DISTRIBUTION OF PLANT NUTRIENTS IN THE SEEDS AND SHOOTS OF *CHENOPODIUM RUBRUM* L. VAR. *PUSILLUM* HAUSSKN. ALONG AN ENVIRONMENTAL GRADIENT

I. BAGI AND
G. KOVÁCS

Department of Botany,
József Attila University,
H-6701 Szeged, P. O. B. 657, Hungary

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Abstract

Distribution of plant nutrients (potassium, nitrogen and phosphorus) was studied in shoots and seeds of *Chenopodium rubrum* var. *pusillum* along a transect which was marked out on the bottom of a flood-plain lake of Körös river. The sampling of plants was performed on seven occasions paralel with the drying out of the lake. The plants in a transect point were at different stages of their development. The nutrient condition of the soil was also measured.

During the vegetation period the potassium and the nitrogen contents of shoots showed decreasing tendencies, the phosphorus content of shoots increased. The potassium content of seed decreased, the nitrogen and the phosphorus content was shown to be constant in a sample site.

Relationships between edaphic factors and the nutrient content of plants might be informative in cases where the contents of nutrient are close to constant during the period of investigation. If the nutrient contents of plants show tendentious changes, a single occasional transect study may (but not necessarily) give questionable results. The mechanical application of tests suggests that there are no strong correlations between phosphorus content of shoots and the soil. In this study only close correlation of phosphorus content of shoots and seeds can be rendered possible, in spite of that fact the mechanical application of correlation tests apparently indicates significant correlation between the potassium and nitrogen content of the shoots, and the soil.

Key words: mud vegetation, nitrate, nitrogen, nutrient uptake, phosphorus, potassium, resource allocation, seasonal dynamics.

Introduction

Relationships between the nutrient content of plants and the soil have important ecological significance (GERLOFF, 1976; GRIME at al., 1988). The studies in this subject are built on the supposition that the resources of the soil distribute among the competitive plants according to their ability of nutrient uptake and utilization, and that these competitive relations can be followed by the element analysis of plants (organs, tissues) (GRIME, 1977; CHAPIN, 1980; ERNST, 1983; LEE et al., 1983; MARRS et al., 1983; AUSTIN et al., 1985, TILMAN, 1985; 1986; KOVÁCS et al., 1995a). As the determination of starting parameters of an investigation needs exact experimental conditions and design, most of the studies were performed in phytotron under controlled conditions (c. f. TILMAN and WEDIN, 1991). Field studies to investigate resource allocation and competition are performed in rare instances (TILMAN, 1984; WILSON and TILMAN, 1991; KOVÁCS et al., 1995b). An important part of these field studies is devoted to the investion of the distribution of nutrients in a plant during the vegetation period (CHAPIN and KEDROWSKI, 1983; GEBAUER et al., 1984; NADELHOFFER and ABER, 1984). Sometimes the distribution of plant nutrients in an environmental (nutrient) gradient is the subject of study (PARRISH and BAZZAZ, 1982; PASTOR et al., 1984). This study belongs to the latter type, but sequential sampling of plant material was performed to detect relationships existing between the nutrients of the soil and the plants, as well as the changes of nutrient content during plant development.

As the interpretation of field data would have required too much consideration in a complicated vegetational situation, a very simple subject has been choosen: *Chenopodium rubrum* var. *pusillum* colonizes almost bare soil in lakes of flood plains after the water recedes. The total cover of vegetation is low, therefore the effects of interspecific competition can be omitted from consideration. This species forms monodominant stands in zones where its coverage is high (c. f. Fig. 4/B). *Chenopodium rubrum* var. *pusillum* is a typical mud-plant, which characterizes the *Nanocyperion* KOCH ex LIBBERT 1932 or *Heleochloo-Cyperion* (BR. -BL. 1952) PIETSCH 1961 alliance of mud vegetation (PIETSCH, 1973a,b; PIETSCH and MÜLLER-STOLL, 1974). Its shoots are 3–7 cm in tall. Its special adaptation to the short available vegetation period is „the fast life cycle", the early flowering and the fast ripenings of fruits and seeds (c. f. ERNST, 1983). The nutrients are in high availability in the soil, therefore none of them is a limiting factor in growth.

