Bioassay experiment for assessment of site productivity in oak forests

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Introduction

Local productivity of forest stands can be estimated by soil analysis or by analysis of herb layer biomass. However, both approaches have some week points:

• **Soil chemical analysis** gives information about the quantity of nutrients in soil, but cannot reveal their real availability for plants.

• In contrast, the nutrient content in **herb biomass** can be highly dependent on species composition (differences in nutrient utilization).

In addition, biomass production depends on light and moisture availability.

A promising method for estimating soil nutrient availability is a bioassay experiment, which has been successfully used in several studies dealing with grassland vegetation. We decided to test this approach in forest vegetation using a set of soil samples from oak stands. We set up a greenhouse experiment based on planting of radish (*Raphanus sativus* subsp. *sativus*) in soil samples taken from these stands. After harvesting, oven-dried biomass of radishes was weighted and analysed for nutrient content (N, P, K and Ca).

The advantages of this bioassay experiment are:

- **unlimited moisture conditions**
- **constant climatic conditions**
- **equal light availability**
- **lack of interspecific competition**

We analysed the relationships between data from bioassay experiment, forest biomass data, soil data and other ecological factors measured in plots.

Methods

The dataset was restricted by selection of plots with dominating *Quercus petraea* and/or *Q. robur*, which has several advantages:

• constant influence on herb layer

• rather open canopy lowers the effect of tree layer on species composition

• ecological gradient of suitable length

The dataset was stratified along the gradient of productivity (based on forestry maps).

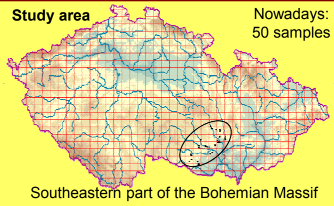
Measured factors:

• soil characteristics (pH, nutrient content N, P, K, Ca, C/N)

• light availability (estimated cover of tree canopy)

• herb layer biomass analysis (dry weight, nutrient content)

• bioassay experiment (see below)

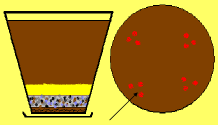


Southeastern part of the Bohemian Massif

Bioassay experiment

After removing the upper litter layer, we took four soil samples per each sampled plot (into the depth of 0–15 cm). These soil samples were then mixed together and sieved (mesh width: 3 mm).

Pots with diameter of 20 cm were filled by constant amount of drainage (on the bottom) and sieved soil. In the beginning of experiment, 12 seeds of radish (*Raphanus sativus* subsp. *sativus)* were sown into each pot and clustered into the groups of three. After successful seedling recruitment, only one seedling from three was left, resulting into four seedlings of radish separated by sufficient distance to ensure lack of competition.



Radish plants were cultivated in a greenhouse for six weeks (September–October 2007). We used special autum cultivar *Tarzan*. The pots were watered daily; to avoid the gradient in light conditions to affect the result, rows of pots and individual pots in rows were systematically shifted during the whole period of experiment.

Control pots with soil replaced by Perlite were watered with known concentration of fertilizer (N, P, K, Ca).

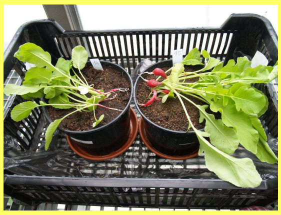
After harvesting, the biomass was dried and weighted (whole plants with only main root) and then analysed for nutrient content (N, P, K and Ca).

The first week

After the third week – half of the experiment

Before harvesting

The most obvious differences



Control pot with Perlite – the lowest concentration of fertilizer

Control pot with Perlite – the highest concentration of fertilizer

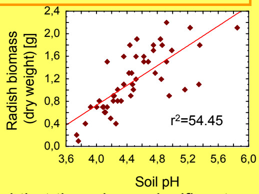
Results

Spearman correlations: significant correlations are marked with asterisks (*p* = 0.01 **, *p* = 0.05 *). Corresponding pairs of nutrient ratios are coloured.

