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PRODUCTION TESTS IN PLANT COMMUNITIES OF MEADOW-LAND WITH SOLONETZ SOIL II. THE EFFECT OF CLIMATIC AND SOIL FACTORS ON THE DRY-SUBSTANCE, CARBOHYDRATE AND NITROGEN CONCENTRATION IN THE SPECIES OF DRAINING SODIC MARSHLAND

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For several years we have conducted near Nagylak synecological investigations in the plant communities of meadow-land with solonetz soil in order to analyze the effects of climatic and soil factors. In view of the aim of the International Biological Programme, we studied the effect of climatic and edaphic factors on the species composition of 3 selected stands, on the dry-substance, total-nitrogen and total-carbohydrate concentration in the stands and in the dominant species. Our studies corcerning the *Artemisio-Festucetum pseudovinae* stand have been summed up in a previous report (1969).

In this paper we present a report on our studies with *Agrosti-Alopecuretum pōtosum angustifoliae* which forms the second zone, in the draining sodic marshland, of the 3 stands selected (Figure 1).

General characterization of the studied area and the stand

Large sodic meadows and pastures have developed on the slightly solonchak meadow-solonetz soils which are typical of the southern region east of the river Tisza. Prior to the realization of the comprehensive plans of river control and inland drainage, the features of this region were shaped after the spring movement of inland waters by the marshland vegetation of gradually alkalifying flats with stagnant waters.

The system of canalization serving inland drainage dried up these areas at an increasing rate. The effect of level differences became a decisive factor as concerns both habitat circumstances and the growth of the vegetation cover. Dissimilar hydrographic conditions developed also in the case of small level differences and resulted in varied biogeocenoses.

According to the water content and salt conditions, a particular zonation system of the stands emerged on the gradually alkalifying soil. The most intense transformation — also in the Nagylak area — appeared in the sections of higher level. Species characteristic of the original sodic marshland and appearing threadwise evidence the initial stage of succession. Through the processes leading to steppe formation the stand on the benches of the sodic flat has proceeded up to the dry meadow-pasutre type of the *Artemisio-Festucetum pseudovinae* (first zone).

The second zone is the deepest of the sodic flat and comprises the transitional meadow-cenoses between the benches; the third is made up of flats of lower levels still dominated by marshland species and belinging to the meadow foxtail type (Figure 1). Changes in species combination and their causes.

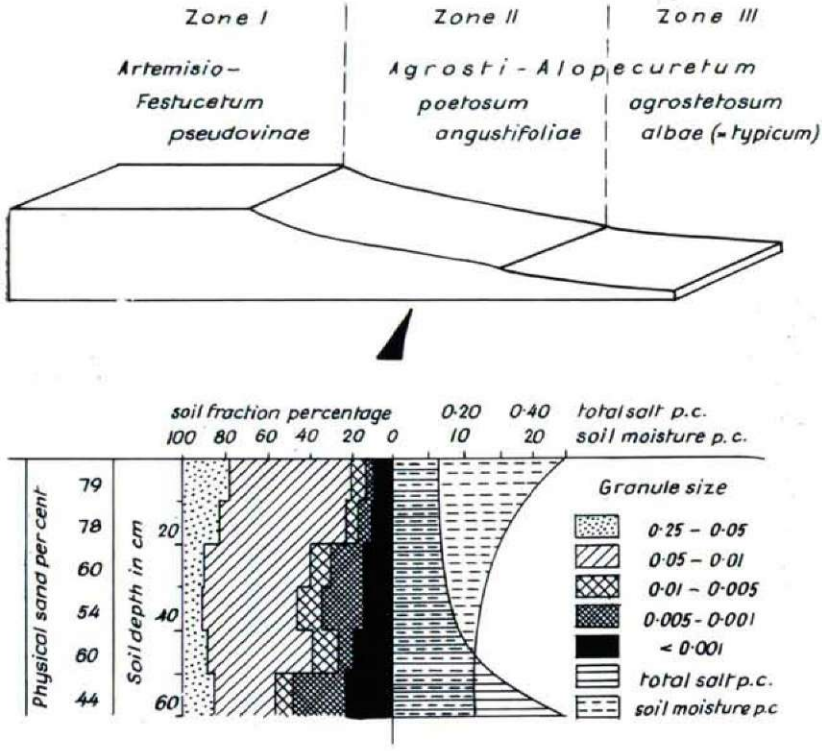


Figure 1. Zonation and soil conditions of the phytocenosis forming the subject of this study

The original *Agrosti-Alopecuretum* species combination underwent a considerable change as a consequence of an increasing drying up of the zone. The salt concentration of the soil increased as a result. This had the consequence that of the *Agrostion* and *Molinio-Arrhenatheretea* species only *Alopecurus pratensis* and *Taraxacum officinale* survived. The accumulation of sodium salt increased as the moisture content of the soil decreased, and this resulted in the appearance of certain *Puccinellion* and *Puccinellietalia* species. The vanishing marshland elements were replaced first of all by *Carex stenophylla* which readily adapts itself to the sodium salts and the low moisture content of the soil. Owing to its poor competitiveness — which is connected mainly with the inadequate moisture conditions — *Puccinellia limosa* was not able to gain any considerable ground. In the autumn season the dominance value of *Atriplex lithoralis* is considerable.