Materials and methods

Study area

The studies were performed along the Körös river, at the bottom of a flood-plain lake located at a distance of 200 m from the river near Békésszentandrás village (Fig. 1/A). Paralel with the continuous evaporation of water, the terrestrial vegetation forms well distinguished zones on the bed soil. On the part of the lake that is under water coverage for the longest period, vegetation of higher plants does

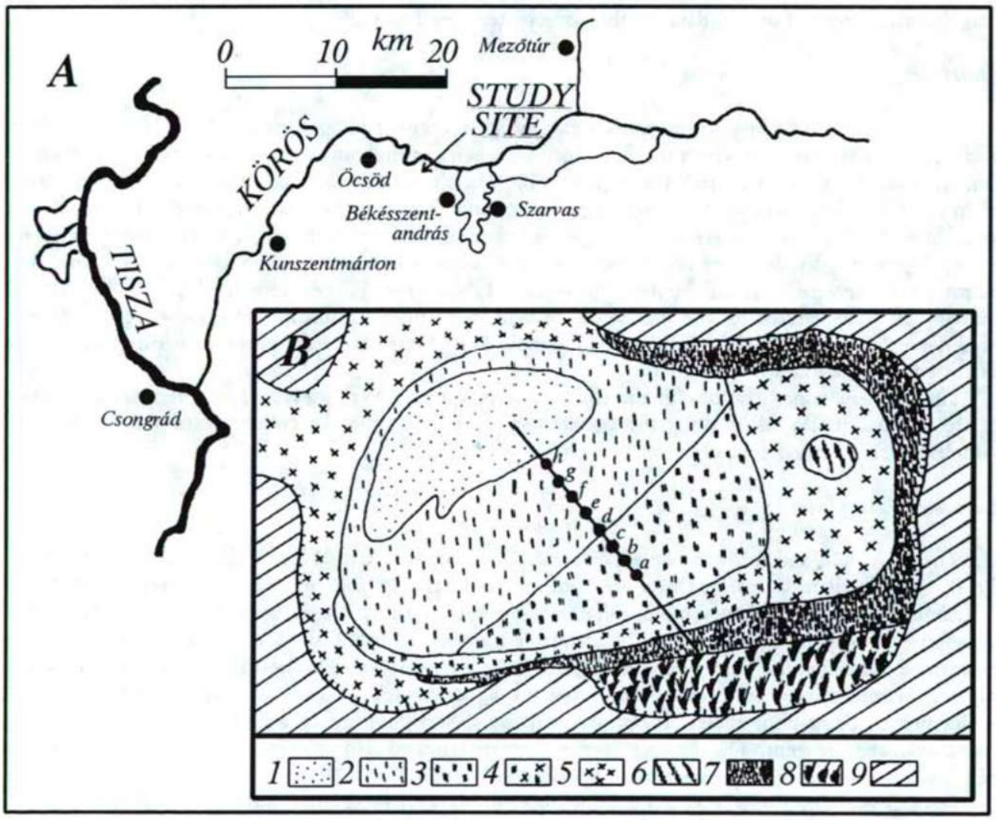

Figure 1 Geographical location of the study area (A). Vegetation of the lake and the location of sample sites (B); 1: *Botrydietum granulati* HÜBSCHMANN 1957 x *Riccio-Physcomitrelletum* (ALLORGE 1921) HÜBSCHMANN 1957 komplex, 2: *Dichostylido-Heleochloëtum alopecuroidis* (TIMÁR 1950) PIETSCH 1973 *chenopodiosum rubri*, 3: *Dich.-Hel. gnaphaliosum uliginosi*, 4: *Dich.-Gnaph. gnaph.* x *typ.* transition, 5: *Dich.-Hel. typ.* x *Eleochareto aciculari-Schoenoplectetum supini* SOÓ et UBRIZSY in UBRIZSY 1948 *eleochariosum* komplex, 6: *Bolboschoenus maritimus* fac., 7: *Agrostis stolonifera* fac., 8: *Caricetum gracilis* ALMQUIST 1929, 9: *Salicion triandrae* and *Salicion albae* TH. MÜLL. et GÖRS 1958. (Nomenclature follows BORHIDI 1996, HÜBSCHMANN 1957.); a — h: sample sites, distance between 'a' and 'h', is about 20 m.