		FOREST BIOMASS (herb layer)					RADISH BIOMASS				
		N/P	N/K	K/P	Ca_total	dry weight	N/P	N/K	K/P	Ca_total	dry weight
SOIL	N/P	0.426**	n.s.	n.s.	n.s.	n.s.	0.524**	0.336*	0.296*	-0.458**	-0.530**
	N/K	n.s.	0.312*	n.s.	n.s.	n. s.	n.s.	0.596**	-0.317*	-0.455**	-0.462**
	K/P	0.391**	n.s.	n.s.	-0.315*	-0.289*	0.506**	n.s.	0.395**	-0.355*	-0.427**
	Ca_total	-0.291*	-0.381**	n.s.	n.s.	n. s.	-0.550**	-0.429**	n.s.	0.495**	0.476**
	pH_H2O	-0.437**	-0.539**	n.s.	n.s.	n. s.	-0.562**	-0.527*	n.s.	0.833*	0.792*
	C/N	n.s.	0.388**	-0.467**	n.s.	n. s.	n.s.	n.s.	n.s.	-0.349*	n.s.

In contrast to the forest herb-layer biomass, the radish biomass better reflects soil characteristics (significant correlations between corresponding nutrient ratios). While neither the total amount of forest biomass nor its Ca content does not reflect soil pH, the radish biomass is significantly correlated with pH (see also the scatter plot).

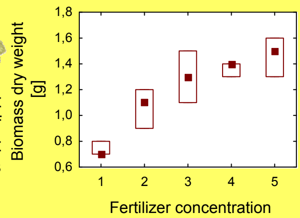
As our sampling covered mostly forests on acidic soils, the availability of phosphorus increases with pH. The positive correlation of radish biomass with soil pH could be therefore caused by its relationship with phosphorus content.

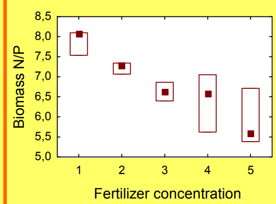


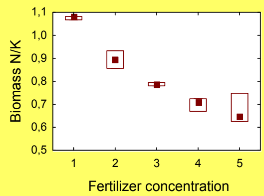
Comparison of forest herb-layer biomass data and radish biomass data revealed that there is no significant correlation except for the N/P ratio, which has even the same range and median of attained values.

Control radish plants (fertilised)

The control experiment confirmed the limitation of radish biomass by amount of available phosphorus and potassium.



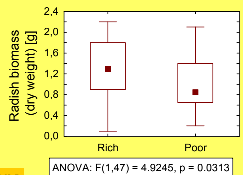




We created multivariate regression models, separately for forest and radish biomass, using soil characteristics and (in case of forest biomass) light availability as explanatory variables.

Multivariate regression models: AIC + F-test
Grey colour indicates variables selected by AIC forward selection, but with non-significant result of F-test.

FOREST HERB LAYER BIOMASS (dry weight)	~	Canopy of tree layer	+	Soil K/P	+	Soil C/N		
Cumulative variance explained		13.64%		23.04%		27.64%		
RADISH BIOMASS (dry weight)	~	**Soil pH**	+	**Soil N/P**	+	**Forestry maps**	+	**Soil C/N**
Cumulative variance explained		54.58%		65.62%		70.49%		73.62%
RADISH BIOMASS (dry weight) - pH excluded	~	**Soil N/P**	+	**Forestry maps**	+	**Soil C/N**	+	**Soil N/K**
Cumulative variance explained		29.70%		45.41%		57.37%		61.57%



Radish biomass in contrast to forest herb-layer corresponds significantly with forestry productivity maps.

For the forest herb-layer biomass, the cover of tree canopy was more important than the soil factors. Compared to the model of radish biomass, where measured variables explained over 75% of variance, the model of forest herb biomass explained only slightly more than 25%, indicating the lack of some important factors in the model. One of them is perhaps moisture, which was not measured; if moisture estimated by Ellenberg indicator values was added as an explanatory variable to the model of forest biomass, the explained variability increased to 31.1% (not shown).

Conclusions

The bioassay experiment showed, that radish as a phytometer plant can be successfully used for estimation of forest site productivity, as also indicated by the results from control pot experiment.

Both forest herb layer biomass and radish biomass more or less reflect the soil conditions, with one significant difference – while the radish biomass is highly correlated with soil pH, the forest herb biomass is not affected by pH.

Results of multivariate regression models support our hypothesis that the biomass of forest herb layer is significantly influenced by light and possibly moisture conditions. The fact that radish biomass reflects potential rather than realised productivity is documented also by significant correlation with forestry productivity maps.

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