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HEALTHY PLANTS BY INCREASING SOIL VITALITY - MONITORING RESULTS OF SOIL ANALYSES IN VEGETABLE CULTIVATION SYSTEMS

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Abstract

The production of healthy vegetables first requires a healthy soil in which to grow. The aim of the research is to evaluate the state of soil fertility in vegetable field cultivation in central Europe and to create a catalogue of measures to stabilize or even increase the soil fertility. To achieve this goal, a scientific monitoring of 13 pilot farms was taking place, start with soil analysis, the selection of area-specific measures and end with the evaluation of the effectiveness of these measures. Soil sampling was done 2021 from 0 - 30 cm and 30 - 60 cm. In one third of the fields the pH was below 6.0. Low humus contents of <2% were also found in one third. Humus enrichment is often advisable. An increase in diversity through intercrops promotes soil life in addition to organic matter. The results showed that the levels of macronutrients were in 50% of the fields very high. As a result, fertilization of P and K can be saved. The success in maintaining good soil vitality should be analysed two years after implementation.

Key words*: soil fertility, nutrient supply status, soil microbial biomass, soil organic carbon, food production.*

INTRODUCTION

Agricultural land worldwide is under increased production pressure. The soil is an important factor for effective food production. Intensive anthropogenic use as well as natural processes leads to nutrient losses and degradation over long time. Our research project "Healthy Soil - Healthy Plants - Healthy Vegetables" aims in to analysing the current state of soil fertility in different farms with divers soil properties in vegetable production areas. Soil fertility is the ability of soils to serve as a site for plants and is related to management effects and yield.

The content, quantity and quality of the humus are decisive in this respect. It influences soil physical, chemical and biological properties, such as water and nutrient balance, cation exchange capacity, pH value and mineralization (Thiel, E. and Kolbe, H., 2011).

The supply of nutrients, especially N, P, and K, from minerals or fertilizers to the soil affects the availability of other nutrients. In turn, the input of nutrients alters soil biogeochemical cycling. Biological characteristics are also used to estimate soil fertility influenced by agricultural activity. These are often soil biological parameters, such as soil organic matter, C/N value, and microbial biomass. Moreover, soil organic matter is considered an important factor of soil fertility. A major driver of SOC turnover are microorganisms. Microorganisms promote the formation of macroaggregates to physically protect carbon. Microbial biomass also plays a critical role in influencing the SOC pool (Zhang et al., 2013). Generally, up to 5% of the total organic carbon and nitrogen is in the soil microbial biomass. A change in microbial biomass can affect the cycling of soil organic matter. To date, there is no dataset on this scale from vegetable crops in Central Europe. During this project, numerous soil samples were collected at various locations in Germany, Poland and the Czech Republic. Now a large dataset of variety of soil chemical and biological parameters in Central Europe is available. Therefore, this work represents a first overview of the status of vegetable production areas. Field specific agronomic measures are recommended from the identified deficits.

One aim of the project is to develop a set of measures to increase the soil fertility and vitality in outdoor vegetable field production. After recording the actual state of the prevailing soils and management measures, the evaluation of the effectiveness of area-specific proposed measures on soil vitality will be conducted.

MATERIALS AND METHODS

The present study was conducted in fields with vegetable growing in Germany (7 farms), Poland (4 farms) and Czech Republic (2 farms). The research areas have an average annual temperature between 8.5 and 10.0°C. The average annual rainfall varies from 660 mm to 800 mm. In last years, rainfall has varied widely and occurs locally. Soils in the studied area are defined mostly as sandy loam (USDA texture classification), but differ from light to heavy soils. A total of around 50 fields with vegetable and arable land use were taken and analysed. The soil samples were collected out of the growing season 2021. Soil sampling was performed on a selected area of approximately 2 ha of the field, depending on the field size. In each field, minimum 20 samples from 0-30 cm and 30-60 cm depth were sampled with a borstick. They were mixed and homogenized for each plot and divided into two subsamples. One subsample was dried and ground before chemical and physical analyses. The other was stored in plastic bags at 4°C PLFA (phosphor lipid fatty acids) analyses. Fungal and bacterial biomass C were measured using this method. To determine the soil organic matter, we used the method of Eurofins Agro accredited by RvA (NIRS (TSC®). For grain size, the analysis ÖNORM L1061-2 (pipette method) was used. Soil pH was determined with $CaCl_2$ (DIN ISO 10390). The concentration of soil nutrient reserves was determined using an extract with ammonium lactate, pH 3.75 (Egner, H. & H. Riehm 1955). The CAT extraction of Mg, B, Mn, Cu and Zn was carried out by VDLUFA. The soluble fraction extracting agent of the nutrient fractions was a 1:5 water extract. The CaO reserve is the sum of the exchangeable Ca ions and the soluble, carbonated Ca ions in the extract. Heavy metal analysis is based on DIN EN 15763 and DIN EN ISO 17294-2:2017-01 and is performed by pressure digestion followed by determination by ICP-MS.

