Investigations on Nutrient Content in Beech (*Fagus sylvatica* L.) Seedlings of Various Provenances

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Introduction

The variability and diversity of the plant species of an ecosystem are of high importance for its stability. The variablility of a single species is of similar importance, if it has a long life cycle, like trees, which have to face various ecologic conditions in the course of their lives and have to become adapted to them. Demands for the adaptability of plants have increased as the environmental factors have gone through great changes within a short time (warming up, drought, environmental pollutions etc.). Those populations of a species have the highest adaptability to changing environmental conditions, which are variable themselves, meaning that they have manifold genetic heritage. Such are the forest stands in Central Europe, if they have been able to regenerate themselves in a natural way. Due to their widespread range and their slow wandering back to their original habitat after the boulder-period (FIRBAS, 1949; KRAHL-URBAN, 1954), it is possible that some provenances were not able to regain their former genetical variability. We may assume that the variability of a species is highest in places where it could survive the boülder-age. Such is the case of beech (*Fagus sylvatica* L.) in Southern Italy (LARSEN, 1986a; MEKIC, 1988; KUMKE, 1991).

For the determination of the genetical variability of populations well-tested techniques are at our disposal (sequentation of nucleotids, REPL, isoenzyme testing methods etc.). The disadvantage of these techniques is that we often don't know the function of a given gene in the growth of plant and its influence on the phenotypical appearance of the plant. In forestry practice the determination of phenotypical differences has great importance, as we have to know the impacts genetical variability may have on the superiority in vitality, growth and adaptability of a provenance. In most cases only a small part of the genetic make-up of a tree species is found in a provenance. This incomplete gene-set is responsible for the inferior adaptability of a local provenance, however, the species itself would be able to show better performance with its complete genetical variability and adaptability (LARSEN, 1981, 1986a,b; LARSEN et al., 1985).

The aim of our work was to test 16 beech provenances and to find the phenotypical (morphological, phenological and physiological) differences that may exist among them, the relationships among the main features and the features that are suitable for the identification of the single provenances. In this paper the results of nutrient content studies are presented.

Material and Methods

16 provenances of beech – collected from various parts of its geographical range – were included in our investigations (MAJER, 1976, 1977; GENCSI & VANCSURA, 1992) (Table l).

Raising of plants. – 24 plants by provenances were raised in the glasshouse covered with wire-netting of the Georg August University Forestry Faculty, Göttingen. The experimental design was random block; plants were arranged in 4 blocks, each containing 6 plants. At the beginning of the experiment (in mid-February) plants were transplanted from containers to pots and were kept there to the end of the experiment. Each block was set on a pushable „tray". In the course of the experiment plants were fertilized twice (at the beginning of June and end of July) and were controlled against green-fly aphids. Irrigation was implemented according to need.

Table 1
Most important features of the investigated beech provenances

Beech Provenance's			Altitude above sea level, m
Name	Sign	Country	
Lensahn - 81003	LE	Germany	50 - 100
Hasbruch - 81002	HA	Germany	600 - 700
Scheänitz - 81013	SZ	Germany	300 - 500
Freising - 81014	FR	Germany	400 - 500
Idrija Mrzla Rupa	SL	Slovenia	900
Strimbu Baiut, Máramaros, A 130 - 1988	R88	Romania	1000 - 1300
Vlasenica	VLR	Bosnia	300 - 600
Aspromonte (Calabria)	C1	Italy	1300
Ferdinandea (Calabria)	C2	Italy	1050
Fossiata - Amocampo, (Calabria)	C3	Italy	1500
Cinquemiglia (Calabria)	C4	Italy	1000
Tortorici (Szicilia)	S1	Italy	1500
Lagopesole (Potenza)	LA	Italy	1000 - 1100
Riffreddo (Potenza)	R1	Italy	1000 - 1100
Capracotte (Molise)	CA	Italy	1475
S. Massimo (Boiano)	MA	Italy	1375

Sampling and investigations. – Plant samples were taken three times in the growing season, namely one-one leaf in June and July, while at the end of September all leaves were collected and sampled. Then their dry mass, surface, number of pieces and the nutrient concentrations in their dry matter were determined. Nitrogen was determined by the Kjeldahl method with Büchi B-426 destruction-rack and Büchi B-323 distillation set. Other elements were determined after digestion (by nitric acid and hydrogen peroxide) with a GBC Integra XM inductively coupled plasma optical emission spectrometer.