not occur. Only algae (e. g. *Botrydium granulatum*), liverwort (*Riccia cavernosa* HOFFM. em. RADDI) and mosses (e. g. *Physcomitrium pyriforme*) can be found on the ground (RUNGE, 1960; ANT and DIEKJOBST, 1967). The next zone towards the shore is dominated by *Chenopodium rubrum* var. *pusillum*, and the next covered by the annual *Gnaphalium uliginosum* and *Heleochloa alopecuroides*. The transition between the two zones is close to continuous. The dominant species of the further zone is *Agrostis stolonifera*, which forms a dense carpet on the soil. It partly consists of specimens transformed into terrestrial (from aquatic) forms, but mainly consists of the new seedlings of the species. The first zone, which is covered by permanent perennials, is dominated by *Carex gracilis* and other *Magnocaricion* species (Fig. 1/B). For a more detailed cenological description see BAGI (1984; 1991). Due to the shallow water and the slow decrease of the water level, wide zones of different vegetation distributions developed. The detailed investigations were restricted to the *Chenopodium rubrum* dominated, and neighbouring zones. For soil data on the zone system see BAGI (1988).

Sampling

The zone where *Chenopodium rubrum* var. *pusillum* occured in appropriate cover, was about 20 m wide. Along a transect, in which the difference between the highest and the lowest part was about 15 cm, eight sample sites were marked out (Fig. 1/B). The shoots of *Chenopodium rubrum* were collected from these sites in paralel with the receding of the water. The collection was repeated about every two week in each sample site, where shoots could be found in sufficient numbers, and in appropriate stages of development. Samples were taken seven times at the higher relief, but only once at the lower. The plants were harvested starting 31 July and ending 1 Nov. 1986.) The most developed shoots (15–20 individuals) were selected for the analyses, each time from different quadrats of a transect point. Shoots of different ages were collected from each sample site. After the fruits become mature, seeds were extracted from the collected shoots.

The nutrient concentrations of the soil in a sample point were measured on the basis of analysis of three soil samples taken along the transect at the time of the last collection of shoots. The soil samples were collected to a depth of five cm.

Laboratory procedures

The plant and soil analyses were performed in accordace with Hungarian standards (cf. BUZÁS 1988). Additional methods, or those not conforming to these standards, are referenced separately.

Plant analyses: The plant samples (after rinsing with distilled water) were dried out at 60°C. The liquefaction of plant samples for the determination of phosphorus and potassium content was performed with a nitric acid : perchloric acid (5:1 v/v) mixture. The liquefaction to determine the nitrogen content was performed using Kjedahl apparatus. The determination of potassium was performed by flame photometry, the phosphorus by spectrophotometer after reaction with molybdate — metavanadate reagent. The nitrogen content was determined also colorimetric way after a procedure of phenol — sodium nitroprusside reaction (Felföldy-method).

Soil analyses: The available potassium and phosphorus were determined after extraction with calcium lactate, the nitrate-nitrogen of the soil extracted with distilled water (1:5 soil : water w/v ratio). The determination of potassium was performed by flame photometry, and phosphorus by spectrophotometer after reaction with sodium molybdate — ascorbic acid reagent. The nitrate concentration of the extract was determined by the phenol disulfonic acid method (BALLENEGGER, 1953), and also using colorimetric method.

The determinations were run in triplicate.

Statistical analysis

Statistical evaluation of the data was restricted to the Spearman rank order correlation analysis. The low number of data pairs made necessary the application of nonparametric statistics, therefore tests of normal distribution were omitted.

Results

Distribution of plant nutrients in shoots and seeds

The nutrient contents of shoots and seeds are close to similar in value, only the potassium content is considerably higher in the shoots than in the seeds. The concentration of a nutrient varies between wide limits in the shoots: For example, the changes in phosphorus content in some sites were more than 200 % during the period of investigation. At the same time, the phosphorus and nitrogen content of the seeds seems to be constant at a sample site (transect point), but between the sites there may be important differences in nutrient contents (Fig. 2).

