinations the calibration curve characteristic of the sandy soil was drawn. The calibration curve expressed the correlation between the soil humidity determined in the traditional way (oven) and the impulse values measured by the instrument. The measured impulse values were expressed in the percentage of a standard impulse number (I etalon). Due to its accuracy and simplicity this method is most suitable for mass weighing on mineral soils and for the periodic observation of the changes in soil humidity (Holmes-Turne 1958, Underwood — Van Bavel — Swanson 1956, di Gleria 1966, Török 1969).

Results

The sandy meadow associations can be described briefly as follows:

Brometum tectorum secaletosum, a one year old sandy meadow composed in spring, in virulent condition, by of *Secale silvestre* (A – D : 5), *Carex stenophylla* (A – D : 1) and *Poa bulbosa* (A – D : 1.) Among dicotyledonous floral plants *Medicago minima* was the only one to occur in great quantities. Sporadically occurring individuals of *Onosma arenaria* appear in summer. *Erigeron canadensis* and *Polygonum arenarium* are dominant in the autumn aspect.

The moss-lichen level of the meadow is very rich. The fresh bolsters of *Syntrichia ruralis* are conspicuous in spring; in summer they are reduced to insignificant brown batches and become again virulent in autumn in the rainy cooler period. The soil is covered by a practically uninterrupted lichen meadow composed of *Cladonia magyarica*, *Cl. furcata*, *Cl. subrangiformis*, *Cl. foliacea*, *Parmelia pokornyi* (cf. Verseghy – Kovács-Láng 1971).

Festucetum vaginatae danubiale, perennial open sandy steppe meadow. Dominant species: *Festuca vaginata* (A – D : 4 – 5), *Koeleria glauca* (A – D: 2), sporadically *Stipa sabulosa* and *S. capillata*. Typical floral plants: *Euphorbia seguieriana*, *Potentilla arenaria*, *Achillea kitaibeliana*, *Veronica dillenii*, *Alkanna tinctoria*, *Medicago minima*. Due to the open character of the meadow, the distribution of the vegetation is inhomogeneous (cf. Simon – Batanouny 1971).

Mainly for its quantity the moss-lichen level is not as rich as in the former association, although it is composed of the same species. The mass constituents of the meadow and the plants of the moss-lichen level can be found throughout the whole vegetation period, but new representatives of floral plants appear by the end of summer, such as *Centaurea arenaria* and *Polygonum arenarium*.

"*Festucetum wagneri*", perennial closing sandy steppe meadow. Poorer in species than the others, both for floral and cryptogamic plants. Dominant constituent: *Festuca wagneri* (A – D: 4 – 5), with *Stipa sabulosa* (A – D: 1 – 3) and *S. capillata* occurring in addition. Similarly to the former associations it is characterized by the following dicotyledonous floral plants: *Veronica dillenii*, *Euphorbia seguieriana*, *Galium verum*, *Eryngium campestre*. In April the yellow flowers of *Gagea minima* attract attention.

Its moss-lichen level is poorer than that of the other associations, both for its mass and for the number of species. The dominant plant is *Cladonia magyarica*; *Cl. furcata*, *Cl. subrangiformis* and, on open areas, *Cl. foliacea* are also of some importance.

Secaletum cultum, rye field. *Secale cereale* with very little weed. After the harvest in July there are only stubbles and some weeds on the surface. In autumn even these rests are ploughed in.

The soils of the associations in question are slightly humic sandy soils with a non-split profile. Only the uppermost layer of 10 – 15 cm presents a darker discolouration due to its 1 per cent humus content. The profile includes sporadically humic layers too (Simon — Kovács-Láng 1964).

In the soil of natural meadow associations the level of underground water remains even in spring under 2 m, and it was reached in the deeper rye field at 100—120 cm in spring and at 150 cm later. (Cf. Szodtfridt — Faragó 1968.) Vigorous gleization appears in the zone over the water level.

The quantitative changes of the phytomass in the ecosystems examined during the vegetation period are presented in Fig. 1.