The other trend of succession in connected with the process of steppe formation. The increasing leaching of the *A* level provides favourable living conditions for certain species of the glycophilous steppes. It was in this way that in the spring and summer season *Poa angustifolia* and, later on, *Cynodon dactylon* attained considerable dominance values. Their flat root systems are in the *A* level above the solonetz layers. On the other hand, the appearance of

Table 1. Changes of temperature maxima and minima in the region including the studied area (average of 50 years, between 1901 and 1950)

Tótkomlós	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
max	8,5	12,1	19,4	24,9	29,1	33,3	35,1	34,6	30,6	25,4	17,1	12,1
min	—15,1	—13,0	—6,3	—1,6	3,1	6,9	10,5	8,8	4,6	—1,3	—5,4	—11,5
mean	—3,3	—0,4	6,5	11,6	16,1	20,1	22,8	21,7	17,6	12,5	5,8	0,3
departure from mean in 1968			—0,5	+2,2	+2,1	+0,6	—2,0	—2,3	—0,6	—0,9		

Table 2. Monthly average number of sunny hours

Mezőhegyes	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
(average of many years	60	87	158	190	252	279	325	294	231	171	76	61
1968	56	84	191	238	230	334	299	230	185	145	65	55
departure from average	—4	—3	33	48	—22	55	—26	—60	—46	—26	—11	—6
departure in %		—3,5	+20,9	+25,2	—8,9	+19,5	—7,9	—21,8	—20,1	—16,5		

Table 3. Rainfall conditions

in mm Mezőhegyes	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
30 years average	37	38	37	42	67	83	47	56	42	51	59	45
1968	32,1	30,6	17,9	26,5	60	44	66,7	79	112,5	2,9		
departure from av.		—7,4	—19,1	—1,5	—7	—39,0	+19,7	+23,0	+70,5	.	.	.
dep. in %		—19,4	—51,6	—36,9	—11,4	—47,2	+41,2	+41,0	+209,8	.	.	.

Table 4. Changes of climatic factors in periods between material collecting

	Mar 1 to Apr 25	Apr 26 to May 9	May 10 to Jun 19	Jun 20 to Aug 1	Aug 2 to Sep 5	Sep 6 to Oct 11
No. of days	56	14	41	43	35	35
Temperature max. highest	29,5	33,0	33,5	36,7	29,0	30,5
°C lowest	1,5	20,5	16,4	16,7	16,0	15,0
mean	15,5	25,2	25,1	27,5	24,7	20,7
min. highest	13,2	17,0	20,5	21,6	17,3	18,4
°C lowest	—6,8	6,3	5,5	9,0	8,8	3,6
mean	2,9	12,5	13,1	14,3	14,2	10,4
No. sunny hours						
Szeged	411	144	318	427	241	239
Tótkomlós	413	142	343	455	246	233
daily average %						
Szeged	7,2	9,6	7,8	9,9	6,9	6,8
Tótkomlós	7,2	9,5	8,4	10,6	7,0	6,7
Robits radiation value	10,016	2,775	9,361	10,617	6,868	5,254
Calorie/cm²	18,298	5,321	18,630	21,840	13,764	10,058
Calorie quantity daily average	321,0	354,7	454,4	508,1	393,0	287,4
Rainfall in mm (1968)	34,9	11,9	72,8	83,3	99,8	94,8
daily average in mm	0,62	0,85	1,77	1,93	2,85	2,71

Limonium gmelini indicates the effect of deeper salt layers. Yet for *Festuca pseudovina,* the dominant species of this country's glycophilous steppes, this zone is still too wet and so this plant does not occur here even threadwise.

We conclude as a result of our soil analyses that the original *A* level of the sections opened up to a depth of 60 cm has suffered erosion and can be found secondarily between 0 and 10 cm which has differentiated from the B_1 level.

It is characteristic of the physical structure of this soil that the coarse mud fraction is dominating in 80% of the sections (0,01—0,05 mm ∅).

Based on our synecological studies to date it may be concluded that this is the hardest ground of all soil sections east of the river Tisza.