At a given transect point, the potassium content of shoots shows a close to linear decrease in the early stages of plant development, but it becomes constant in older plants (Fig. 2/A). The decrease in potassium content of the seeds seems to be exponential. This decrease is especially fast at the transect points of lower reliefs (Fig. 2/B). The nitrogen content of the shoots at each given transect point, decreases linearly over the period of sampling (Fig. 2/C). The nitrogen content of the seeds, over time, is close to constant at a transect point, only a very slight decrease can be detected (Fig. 2/D) (c. f. KIRKBY, 1981). A linear increase can be observed in the phosphorus content of shoots (Fig. 2/E). The phosphorus content of the seeds seems to be constant (Fig. 2/F).

Along the transect, the distribution of nutrient contents of plant samples collected at the same time can be followed in Fig. 3. The potassium content of shoots seems to be constant in the outer (higher) parts of the transect, but steep increases can be detected in the lower parts of the lake. A similar distribution in the potassium content of seeds can be observed (Fig. 3/A,B). The linear increase in the nitrogen content of shoots can be measured towards the deeper parts of the lake along the transect (Fig. 3/C). The phosphorus content of the shoots is close to constant in the outer parts, but a steep decrease can be observed in the inner ones (Fig. 3/E). The nitrogen and potassium content of the seeds show more complicated distribution along the transect: The phosphorus content shows a clearly recognizable maximum at the transect point 'd' (Fig. 3/D,F).