Data of measurements were processed by one factor variance analysis with SPSS for WINDOWS package (SAUERWEIN & HÖNEKOPP, 1990; SPSS ..., 1993). As the first step of the data processing, the provenance means, standard deviation, error of standards, their minimum and maximum and confidence limits at 95% probability were determined. Following the completion of the variance analysis table and the determination of significance levels, Duncan multiple-size tests were used to find which means differ from each other and to what extent. In order to find relationships among the measurement data regression and correlation analyses were made, and for the formation of groups cluster analysis was applied (DÉVÉNYI & GULYÁS, 1988; PODANI, 1988). 95% was taken as significance level for the statistical analysis.

Results

Nitrogen content in the leaves

On the basis of our measurement data the mean nitrogen content was 2.8% in June and 2.3% in July, both corresponding with the literature data (PAVLOV, 1972; RZEZNIK & NEBE, 1987; FLÜCKIGER et al., 1986; BERGMANN, 1988; JÁRÓ, 1988/89; LYR et al., 1992; ASCHE, 1994). No significant difference was found among the provenances.

In autumn (Table 2) the nitrogen content in leaves ranged between 1.0 and 2.3%, the lower limit is somewhat below the literature data (PAVLOV, 1972; RZEZNIK & NEBE, 1987; FLÜCKIGER et al., 1986; BERGMANN, 1988; JÁRÓ, 1988/89; LYR et al., 1992; ASCHE, 1994). This quantity was closer to that found in beech litter (JÁRÓ, 1963; PÁNTOS et al., 1983), indicating that nitrogen wandered back from the leaves to the shoots and buds before the leaves fell down. The declining tendency in the three measurements supports this assumption and is similar to findings published in literature. Significant differences were found between the autumn means of single provenances. The lowest nitrogen content (1.5-1.6%) was found in provenances C1, SL, R1 and CA, while high nitrogen contents (1.78-1.90%) were registered for provenances R88, S1 and LE. There was no difference among the provenance regions.

Table 2

Average element content in the leaves of the investigated beech provenances in autumn

Prove-	N	P	K	Mg	Ca	S	Mn	B	Cu	Fe	Zn	Al
nance	%	mg/g					ppm					
C1	1.50	2.9	8.5	6.3	25.4	5.7	156.4	12.7	15.7	128.9	135.8	29.4
C2	1.61	2.8	8.2	5.3	23.3	5.7	139.8	15.5	17.9	128.2	166.1	27.5
C3	1.63	2.1	7.1	4.4	25.5	5.4	180.7	13.1	17.6	166.3	134.8	28.2
C4	1.66	2.4	8.6	4.5	22.0	5.5	115.4	11.5	17.2	135.2	187.5	27.3
CA	1.57	3.2	7.6	5.8	24.7	5.1	163.9	28.9	17.2	166.3	162.0	34.5
FR	1.77	2.9	7.4	5.3	21.6	5.2	202.1	15.0	15.1	139.9	170.7	24.8
HA	1.65	2.8	7.8	4.8	21.8	5.0	160.1	18.3	18.4	133.3	141.0	25.4
LA	1.73	3.3	8.1	4.8	25.1	5.1	181.7	20.8	17.2	112.9	151.7	22.7
LE	1.90	2.4	7.1	5.0	21.6	5.1	156.3	15.4	17.5	119.4	151.1	25.8
MA	1.76	3.2	8.2	4.7	24.9	5.7	189.9	18.6	17.3	163.9	190.7	29.7
R1	1.51	3.5	7.5	6.3	27.9	5.7	178.9	18.1	17.4	146.5	212.4	28.8
R88	1.78	2.6	7.8	5.4	23.7	5.5	156.0	17.8	17.7	138.2	146.5	28.5
S1	1.80	2.4	8.2	5.3	23.9	5.7	157.5	13.3	18.9	123.8	215.1	24.9
SL	1.50	3.3	8.4	5.1	23.1	5.1	154.3	21.7	17.7	165.4	152.1	30.4
SZ	1.70	3.2	8.1	5.6	24.4	5.5	161.2	15.4	17.9	146.9	198.7	27.5
VLR	1.74	2.4	7.2	5.2	20.8	5.3	155.1	21.9	17.1	130.1	152.5	25.6
Mean	1.68	2.8	7.9	5.2	23.8	5.4	162.7	17.3	17.4	140.0	166.6	27.5