As concerns the chemical composition, the total salt content in levels A and B_1 does not reach 0,2% and rises to 0,3—0,4% in the deeper B_2 level only in the summer season (Figure 1). Thus it is understandable why a considerable proportion of the species components — which make up the cenosis and have a flat root system for the most part — is a glycophilous species.

The data relating to the characterization of the climatic conditions of 1968, to the temperature, the number of sunny hours and the rainfall conditions are summed up in Tables 1, 2, 3 and 4 and are compared with the averages of many years.

The values of important climatic factors referred to the periods between

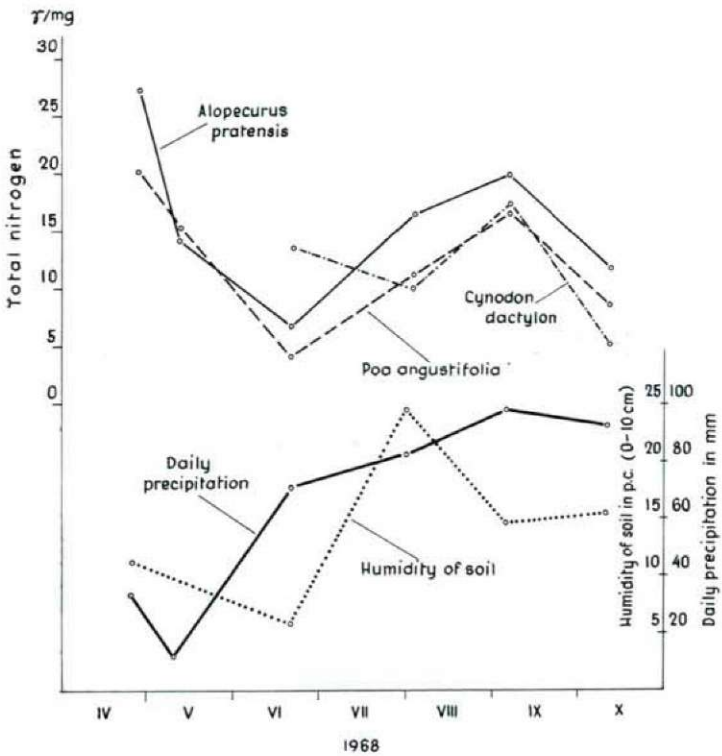


Figure 2. Correlation between the total nitrogen concentration of the three grass species and the changes during the growth season in the percental quantity of rainfall and soil moisture

material collecting have been supplied by the meteorological station of Tótkomlós and are shown in Table 4.

The methods employed in the course of our studies and the literature used have been discussed in detail in our previous publication (1969).

The changes taking place during the growth season in the species composition of the stand are shown in detail by the star diagrams of Figure 5, and the data relating to the dry-substance, total-N and total carbohydrate contents of the investigated species are summed up in Fig. 2., 3., 6a.

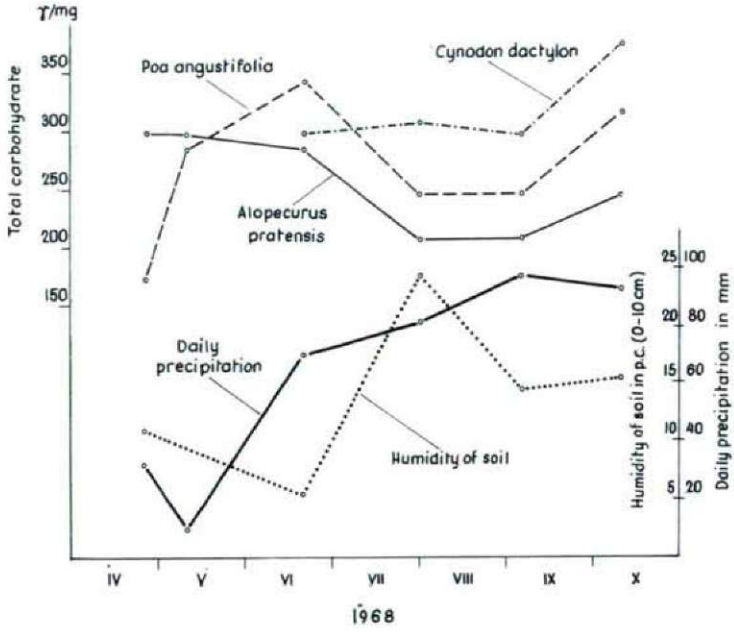


Figure 3. Correlation between the total carbohydrate concentration changes of the three grass species and the changes of the two external factors

Test results

The middle phase of the spring aspect (test date April 26, 1968)

Counted from March, the beginning of the growth season, it has been found that the extreme temperature values showed no considerable departure from the average of many years. On the other hand, the number of sunny hours was much more, and rainfall was much less than the average of many years.