The underground changes of the phytomass are different in the four ecosystems. In the one year old meadows of *Brometum tectorum secaletosum* and *Secaletum cultum*, as well as in the perennial open *Festucetum wagneri* the maximum is in May. The closing sandy meadow — *Festucetum wagneri* — presents the maximum of its underground phytomass in April and July. Dahlman — Kučera (1965) in their paper on prairies, have reported on a root phytomass maximum in July, the investigations of Wiegert — Evans (1964) a maximum in June—July, and the work of Précsényi (1969) on *Festucetum sulcatae* with a root maximum in April.

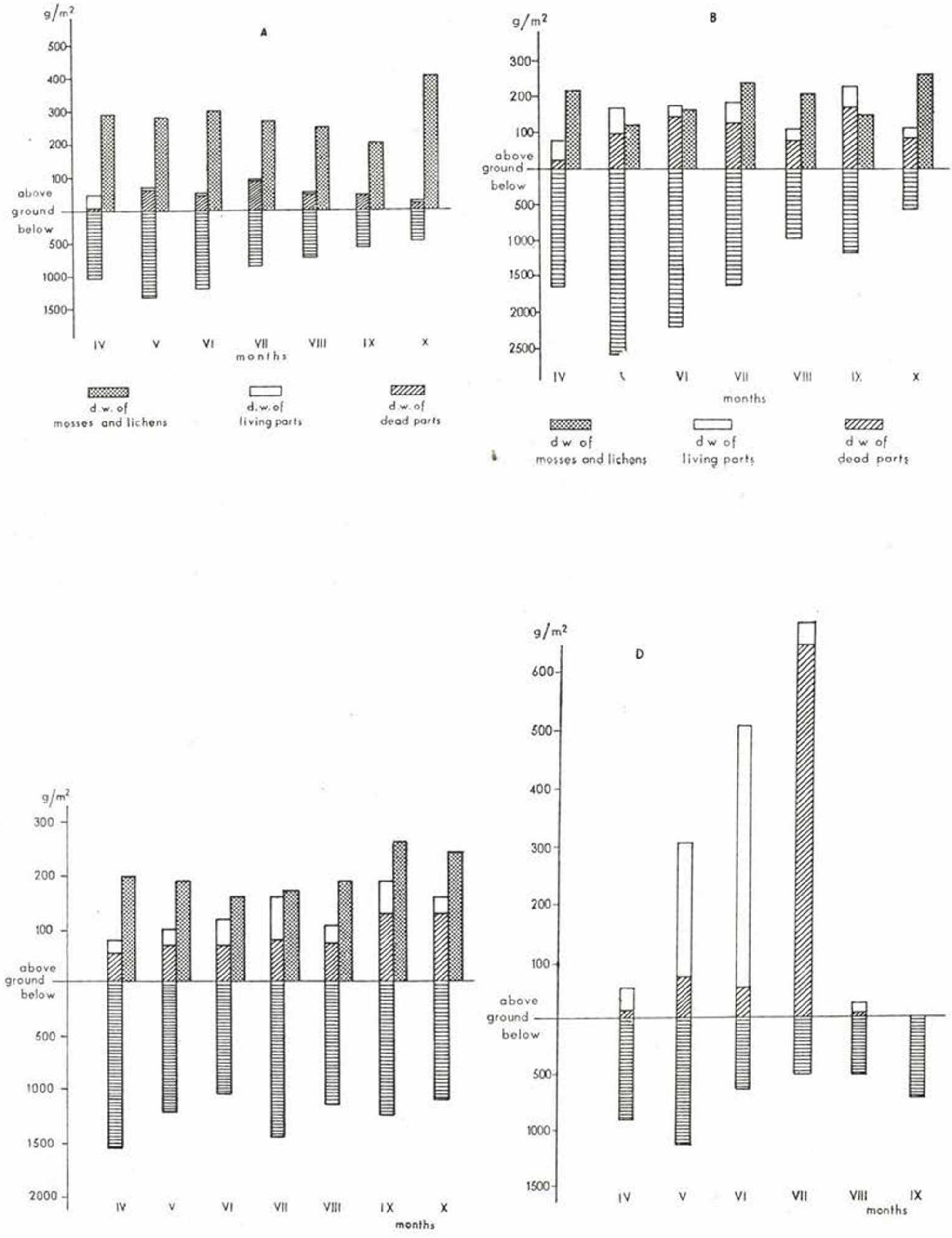
The dry matter content of the phytomass over ground presents a more variable aspect. In *Brometum*, living parts are dominant at the beginning of the vegetation period and the quantity of decayed organic substance after the rapid maturation of the fruit increases. Parallel by the underground parts, the overground phytomass of *Festucetum vaginatae* presents the maximum values in May and September. The fluctuation of the quantity of floral living parts indicates changes of the aspect. The phytomass of the closing *Festucetum wagneri* meadow presents an even increase till July; after a temporary decrease in August it reaches a second maximum in September.