Phosphorus content in the leaves

The phosphorus content in leaves was much the same in June and July: 2.1 and 2.2 mg P/100 g plant mass, respectively. Regarding this slight dispersion, it is evident that no significant difference was found among the provenances. The same can be proven with the groups formed by the Duncan test. Only two groups could be formed on both sampling occasions, there was a great overlapping between them. The phosphorus content was higher to a slight extent in autumn (2.8 mg P/100 g plant mass) (Table 2). Both the summer and autumn values were somewhat higher than the means published in the literature (FLÜCKIGER et al., 1986). In autumn there were differences among the provenances. The lowest phosphorus content (2.0-2.4 mg P/100 g plant mass) was recorded in provenances C3, C4, LE, Sl and VLR. 50% more phosphorus was present in provenances SZ, CA, MA, SL, LA and R1. There was no difference among the provenance regions.

Potassium content in the leaves

The potassium content in leaves was 5.8 and 6.2 mg K/100 g plant mass on average in June and July, respectively. There was no statistically confirmed difference among the provenances. There was almost as much difference within the provanances themselves than among them. Higher means (7.9 mg K/100 g plant mass) were gained when 178 samples taken from the autumn leaves were evaluated (Table 2). The difference among groups is minimal according to the variance analysis and the Duncan test. The lowest potassium content (7.1 mg K/100 g plant mass) was performed in provenances C3, LE, VLR, while the highest values (8.4-8.6 mg K/100 g plant mass) in provenances SL, C1 and C4. The difference between the two groups is scanty. With regard to the large dispersion of data it can be neglected.

Magnesium content in the leaves

The mean magnesium content in the 140 plants analyzed in June was 7.6 mg Mg/100 g plant mass, while it was 6.7 mg Mg/100 g plant mass (out of 47 plants) in July. Of the two sampling dates it was only June, when we could attain statistical differences among the provenances. This time three statistically homogenous groups were formed by the Duncan test, but they all largely overlapped each other. Low magnesium content (6.4-6.6 mg Mg/100 g plant mass) occurred in provenances C4 and C3, while in provenances CA and SZ the magnesium content was high (8.8-9.3 mg Mg/100 g plant mass). The mean was less in the autumnal leaves (Table 2) (5.2 mg Mg/100 g plant mass). There were significant differences among the provenances, this could be proven not only by variance analysis, but by the Duncan test, too. Similarly to the investigations in June the C3 and C4 provenances showed the lowest magnesium content (4.4-4.5 mg Mg/100 g plant mass). The similarity cannot be proven in autumn for the highest magnesium contents, as provenances R1 and C1 had the highest (6.3 mg Mg/100 g plant mass) values. It was not possible to find out whether the similarities found in June and autumn are by chance or have some internal physiological reason. However it is remarkable, that there are such tendencies.

Calcium content in the leaves

The calcium content in leaves was 14.5 and 15.5 mg Ca/100 g plant mass in June and July. There was no significant difference among the provenances. Much higher calcium contents (23.8 mg Ca/100 g plant mass) were measured in autumn (Table 2). This increasing tendency from the beginning towards the end of vegetation season is in accordance with literature data (FÜZESI et al. ,1962). Though the deviation is not as high as mentioned by JÁRÓ & HORVÁTH (1960), the reason of it may be that summer leaves already contain more calcium than those in spring. Regarding the autumnal calcium contents there were significant differences among the provenances according to the variance analysis and Duncan test, too. Lowest calcium contents (20.7-21.8 mg Ca/100 g plant mass) were registered for provenances VLR, FR, LE and HA, while the highest values

(25.4-27.9 mg Ca/100 g plant mass) for provenances C1, C3 and R1. Comparing the summer and autumnal data, it is peculiar that the absolute calcium content changed in the provenances, some ones were always performing scanty (e. g. LE) or high (e. g. C3, R1) calcium contents. This fact needs some further investigation.