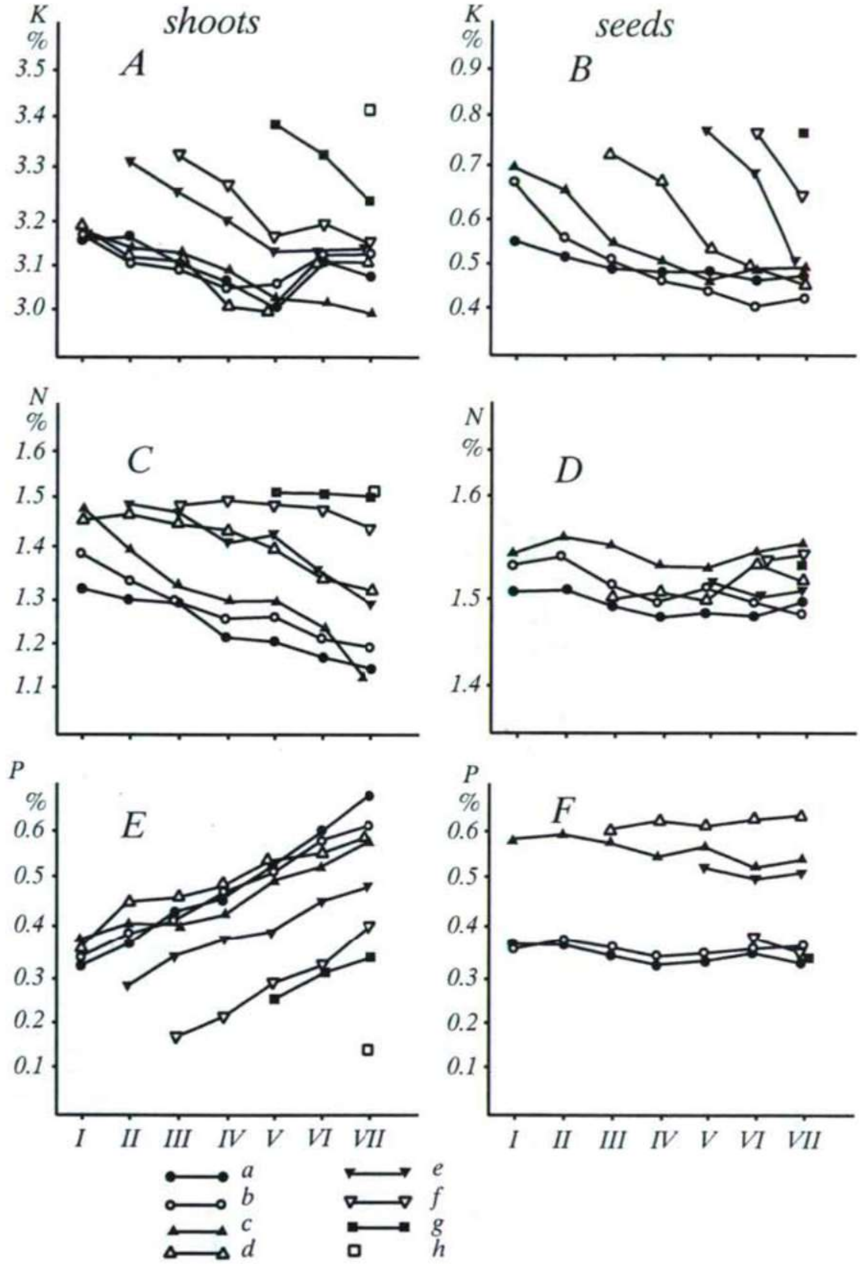

Figure 2 Changes of nutrient content in the transect points in relation to vegetation period. Dates of samplings are I–VII in order 31. 07, 12. 08, 30. 08, 12. 09, 03. 10, 15. 10 and 01. 11. The transect points (a–h) are connected with the lines.