(No soil analysis was made on this occasion)

We selected 7 species from the 11 (including those appearing threadwise) which made up the community. Dominant were *Carex stenophylla, Poa angustifolia,* and *Alopecurus pratensis.*

We measured the highest total-N concentration in *Alopecurus pratensis. Taraxacum officinale* known for its high N content was ranking fifth with its 12 γ/mg value. An outstandingly high total carbohydrate concentration was measured also in *Alopecurus pratensis.*

The post-phase of the spring aspect (test date May 9, 1968)

In the period between the two tests the mean temperature was higher by 2 °C than the average of many years, and the number of sunny hours was also higher. As a consequence of scanty rainfall the dry weather became permanent from March and affected the community particularly in the latter period.

As a result of increased insolation and little rainfall the moisture content of soil was low also in the lower *B* and *C* levels, amounting on the average to 10%.

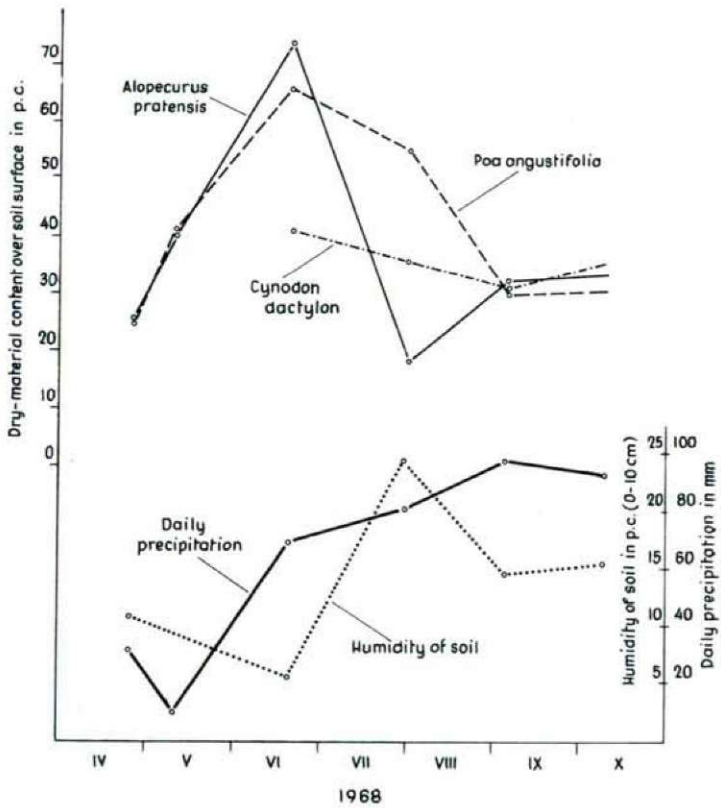


Figure 4. Correlation between the change in the dry-substance content of the three grass species of the studied species combination and the changes of the value of rainfall and soil moisture

As a result of decreasing soil moisture and scanty rainfall the dry-substance content of these species grew considerably compared to the previous analysis.

As a result of the dry period, we found a major change in the N concentration and a minor change in the carbohydrate concentration (Fig. 2., 3).

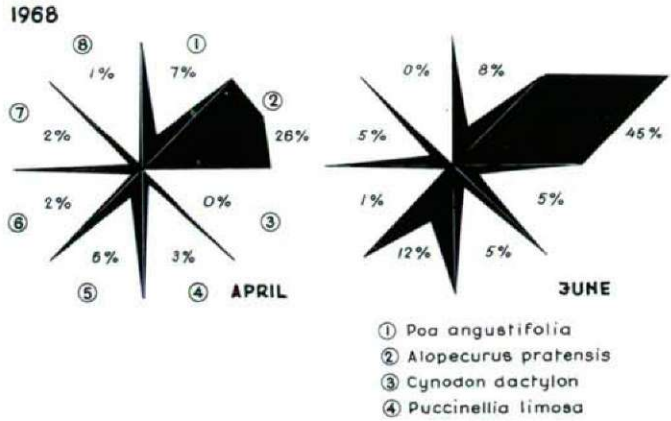


Figure 5. Qualitative and quantitative changes in the species composition of the stand during

The pre-phase of the summer aspect
(test date June 19, 1968)

The temperature was higher by 1,4 °C than the average of many years (13,1 °C), and there were more sunny hours as well.

Compared to the first two periods, there was a considerable quantity of rainfall, but the June rainfall maximum so typical of this country's climate did not come about that year. Rain fell on 4 occasions only and this was not sufficient to moisten the deeper soil layers; their water content decreased further, amounted to 5% in the *A* and *B* levels and reached 10% only in the *C* level.