Sulphur content in the leaves

There were no considerable differences among the results of analyses carried out in June (6.0 mg S/100 g plant mass), in July (5.5 mg S/100 g plant mass) and in autumn (5.4 mg S/100 g plant mass) (Table 2). In June there were statistically proven differences among some provenances. Low sulphur content was measured in provenances VLR and LE (4.9-5.1 mg S/100 g plant mass), while C1 and S1 provanences had sulphur contents ranging from 7.2 to 8.4 mg S/100 g plant mass). In the latter plants the sulphur content was high at all three analysis dates, though it ought to have been less in accordance with the general tendency.

Manganese content in the leaves

Because of the little leaf mass at our disposal, the concentration was scarcely traceable in June, while that in July just attained the tracing limit. Manganese content was 47 ppm on average in July, but this value can only be taken as informatory. The mean concentration was much higher (162.7 ppm) in autumn (Table 2). The difference among provenances was considerably less than in summer. With the help of the Duncan test two statistically homogeneous groups could be formed, but – due to the results of variance analysis – some precaution is necessary for taking them into consideration. Low manganese contents (115-155 ppm) were detected in provenances C4, C2, SL and VLR, while C3, LA, MA and FR belonged to provenances with high Mg contents (180-202 ppm). There was no difference among the provenance groups.

Boron content in the leaves

Boron contents were determined only in the autumnal samples. On ground of this, it was 17 ppm on average (Table 2). Based on variance analysis and the Duncan test there were differences – on a very high significance level – among the provenances. C4 and C1 were provanences with low boron content (11.5-12.7 ppm), while SL and VLR had high values (21.6-21.9 ppm). The boron content was extremely high (28.9 ppm) in CA, which statistically differed from all other provenances.

Copper content in the leaves

Copper contents were analyzed only in case of the autumnal leaf samples, which had a mean copper content of 17.4 ppm (Table 2). The difference among the provenances and within the provenances themselves was similar, meaning that the provenance has no impact on the copper content of leaves. This can be explained by two reasons, namely by a physiological one, and by the fact that very low concentrations (0.007-0.5 ppm) were measured, showing very large dispersion and this may cover the differences among the provenances.

Iron content in the leaves

The mean iron content of the leaves was 59.8 ppm in June and 56.3 ppm in July. Significant differences were found among the provanences, but only on a minimal significance level. In June low iron contents (31.5-41.6 ppm) were attained in provenances VLR, SL, MA and CA and in July (25.9 - 37.6 ppm) in S1 and C1. High iron contents (119.1-128.3 ppm) occurred in S1 and C3 in June and one month later (75.8-87.6) in R88, C2 and C3. In the autumnal samples (Table 2) the iron content was much higher (140.0 ppm). There was no statistical difference among the provenances.

Zinc content in the leaves

The zinc content of the samples was 80.4 and 103.7 ppm in June and July. In June two provenances performed very different contents from the others: R88 (65.2 ppm) and S1 (103.3 ppm). All other provenances did not differ statistically from each other. In July again the S1 performed a salient value with a zinc content of 147.0 ppm. Even more zinc (166.6 ppm in average) was determined in the autumnal leaves (Table 2). The provenances statistically differ from each other according to the variance analysis and Duncan test. C3, C1, HA, R88 and LE were provanences with low zinc content (134.9-151.1 ppm). The highest zinc concentration (215,2 ppm) was recorded in S1. This may be due to biological reason.

Aluminium content in the leaves

The aluminium content was 37.0 ppm in June and 30.3 ppm in July. Based on the analytical results, variance analysis and Duncan test, the provenances statistically differ from each other. Low aluminium contents were observed in provenance SL (32.7 ppm) in June and in LA and FR (22.2-22.7 ppm) in July. Very high aluminium content was characteristic of S1 (68.4 ppm in June and 57.6 ppm in July). The latter value is 20 ppm higher than the second highest aluminium content obtained in C1 (39.6 ppm). In autumn less aluminium (27.5

ppm on average) occurred in the leaves than in summer (Table 2). There was a strong decrease in the diffferences among provenances and among individuals within a provenance. Therefore there is no demonstrable difference among the provenances. Our aluminium data were lower than those published in the literature, only HÜTTL (1991) mentioned similar values for withering leaves.