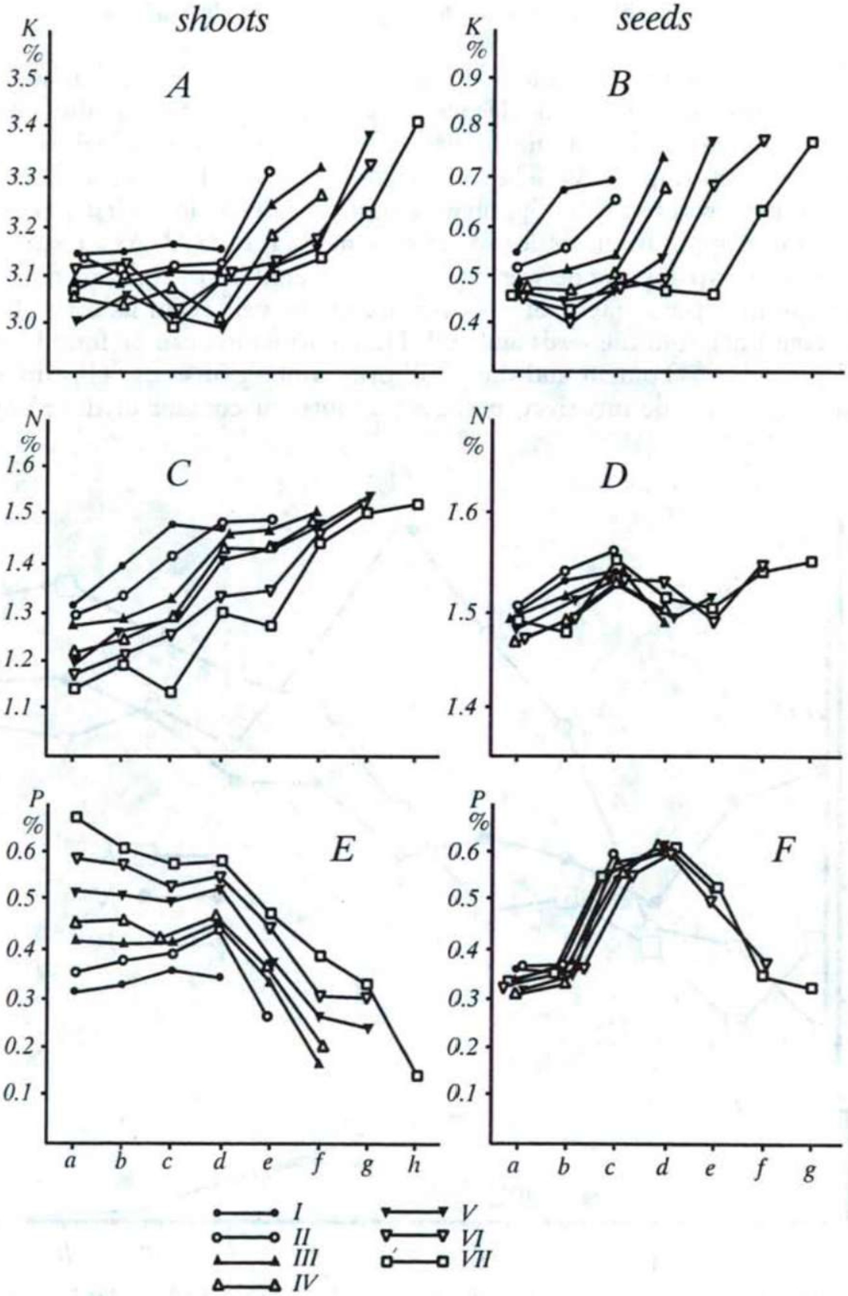

Figure 3 Distribution of plant nutrients in plant shoots and seeds along transect 'a–h'. The lines connect values that were sampled at the same time (I–VII). See Fig. 2.

Connection between plant nutrient content of plants and the soil

The concentration of available potassium and nitrate nitrogen in the soil shows tendency to increase towards the deeper parts of the lake. The available phosphorus has a maximum value at the transect point 'd', but is also high at transect points 'c' and 'e' (Fig. 4/A). The relationship between the soil and the plant nutrient content was tested by Sperman rank order correlation. Firstly the results of a mechanical application of the test are presented (Tab. 1/A). As a result of this, a close relationship appears betwen the potassium content of soil and shoots, and between the nitrogen content of soil and shoots, as well as (in its early developmental stages) between the seeds and soil. High correlation can be found between the soil phosphorus content and the phoshorus content of seeds. This interpretation, however, may be incorrect, because the nutrient content of the plants had

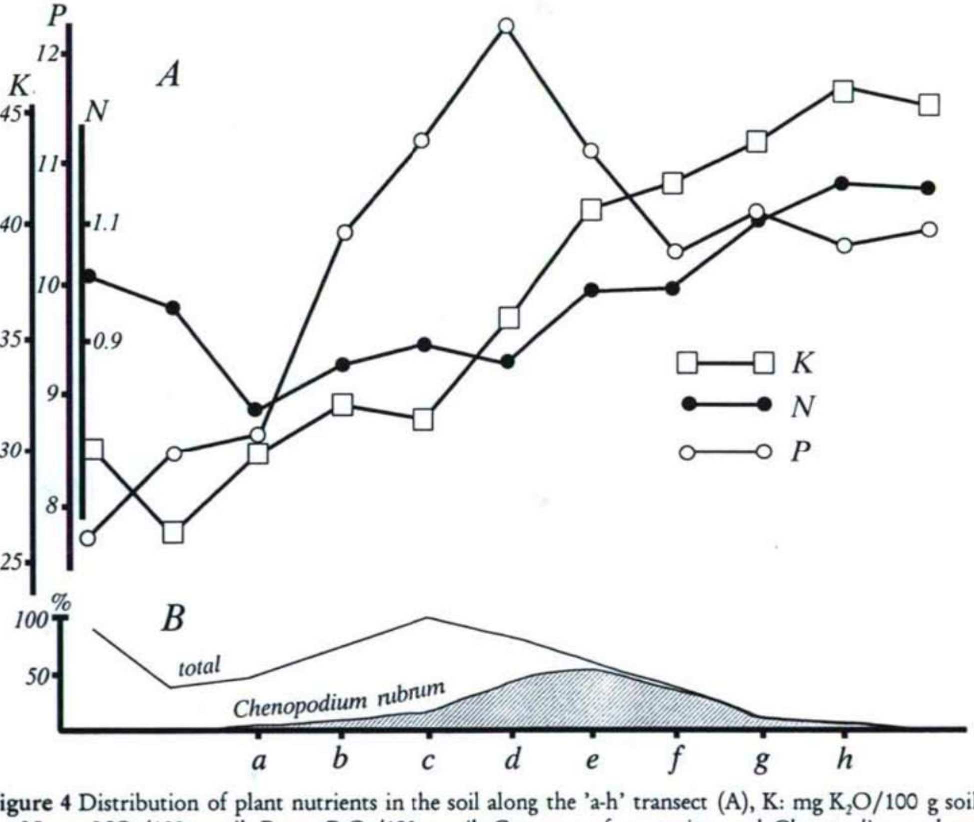

Figure 4 Distribution of plant nutrients in the soil along the 'a-h' transect (A), K: mg K_2O/100 g soil, N: mg NO_3/100 g soil, P: mg P_2O_5/100 g soil. Coverage of vegetation and *Chenopodium rubrum* var. *pusillum* along the transect (B).