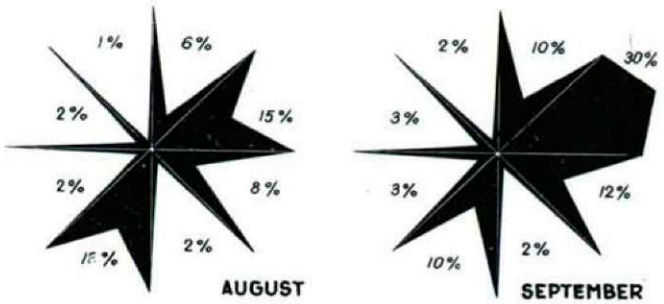
As a consequence of considerable solar energy and insufficient rainfall, clearly xerophilous habitat conditions developed in this marshland zone. The overground portion of most species was largely in a withered state at the time of gathering, hence the average content in dry subsstance was high. (Compared to the previous measurements, increase was 34% in the case of *Alopecurus pratensis,* 25% in the case of *Poa angustifolia,* and 19% in the case of *Carex stenophylla).*

As a consequence of increasing drought there was no winter rainwater supply to the soil; the 3 dominant species shifted their order of succession because the adaptability of the meadow-foxtail as a hygro-mesophilous species is (poorer) than that of the meso-xerophilous blue-grass and sedge. *Cynodon dactylon* showed the greatest adaptability among the *Gramineae* species.

The smallest change in dry-substance content was found in *Limonium gmelini* and *Scorzonera cana,* the two characteristic species of meadow solonetz soils becoming steppe.

Compared to the previous analysis, the total N concentration decreased considerably in all species, while the total carbohydrate concentration changed but slightly.

The main phase of the summer aspect
(test date August 1, 1968)



⑤ Carex stenophylla
⑥ Taraxacum officinale
⑦ Limonium gmelini
⑧ Inula britannica

the growth season

The mean temperature of the 43 days that had passed since the previous collecting was 20,9 °C. The number of sunny hours hardly exceeded the values of the late April and early May period. Because of an increase in the quantity of rainfall, and a decrease of evaporation from the stand due to the withering of plant parts in the preceding period, the water content of the soil increased fivefold in the A level and threefold in the B_1 level. A few per cent of the sodium salts were washed into the B_1 level. (Figure 6b).

The dry-substance content decreased as a consequence of resprouting taking place in most species. This was seen to the greatest extent in *Alopecurus pratensis,* but this may be explained also by the fact that by the action of wind the previously withered sprout portions were broken off.

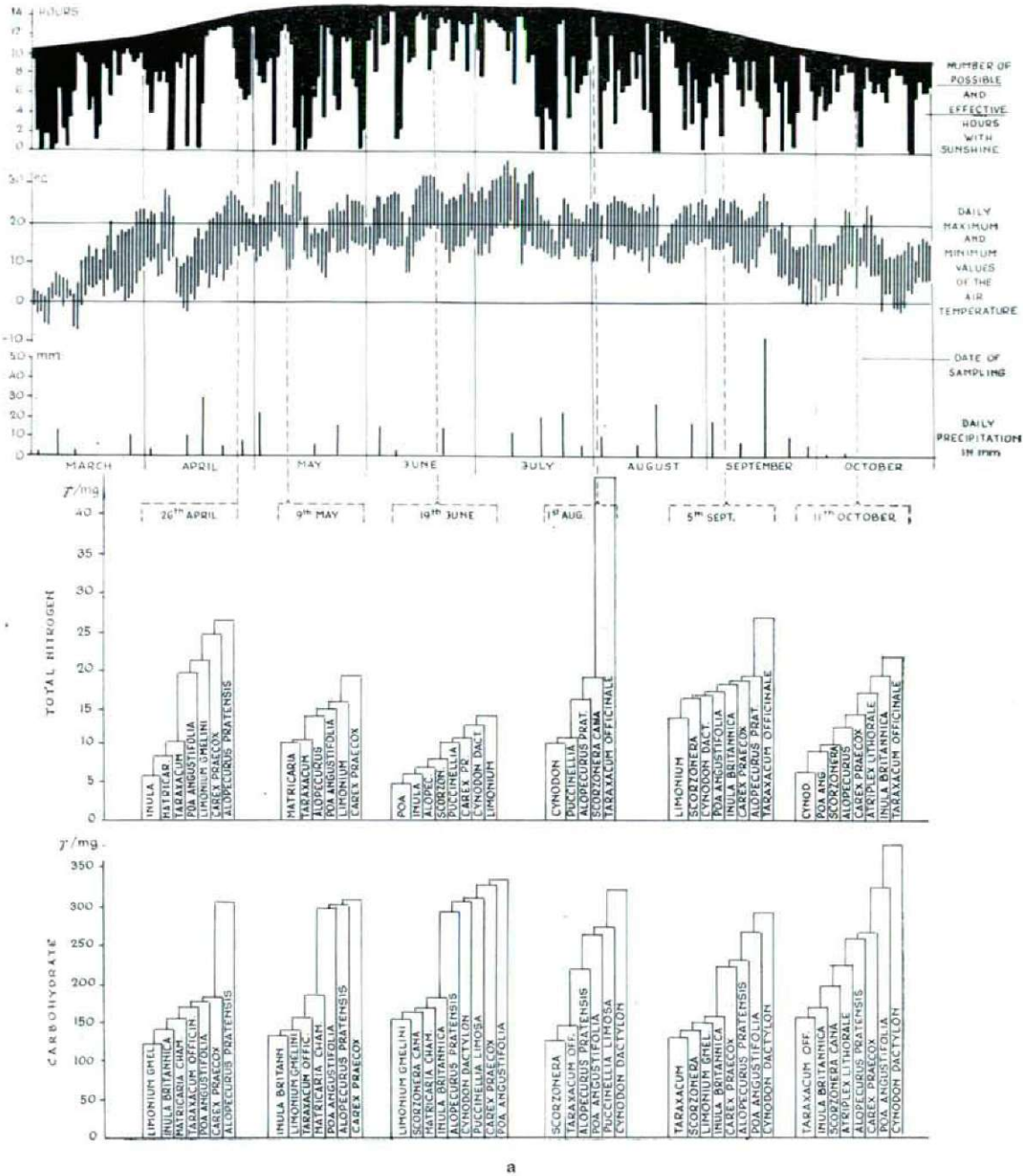
The total carbohydrate content was reduced and — except for two species, i. e. *Poa angustifolia* and *Cynodon dactylon* — was the lowest in the entire growth season at this time.