The overground phytomass of the rye field presents a most rapid increase. Of course, the maximum is reached before the harvest, but by that time there is not much green living substance left.

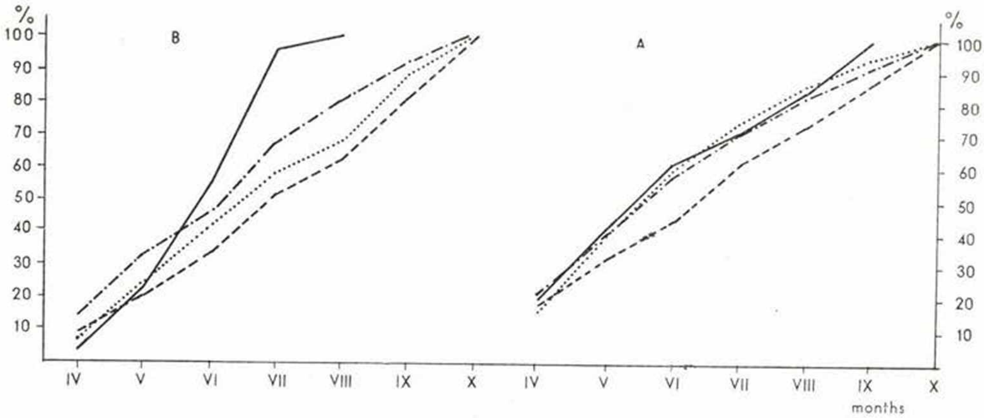
The phytomass of the moss-lichen level is of considerable weight in all of the three natural meadow associations and presents maximum values in spring and autumn. According to the diagrams the dry matter contents of *Brometum* and *Festucetum wagneri* are in every month superior to those of the phytomass produced by the floral plants. However, these values do not truly reflect the actual mass, because on these xerotherm sites the lichens are nearly always present in a mass corresponding to their dry state, while the floral plants in native state represent a mass by far superior to the values marked in the diagram.

As regards the accumulation rhythm of organic substances there is some difference between the associations both in the underground and the overground phytomass (Fig. 2/3).

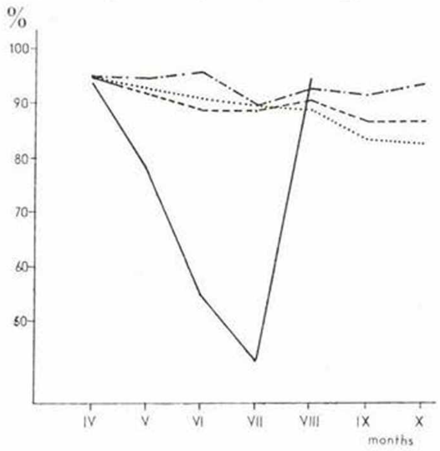
The underground phytomass accumulation of *Brometum* is fairly even, presenting only a more intensive rhythm at the beginning and a somewhat reduced one at the end of the vegetation period. The accu-



1. Changes in the phytomass of sandy meadow associations during the vegetation period. A) Brometum tectorium 1968, B) Festucetum vaginatae danubiale 1968, C) Festucetum wagneri 1969, D) rye field 1969



2. Accumulation rhytm of organic substances in the associations examined. A) Underground parts, B) overground parts.



3. Changes of the root importance index during the vegetation period.

-·-·-· Brometum tecterum
...... Festucetum vaginatae
– – – – Festucetum wagneri
——— rye field

mulation trend of *Festucetum vaginatae* is similar but the aforesaid tendencies are more definite. Apart from minor fluctuations the underground phytomass of *Festucetum wagneri* presents an even growth rhythm.