changed during the plant development in several cases (see above). The interpretation would be more correct if plant material of similar developmental stages was compared. A possible resolution of this problem is to compare plants that are close to similar distances from the receding water. A graphical illustration of the selection (and some cases of the reduction) of such a sample can be followed in Fig. 5. The results are derived from the comparison of the corrected data of plant materials and the soil conditions, and can be studied in Tab. 1/B. (Tab. 1/B). The most important difference is that the close correlation between the potassium concentration of soil and the potassium content of shoots, as well as between the soil nitrogen and nitrogen content of shoots, are lost, but high correlation arises between the phosphorus content of the soil and the shoots. The distribution of phosphorus content in the soil and in the seeds remains in close correlation.

Table 1. Connection (Spearman R) between nutrient content of plants and the soil. ***: P<0. 01, **: P<0. 05, *: P<0. 1, age in weeks.

(A) date	n K shoots	N shoots	P shoots	n K seeds	N seeds	P seeds
31.07	4 0.400	0.949*	0.800	3 0.500	1.000***	0.500
12.08	5 0.100	0.821*	0.700	3 0.500	1.000***	0.500
30.08	6 0.783*	0.794*	0.257	4 0.800	0.632	1.000***
12.09	6 0.486*	0.706	0.290	4 0.400	0.949*	1.000***
03.10	7 0.893***	0.927***	-0.036	5 0.600	0.616	1.000***
15.10	7 0.883***	0.927***	-0.179	6 0.829*	0.441	0.943***
01.11	8 0.905***	0.771**	0.000	7 0.429	0.661	0.786**
(B) age						
2-3	5 0.900**	0.872*	0.900**			
4-5	5 0.500	0.154	1.000***			
6-7	5 -0.500	-0.316	0.800	5 0.600	0.359	0.900**
8-9	5 -0.300	-0.667	0.900**	5 0.600	0.474	1.000***
10-11	4 -0.200	-0.632	1.000***	5 -0.800	0.205	0.900**
12-13	3 0.500	-0.500	1.000***	4 0.200	0.949*	1.000***