On the other hand, the N concentration showed more of an upward trend. (It should be noted that no generalization is possible here because we were only able to determine the total N concentration of 4 species at that time).

The prephase of the autumn aspect
(test date September 5, 1968)

The mean temperature was 19,4 °C during this test period. The daily average number of sunny hours was less by three than in the preceding period. The quantity of rainfall was greater and the distribution was even. Tables 1, 2, 3). But under the effect of an increasing evaporation due to a growing phytomass the water content of the soil decreased by some 10%.

As a result of a more favourable climate and soil-ecological factors, also the number of species increased. Compared to the previous analyses, the dry-substance content of *Cynodon* showed the smallest change among the species that made up the species combination in early autumn. The content in other species decreased or increased depending on the extent of resprouting.

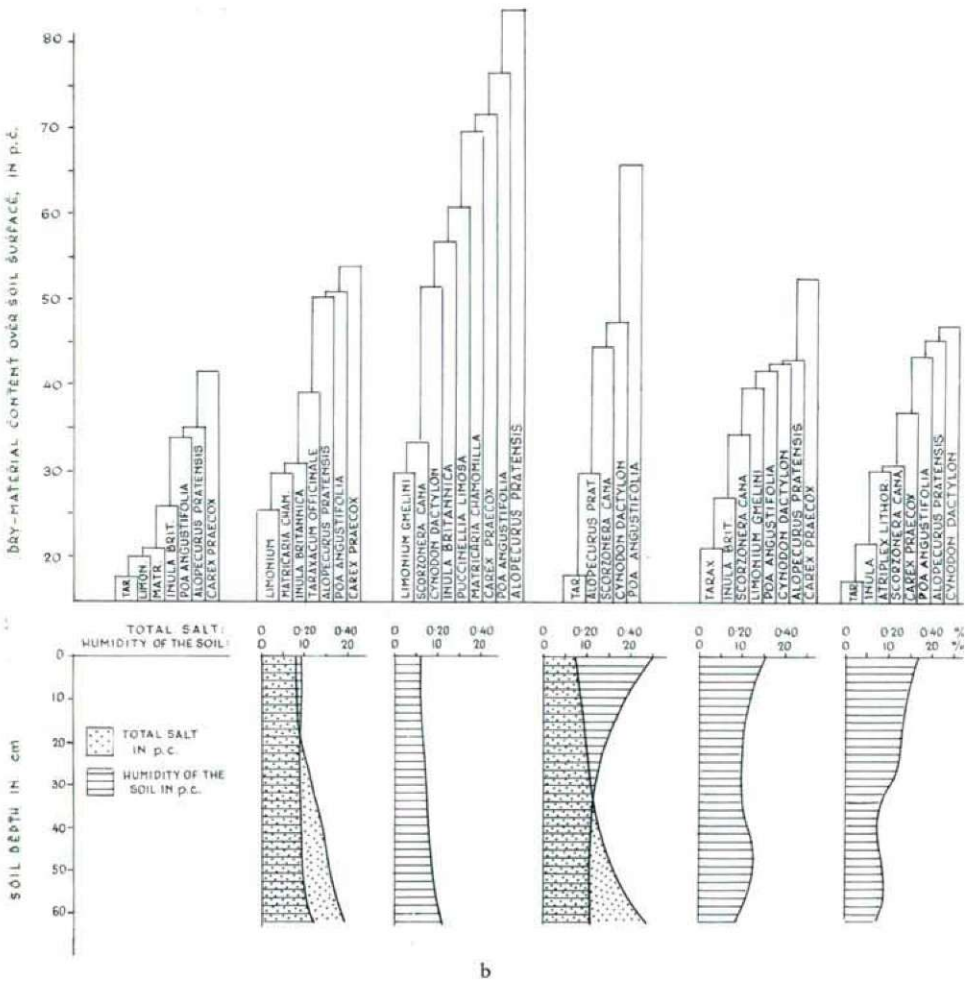

HOURS
NUMBER OF POSSIBLE AND EFFECTIVE HOURS WITH SUNSHINE
°C
DAILY MAXIMUM AND MINIMUM VALUES OF THE AIR TEMPERATURE
mm
DATE OF SAMPLING
DAILY PRECIPITATION IN mm
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
γ/mg
20th APRIL
9th MAY
19th JUNE
1st AUG.
5th SEPT.
11th OCTOBER
TOTAL NITROGEN
INULA
HYPOCAR
TARAXACUM
POA ANGUSTIFOLIA
LIMONIUM GMELINI
CAREX PRAECOX
ALOPECURUS PRATENSIS
MATRICARIA
TARAXACUM
ALOPECURUS
POA ANGUSTIFOLIA
LIMONIUM
CAREX PRAECOX
POA
INULA
ALOPEC.
SCORZON.
PUCCINELLIA
CAREX PR.
CYNODON DACT.
LIMONIUM
CYNODON
PUCCINELLIA
ALOPECURUS PRAT.
SCORZONERA CANA
TARAXACUM OFFICINALE
LIMONIUM
SCORZONERA
CYNODON DACT.
POA ANGUSTIFOLIA
INULA BRITANNICA
CAREX PRAECOX
ALOPECURUS PRAT.
TARAXACUM OFFICINALE