In the rye field an intensive initial rhythm is followed by a slower phase and this, in turn, is followed by a rising tendency.

The overground phytomass of floral plants in natural meadows presents an almost equal and fairly even rising trend, but the autumnal steep rising curves characteristic of the *Festucetum vaginatae* and *Festucetum wagneri* indicate a more intensive accumulation due to the second production maximum. A similar trend was observed by Máthé – Précsényi – Zólyomi (1967) in the case of the meadows *Festucetum pseudovinae* and *Artemisio-Festucetum pseudovinae*.

Unlike the other associations, the rye field presents a very intensive accumulation of organic substances, coming to a sudden end with harvest.

Besides the considerable quantity of lichens, the diagrams of phytomass quantity present a conspicuous amount of underground phytomass due to the extensive radication situated in the upper 20 cm soil layer. Such radication is characteristic of the vegetation of loose soils on open, dry sites (Weaver 1958), according to Simon – Batanouny (1971) two-thirds of the roots can be found in the upper 20 cm soil layer in the associations examined. According to the data of Máthé – Précsényi – Zólyomi (1967), Précsényi (1969), Rusztamov (1965), Weaver (1958), Pearson (1965) and Dahlman – Kučera (1965) these values can be estimated even higher. The predominance of root phytomass in meadow associations has been demonstrated by Précsényi (1969) and Struik (1965), while Rusztamov (1965) stated that the root phytomass of desert plants is four or five times as much as the overground phytomass.

As compared to the total phytomass, the percentage of root phytomass is changing during the vegetation period within an individual association as well (Fig. 3). Higher values can be found at the beginning of the vegetation period in natural meadows, with a gradual decrease in *Festucetum vaginatae* and a slight augmentation in autumn e.g. in meadows Brometum and Festucetum wagneri. The rye curve characteristic is utterly differed, indicating another dynamism.

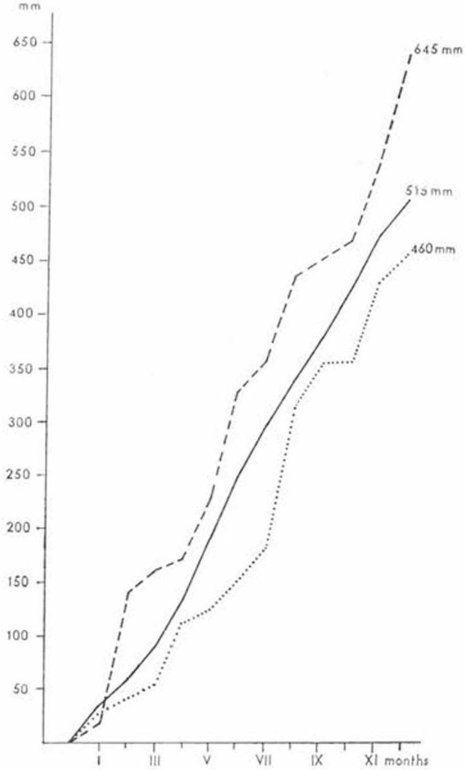
Precipitation and soil humidity, and their relation to phytomass production.

The amount and distribution of rainfall was examined on the basis of the data of the Monor Meteorological Station (about 5 km from the test area). As shown by the accumulation curves of rainfall (Fig. 4), the rainfall diffeented from the average in both years examined. The average of 50 years, 515 mm annual rainfall as measured in Monor, shows that the area is one of the driest part of the country. The average curve for 50 years shows that the months May and June are the most rainy, while the summer months are rather scanty in rainfall.

During the examinations on *Brometum tectorum* and *Festucetum vaginatae* in 1968, the climate was drier than the average and the monthly distribution of precipitation was also different. The most conspicuous feature was the absence of the usually typical rain maximum early in summer, while August, which was usually the driest month, was this time remarkable for the maximum rainfall.