Nutrient content in shoots

The autumnal nutrient content in shoots was also determined (Figure 1). Because all plants could not be analyzed, no statistical evaluation was made.

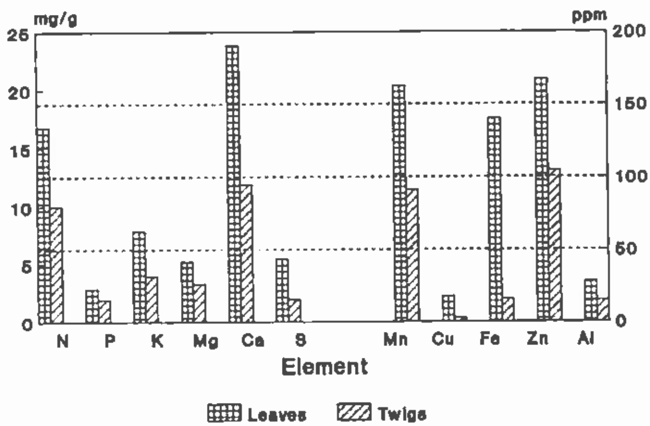

Figure 1
Autumnal nutrient contents in the leaves and shoots of the studied provenances of beech

Nutrient contents in the shoots were always lower than those determined in the autumnal leaves. The difference was twofold on average in case of all elements, but there were elements (copper and iron) for which the difference was tenfold. In the course of calculations the nutrient contents that may get built into the aboveground part of the plants were determined. Of the aboveground dry matter leaves account for about 25% and woody materials for 75%. These proportions do not fall in line with the data of JÁRÓ (1988/89), who stated that the proportion of leaf matters in the aboveground part of a 6-year-old beech tree amounts to 56% and that of shoots and woody materials to 44 %. With ageing the proportion of leaves decreases to the total. The deviations in the two cases can be explained by the heterogeneous raising techniques, too.

With the help of plant mass and its nutrient content data the quantity of nutrients built into the leaves and shoots were calculated separately from each other and their ratio was also established (Figure 2). In most of the elements

60% of the nutrient content was found in the shoot, but there were two exceptions: 41% of the copper and 25.5% of the iron were built into the shoot. This low ratio is understandable if the very low concentrations of the two elements in the shoot as compared to leaves are regarded.

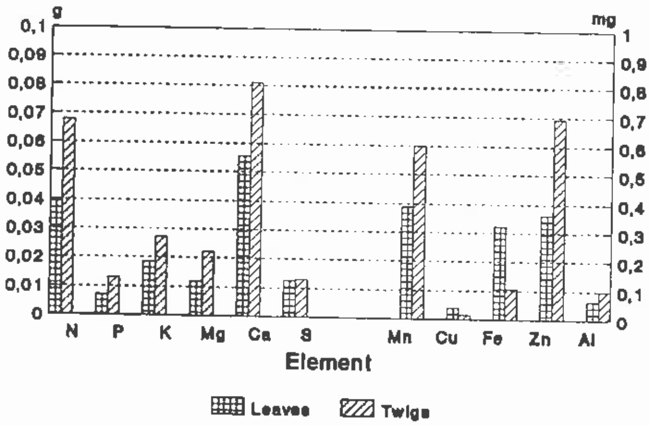

Figure 2
Quantity of nutrients accumulated in the leaves and twigs

These findings have to be taken into consideration when planning the nutrient supply in nurseries, because the major part of nutrients is carried away when seedlings are lifted and transported away.

Interrelationship among nutrient elements

To find interrelationships among the nutrient elements, correlation was calculated. For the autumnal data the tightness of the interrelationships among nutrient elements together with the statistical confidence were determined. There was no close correlation among most of the nutrient elements. A very close relationship was found, however, between iron and aluminium (0.8792), and a close positive correlation between sulphur and zinc (0.5202), calcium and manganese (0,5171), as well as between sulphur and nitrogen (0.4228), phosphorus and calcium (0.4243), manganese and phosphorus (0.4161). A negative correlation was established between potassium and copper contents (-0.4778).