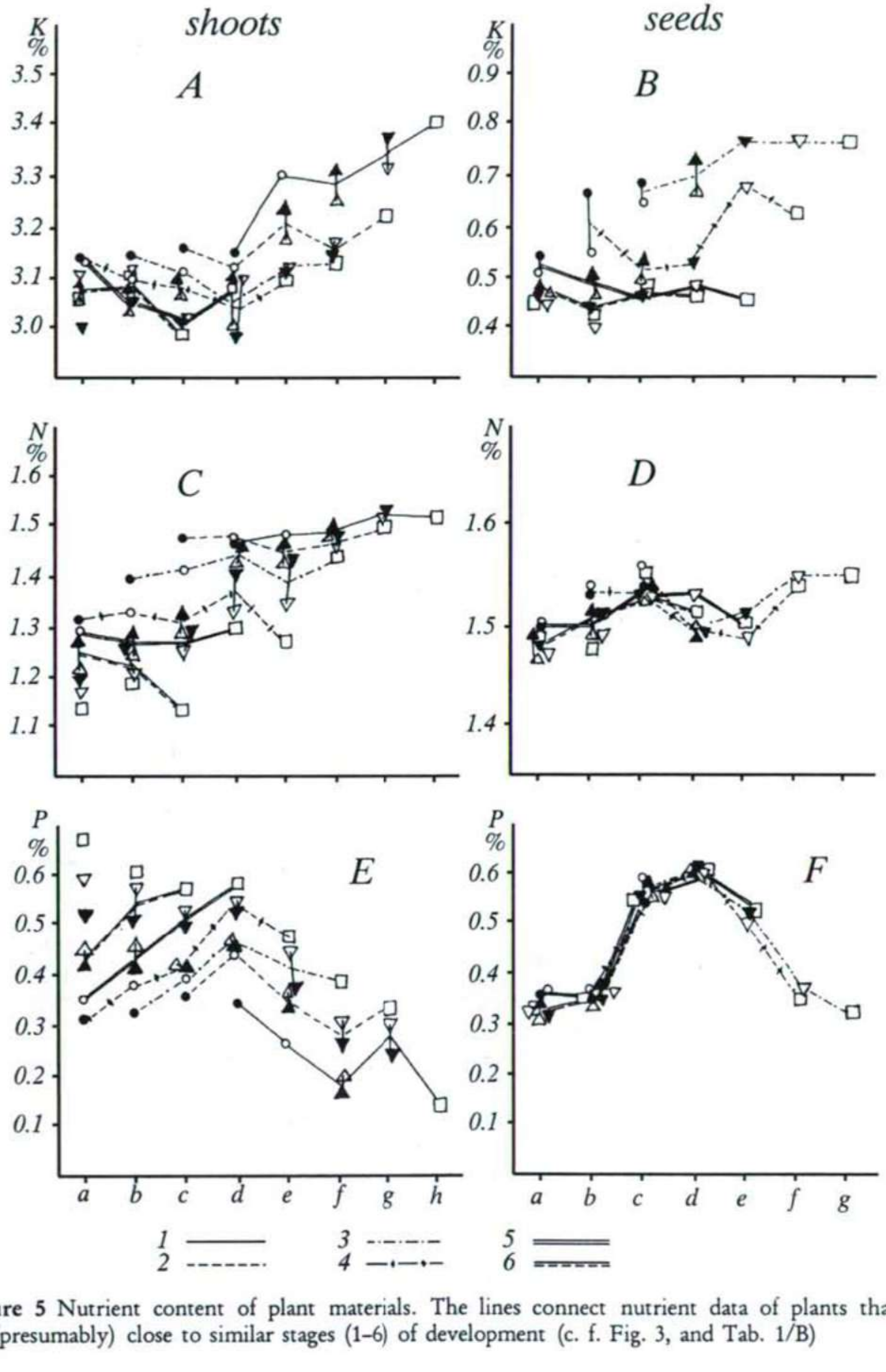

Figure 5 Nutrient content of plant materials. The lines connect nutrient data of plants that are (presumably) close to similar stages (1–6) of development (c. f. Fig. 3, and Tab. 1/B)

Discussions and Conclusions

Relationships between edaphic factors and the nutrient content of plants may be informative in cases where the concentrations are close to constant during the period of investigation. If the nutrient contents of plants show tendentious changes, a single transect study may give questionable results: For example, as a result of this study, it is probable that false significant correlations arose between the potassium as well as the nitrogen content of shoots and the soil. The mechanical application of tests suggests that there are no strong correlations, in, for example, those which exists between the phosphorus content of shoots and the soil. If the nutrient contents of plants show tendentious changes, a single, occasional transect study may (although not necessarily) give questionable results. In this study the phosphorus and potassium content of seeds are close to constant. In spite of this, only the phosphorus content of the seeds shows probable significant positive correlation to that of the soil. The relationship between the seed nitrogen content and the soil nitrate concentration is dubious. At the same time, the tendentiously decreased phosphorus content of the shoots is probably in close correlation to the available phosphorus in the soil.

In spite of the intentionally choosen elementary field samples (c. f. PEMADASA and LOWELL, 1974; CHAPIN, 1980; GOLDBERG and MILLER, 1980; WOODMANSEE and DUNCAN, 1980; ERNST, 1983; LEVINE et al., 1998), interpretation of correlations between the distribution of plant nutrients in the plants and the soil needs due foresight. In the case of dynamic or more complex vegetation situations, since the interpretation of field data requires too much consideration, the ecological investigation of relationships between the plant nutrient conditions and the edaphic factors (not to mention the competitive relations) needs controlled conditions particularly in relation of nutrition (SHAVER and MELILLO, 1984). If the production of controlled conditions is difficult (e. g. in forest sites), the investigation of the seasonal nutrient cycle is of the utmost importance (COLE, 1981; JAKUCS et al., 1981; VITOUSEK, 1982; BIRK and VITOUSEK, 1986).

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