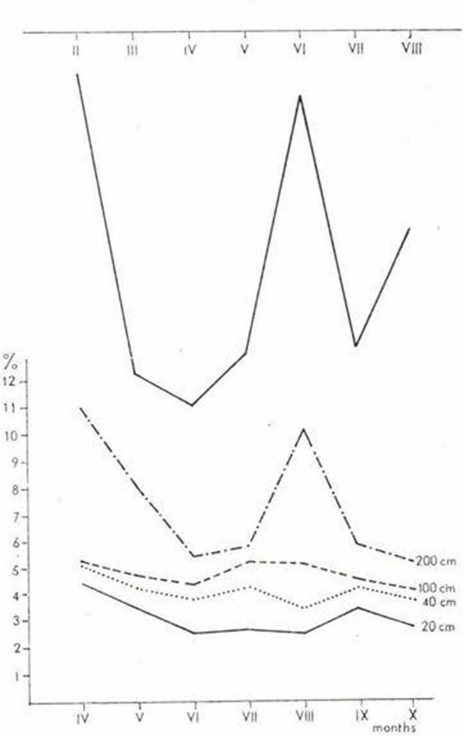
The year 1969, when the examinations on *Festucetum wagneri* and on the rye field were carried out, was rainy above the average, with maximum values in February, June and late in autumn.

In deeper soil layers the humidity utterly complied with the precipitation trend, although with characteristic time shifts. This is clearly shown



4. Accumulation curves of rainfall according to the data of the Meteorological Station of Monor

——— average of 50 years
...... 1968
– – – – 1969



5. Humidity contents of the soil the meadow Festucetum wagneri at different levels during the vegetation period and monthly total rainfall measured in 1969.

on Fig. 5 presenting the humidity values measured in the different soil layers of the meadow *Festucetum wagneri*, and the monthly precipitation values of 1969. The water penetrating with rain is accumulated in the form of underground water and affects the water level which moistens the subsoil by means of capillary action.

According to the measurements of Szodtfridt – Faragó (1968) the water level can be found in spring about 2,5 m under the surface in the soil of *Festucetum vaginatae* meadows and in the dry summer months 1 m deeper.

The humidity of the upper layers is more variable, being dependent on several factors (rainfall, gravitational movement of water, evaporation dependent on wind and temperature, water uptake of plants, etc.) which result in the variability of soil humidity through the difference in the intensity of their action.

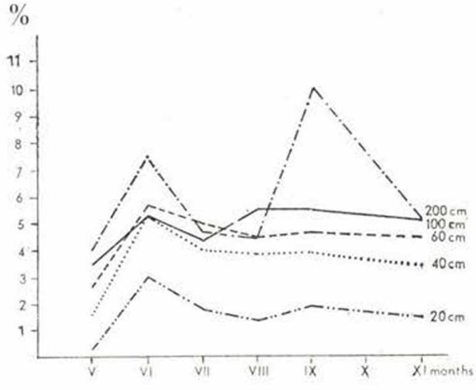
These sandy soils have a considerable water permeability, water retention being only 3 – 5 per cent, and the rain penetrates rather quickly downwards. The strong warming up of the surface causes intensive evaporation (J u h á s z has measured in July 1966 in a 2 cm layer of the soil of *Festucetum vaginatae* a temperature of 35 – 38 °C) and very fast desiccation of the surface layers. So the humidity fluctuation in humidity is much stronger in the layers near the surface and is influenced rather by the distribution of rainfall. In every profile the upper 20 cm layer is the driest one during the entire vegetation period.

The humidity contents of one year old *Brometum* meadow are very low, ranging from 0,3 to 2 per cent and offering a sharp contrast to the values measured in the deeper layers of every profile (3 – 6 per cent). Since the upper layers of these sandy soils have hygroscopicity values of approximately 0,20, the humidity value of 0,3 per cent represents in physiological terms an entirely dry medium for the plants.

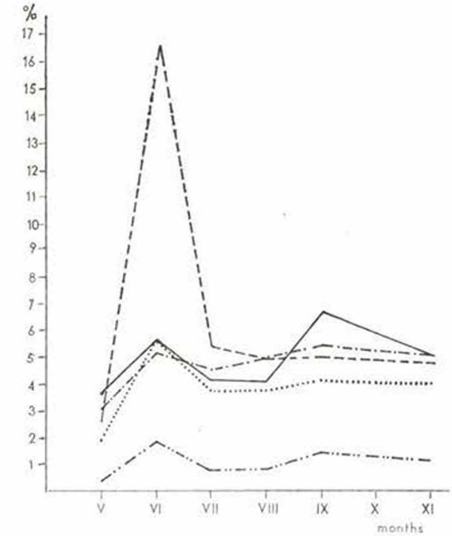
In the course of succession it seems that the humidity (water-retaining capacity) of the upper soil layer increases, the difference from the lower layers being always smaller. This phenomenon may be ascribed to the closed meadow, since the vegetation consisting of tightfitting plants reduces the evaporation of the upper soil layer.