Similarity analysis on the basis of nutrient contents

Similarity analysis with the provenances were conducted by cluster analysis. The nutrient data of leaves served as basis of the similarity analysis. The results of the study are presented in a dendrogram (Figure 3). As it can be seen in the dendrogram, the Sicilia progeny differs from the others, and those from Calabria (C1 and C3) also differ. The other provenances could be formed into smaller groups, namely provenances Molise (CA), Slovenia (SL), Hasbruch (HA) and Transsilvania (R 88) were arranged into one group. Provenances Lensahn (LE) and Bosnia (VLR) were mathematically close to these. The provenances from Italy and Germany were between these groups.

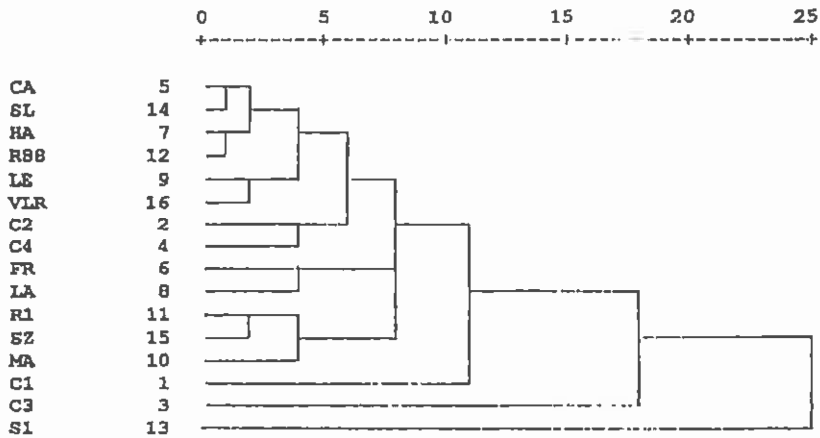

Figure 3

Dendrogram showing the similarity of the studied provananсes of beech on the basis of the nutrient contents of leaves

It is interesting that the provenances of Calabria can be found in two groups. This distribution is connected with the altitude of their habitat. Provenances C1 and C3 have their habitat at an altitude of 1300 and 1500 m, while the other ones (C2 and C4) at 1000-1050 m, respectively. This height difference may have more importance than the geographical distances of several thousand km.

Summary

16 beech (*Fagus sylvatica* L.) provenances were investigated by comparing the nutrient content in their leaves and shoot. The experimental plants were sampled three times in a vegetation period. It was found that some nutrient contents (nitrogen, magnesium, aluminium and sulphur) decreased in the leaves during the vegetation period, whereas phosphorus, potassium, calcium, manganese, iron and zinc contents increased. Based on nutrient investigations no significant differences could be found among the geographical provenances of beech. But with the help of some elements (nitrogen, phosphorus, magnesium calcium, boron, zinc) groups of provenances could be formed, which signifi-

cantly differed from each other. Nutrient concentrations were always lower in the shoots than in leaves. In spite of this, in the shoots of two-year-old beech seedlings more nutrients accumulate because of their bigger absolute mass by the end of the vegetation season.

References

ASCHE, N., 1994. Elementgehalte von Buchenblättern auf ausgewählten Kalkversuchsflächen. Allgemeine Forstzeitschrift. 14. 792-794

BERGMANN, W., 1988. Ernährungsstörungen bei Kulturpflanzen: Enstehung und Diagnose. VEB Gustav Fischer Verlag, Jena

DÉVÉNYI, D. & GULYÁS, O., 1988. Mathematical Statistical Methods in Meteorology. (In Hungarian) Tankönyvkiadó. Budapest

FIRBAS, F., 1949. Spät- und nacheiszeitliche Waldgeschichte Mitteleuropas nördlich der Alpen. Verlag von Gustav Fischer. Jena

FLÜCKIGER, W. et al., 1986. Untersuchungen über Waldschäden in festen Buchenbeobachtungsflächen der Katone Basel-Landschaft, Basel-Stadt, Aargau, Solothurn, Bern, Zürich und Zug. Schweiz. Z. für Fosrtwesen. 137. 917-1010.

FÜZESI, I., NEMKY, E. & VANCSURA, R., 1962. Investigations on the Ca content of falling leaves with regard to acid soils of Sopron Hills. (In Hungarian). Erdészettudományi Közlemények. 2. 151-159

GENCSI, L. & VANCSURA, R., 1992. Dendrology. Forestry Botany II. (In Hungarian) Mezőgazda Kiadó. Budapest.