CYNOD
POA ANG.
SCORZONERA
ALOPECURUS
CAREX PRAECOX
ATRIPLEX LITHORALE
INULA BRITANNICA
TARAXACUM OFFICINALE
CARBOHYDRATE
LIMONIUM GMEL.
INULA BRITANNICA
MATRICARIA CHAM.
TARAXACUM OFFIC.
POA ANGUSTIFOLIA
CAREX PRAECOX
ALOPECURUS PRATENSIS
INULA BRITANNICA
LIMONIUM GMELINI
TARAXACUM OFFIC.
MATRICARIA CHAM.
POA ANGUSTIFOLIA
ALOPECURUS PRATENSIS
CAREX PRAECOX
LIMONIUM GMELINI
SCORZONERA CANA
MATRICARIA CHAM.
INULA BRITANNICA
ALOPECURUS PRATENSIS
CYNODON DACTYLON
PUCCINELLIA LIMOSA
CAREX PRAECOX
POA ANGUSTIFOLIA
SCORZONERA
TARAXACUM OFF.
ALOPECURUS PRATENSIS
POA ANGUSTIFOLIA
PUCCINELLIA LIMOSA
CYNODON DACTYLON
TARAXACUM
SCORZONERA
LIMONIUM GMEL.
INULA BRITANNICA
CAREX PRAECOX
ALOPECURUS PRATENSIS
POA ANGUSTIFOLIA
CYNODON DACTYLON
TARAXACUM OFF.
INULA BRITANNICA
SCORZONERA CANA
ATRIPLEX LITHORALE
ALOPECURUS PRATENSIS
CAREX PRAECOX
POA ANGUSTIFOLIA
CYNODON DACTYLON

a

The total N concentration usually continued to show and upward trend and it was striking to see that it was nearly identical in all species we have studied, with the exception of *Taraxacum*. With the exception of *Scorzonera*, the carbohydrate concentration was nearly unchanged in all species compared to the previous analysis.

Postphase of the autumn aspect
(test date October 11, 1968).

The average daily temperature of the last test period was 15 °C (maximum 30,5, minimum 3,6 °C). The number of sunny hours more or less agreed with



b

Figure 6. Changes of the climatic and edaphic factors, and changes in the dry-substance contents, total nitrogen and total carbohydrate concentrations in the species components of the studied phytocenosis during the growth season of 1968

the average of many years. The first third of this test period was the rainiest of the year, but there was hardly any rainfall in October.