The permeability rate is readily demonstrated by the data obtained in 1968. Though the precipitation curve presented minimum values in May, June and July, the upper soil layers under *Brometum tectorum* and *Festucetum vaginatae* still had high humidity values in June. As a matter of fact, measuring took place the next day after a rainfall. Fig. 7 clearly shows the depth of infiltration; most of the rain infiltrated in this profile as deep as 60 cm in one day. The effect of the exceptional rainfall maximum in August can be readily observed in the deeper layers in September.

With no deep roots, the prairie vegetation is acclimatized to most extreme humidity conditions. When, after rain, the soil is saturated with water, the plants absorb a maximum amount of humidity as quickly

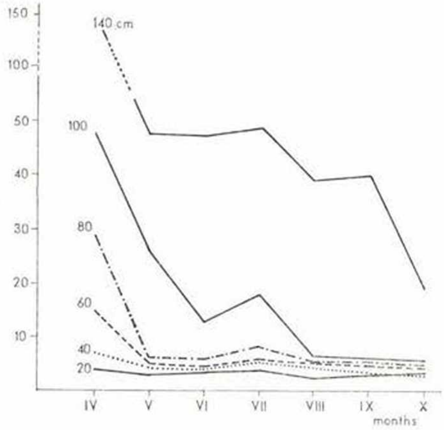


6. Changes of the soil moisture 1968
Festucetum vaginatae



7. Changes of the soil moisture of Brometum tectorum. 1968

—·—·—·— 20 cm —·—·— 100 cm
. . . . 40 cm ——— 200 cm
– – – – – 60 cm



8. Changes of the soil moisture of the rye field 1969

as possible. At the same time they are able to tolerate even prolonged and intensive desiccation of the upper soil layer (about 1 per cent humidity).

This is probably made possible by the outbalanced humidity of the layers under 40–60 cm, ranging from 3 to 6 per cent, providing in dry periods the minimum humidity required for the existence of the plants, by means of water lift through evaporation.

As shown by the present investigations, these prairies have an independent production rhythm which may have developed in the course of a prolonged evolution under the influence of environmental factors. Under our moderate continental climatic conditions the development and production of the meadows are stimulated by the appropriate quantity and distribution of rain in spring and at the beginning of summer; the more or less dry and hot summer results in a period of stagnation, while the rainy autumn initiates a second phase of development in perennial meadows.

The development rhythm of the one year old meadows is also definite, even the very heavy rain in August 1968 did not cause a second production maximum.

If the rainfall and, in consequence, the soil humidity differ from the average, the development rhythm of the coenosis will not change and only the quantity of the phytomass produced will be affected.

Data obtained for several years in one and the same association would be required in order to establish more exact correlations.

Summary

In prairie associations characteristic of the sandy area between the rivers Danube and Tisza the phytomass production of overground and underground parts and its relation to precipitation and soil humidity were examined in one year old *(Brometum tectorum)* and perennial meadows *(Festucetum vaginatae danubiale* and *Festucetum wagneri)* as well as in a rye field.

In the vegetation periods of the years 1968 and 1969 soil humidity was regularly measured every month at 20, 40, 60 100, 140 and 200 cm depth by means of a neutron scattering moisture meter.

The predominance of underground phytomass was found to be characteristic of these natural associations. The production maximum of the one year old meadow was observed in spring, followed by a gradual decay of organic substances in summer.

The perennial meadows have a production maximum at the beginning of summer and another during the rainy autumn season.

Soil humidity is influenced in the deeper layers by the quantity and in the upper layers rather by the distribution of rainfall.

The prairies examined have an independent production rhythm, slightly influenced but not changed by humidity.

In order to obtain exact quantitative correlations, further examinations of several years are required.

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