HÜTTL, R., 1991. Die Nährelementversorgung geschädigter Wälder in Europa und Nordamerika. Freiburger Bodenkundliche Abhandlungen. 28. füzet.

JÁRÓ, Z., 1963. Decomposition of leaf-litter under various forest stands. (In Hungarian). Erdészeti Kutatások. 10. (1-2) 95-106.

JÁRÓ, Z., 1988/1989. Organic matter and nutrient cycle of beech forests. (In Hungarian) Erdészeti Kutatások. 80/81. 83-98.

JÁRÓ, Z. & HORVÁTH, E., 1960. Calcium content of the forest litter and its importance. (In Hungarian) Erdészeti Kutatások. 7. (1-3) 99-103

KRAHL-URBAN, J., 1954. Buchenrassenstudien im Bayerisch-Böhmischen Wald, in den Bayerischen Alpen und in den Karawanken. Forstwissenschaftliche Centralblatt. 73. 309-325

KUMKE, J., 1991. Untersuchung über den Einfluß von Licht- und Nährstoffunterschieden auf Gaswechselphysiologie, Wachstum und Morphologie von Buchenkeimlingen (*Fagus sylvatica* L.) verschiedener Provenienzen. Göttingen.

LARSEN, J. B., 1981. Waldbauliche und ertragskundliche Erfahrungen mit verschiedenen Povenienzen der Weißtanne (Abies alba mill.) in Dänemark. Forstwissenschaftliche Centralblatt. 100. 275-287.

LARSEN, J. B., 1986a. Das Tannensterben: Eine neue Hypothese zur Klärung des Hintergrundes dieser rätselhaften Komplexkrankheiten der Weißtanne (*Abies alba* Mill.). Forstwissenschaftlichen Centralblatt. 105. 381-396

LARSEN, J. B., 1986b. Die geographaphische Variation der Weißtanne (*Abies alba* Mill.) Wachstumsentwicklung und Frostresistenz. Forstwissenschaftliche Centralblatt. 105. 396-412.

LARSEN, J. B. & SCHAAF, W., 1985. Erste Ergebnisse des Weißtannen-provenienz-versuchs von 1982, 4. Tannen-Symposium, Syke. Schriftenreihe der Forstliche Fakultät Göttingen 1985.

LYR, H., FIEDLER, H. J. & TRANQUILLINI, W., 1992. Physiologie und Ökologie der Gehölze. Gustav Fischer Verlag. Jena.

MAJER, A., 1976. Half century old experiments in the beech forests of Farkasgyepü. (In Hungarian) Magyar Tudományos Akadémia Veszprémi Akadémiai Bizottsága monográfiái. Erdészeti Szakbizottság közleményei **2.** (1)

MAYER, H., 1977. Waldbau auf soziologisch-ökologischer Grundlage. Gustav Fischer Verlag. Stuttgart.

MEKIC, F., 1988. Gaswechselphysiologische und morphologische Untersuchungen an 5-6 jährigen Weißtannen-Provienzen (*Abies alba* Mill.). Disszertáció. Göttingen.

PÁNTOS, D. T., PÁNTOS, GY. & VAHAYE, G. H., 1983. Transformation of the litter cover in some forest ecosystems in Hungary. (In Hungarian). Agrokémia és Talajtan. **32.** 365-371.

PAVLOV, M. B., 1972. Bioelement-Inventur von Buchen- und Fichtenbeständen im Solling, Göttinger Bodenkundliche Berichte. **25.** 1-174.

PODANI, J., 1988. SYN-TAX III., User's Manual. Abstracta Botanica. **12.** 1.

RZEZNIK, Z. & NEBE, W., 1987. Wachstum und Ernährung von Buchen-Provenienzen. Beiträge für die Forstwirtschaft. **21.** (3) 106-111.

SAURWEIN, K. H. & HÖNEKOPP, T., 1990. SPSS/PC+, Eine anwendunsorientierte Einführung zur professionellen Datenanalyse. Addison-Wesley. Bonn.

SPSS für Windows, 1993. Anwenderhandbuch für das Basis System.SPSS GmbH Sofware. München.