The soil-ecological conditions showed hardly any change compared to the preceding period.

Certain species were absent from the plant community, others — e. g. *Atriplex lithoralis* — appeared.

The dry-substance content showed a downward trend as a rule, with the exception of *Alopecurus pratensis* and *Cynodon dactylon* (Figure 6b).

Except for *Inula britannica,* the total N concentration decreased considerably in the species we studied. On the other hand, the carbohydrate concentration showed a marked increase, particularly in *Poa angustifolia* and *Cynodon dactylon.*

* * *

In the following we present a few important findings of our studies as seen in their correlations with climatic and soil factors:

Dry-substance content

It increases in most species during the growth season, after which it shows a downward trend. Except for *Taraxacum officinale* and *Scorzonera cana,* it is the highest in June.

The dry-substance content shows a correlation through the water content of the soil with the climatic factors, i. e. with rainfall, the number of sunny hours and temperature. This was seen particularly at the test on June 19. Yet this correlation is not exclusive as was evidenced, for example, by the test on August 1. Namely the greatest ground water content of the growth season was found at that time (in the upper 20 cm layer) while the dry-substance content was average.

The dry-substance content shows a correlation with the phenological phases, i. e. it is usually the highest at the time of crop ripening. This internal rhythm acts in certain species more intensely than the water content of the environment. For example, the highest dry-substance content was found in *Scorzonera* in August when the ground water content was the greatest (Fig. 4., 6b).

The percental changes in the dry-substance content are two and threefold in the growth season in the species we have studied, and are nearly identical as concerns proportion. But taken in absolute values, the dry-substance content of grasses is higher than that of the dicotyledons (1,5 to 2 times higher).

The total carbohydrate concentration

The changes of total carbohydrate concentration during the growth season differ considerably in grasses and dicotyledons. There is hardly any change in the latter, even the difference in this respect between the 4 species we have studied is insignificant.

The total carbohydrate concentration is substantially higher in grasses, nearly twice as high as in the dicotyledons. There are 2 types in respect of change. In one type the concentration is increasing till June, decreases afterwards, but increases intensely again at the end of the growth season. (It should be noted that the carbohydrate concentration shows a correlation with the

changes of the dry-substance content only in this type, and that the end of the growth season must be disregarded even in this case).

In the other type the change of the carbohydrate concentration shows an upward trend during the entire growth season. Among the grass species we have studied only *Alopecurus pratensis* differs from these two types; its carbohydrate concentration is high throughout and decreases only to a slight degree.

Thus, in essence, the carbohydrate concentration shows no correlation with the dry-substance content, nor does it show a correlation with the phenological phases.

The correlation of carbohydrate concentration changes with the quantity of rainfall and the water content of the soil is inverse.

Total nitrogen concentration

The total nitrogen concentration is usually in inverse ratio to the dry-substance content: the highest dry-substance content is accompanied by the lowest nitrogen concentration in most cases (especially in grasses).

The total nitrogen concentration is nearly identical in the grasses and the dicotyledon species we have studied. The only exception we found was the very high nitrogen concentration measured in *Taraxacum* officinale on August (it was resprouting in August) but this might have been a measuring error.

In the case of grasses we have found a direct correlation between the total nitrogen concentration and the water content of soil and rainfall.

The changes of carbohydrate and nitrogen concentrations are always opposite in grasses. We have found no correlation between the changes of total carbohydrate and nitrogen concentration in dicotyledons.

Summary

On the basis of synecological studies carried out in a stand of *Agrosti-Alopecuretum poētosum angustifoliae* in the Nagylak area, the following conclusions may be drawn:

1. In most species the dry-substance content changes in the growth season in an increasing direction, and afterwards in a decreasing direction. These changes show a correlation through the water content of the soil with the climatic factors and also with the phenological phases.

In the growth season the percental changes of the dry-substance contents are of indentical proportions in the species studied, but the dry-substance content of grasses is higher (1,5 to 2-fold) than that of the dicotyledons.

2. Total carbohydrate concentration hardly changes in dicotyledons during the growth season, and differences in this respect are insignificant between species.

The total carbohydrate concentration of grasses is substantially higher, and also the changes are of a greater degree.

The carbohydrate concentration shows a correlation neither with the dry-substance content nor with the phenological phases. It shows an inverse correlation with the quantity of rainfall and the water content of the soil.

3. The total nitrogen concentration of the studied grasses and dicotyledon species is nearly identical and shows an inverse correlation with the dry-substance content.

There is a direct correlation between the total nitrogen concentration of grasses and rainfall and the water content of soil.

4. There seems to be no correlation between total carbohydrate and total nitrogen concentration in dicotyledons, while this change is always opposite in grasses.

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