RESULTS AND DISCUSSIONS

The differences in soil substrates are shown by the fact that the soil properties vary greatly (Table 1). The coefficients of variation (cv-%) often assume values above 50%. Only for the parameters pH and C/N was the cv rather low, as expected, in the range between 14.5 and 17.8.

Table 1. Soil physiochemical and microbial properties

variable	Units	49 vegetable fields			
		Mean	Min	Max	Cv %
sand	%	61.1	5.1	93.0	43.7
silt	%	26.3	3.7	72.0	75.6
clay	%	12.7	1.7	43.0	75.0
SOC	%	1.17	0.50	2.30	41.9
pCEC	meq/100 g	11.90	4.40	33.90	55.4
pH	-	6.43	3.90	7.50	14.5
TN	%	0.14	0.07	0.28	33.7
C/N	-	9.1	6.5	13.7	17.8
K2O-Res	mg/100 g	23.0	7.0	65.0	51.6
P2O5-Res	mg/100 g	43.5	16.0	114.0	53.4
Mg-CAT	mg/100 g	10.1	1.8	24.7	45.1
B-CAT	mg/100 g	5.3	0.6	14.8	66.7
Mn-CAT	mg/100 g	587.3	91.0	2185.0	83.1
Cu-CAT	mg/100 g	22.1	5.3	86.8	76.3
Zn-CAT	mg/100 g	40.8	12.0	199.0	83.5
CaO-Res	mg/100 g	811	11	6766	191.4
Humic	%	2.14	0.90	4.80	38.0
MBC	mg C/kg	144.8	58.0	365.0	46.7
BBC	mg C/kg	61.0	23.0	161.0	48.8
FBC	mg C/kg	46.3	15.0	147.0	57.3
Pb	mg/kg	14.5	5.4	38.9	52.2
Cd	mg/kg	0.6	0.0	18.6	466.1
Cu	mg/kg	9.8	2.3	29.5	72.0
Hg	mg/kg	0.03	0.00	0.19	132.9

SOC- soil organic matter; pCEC- potential Cation Exchange Capacity; TN- total nitrogen; Res. –reserve, CAT- calcium chloride/DTPA method; MBC- soil microbial biomass carbon (Cmic); BBC- bacterial biomass carbon (Cbac); FBC- fungal biomass carbon (Cfungi)

pH values ranged from 3.9 to 7.5 in the soils. Maximum values of CaO reserve of 6,766 mg/100 g were observed. The minimum values were 11 mg/100 g for vegetable crop fields.

The soil results revealed deficits with regard to soil fertility. Thus, very low pH values occur, in extreme case this was 3.9 in one field. This can have numerous consequences on soil dynamics, such as ionic bonds and microorganism activities. Low pH may reduce Mg uptake and reduce available organic phosphorus. Our correlation results could not provide confirmation of this. Liming could be an effective tool to improve soil nutrient retention. Mg-CAT contents varied between 1.8 and 24.7 mg/100 g. Large differences also appear in the content of the micronutrient boron. In the fields, the values ranged from 0.6 to 14.8 mg/100 g. Our study partly revealed a deficiency of nutrients, mainly B as well as Mg, in the soil.

Very low levels of SOC (soil organic matter), reservers of CaO and various nutrients could also be observed. Due to these deficiencies, measures to improve these soils are necessary to ensure soil fertility in the long term. Corg content has roughly equal ranges of approximately 0.5 to 2.3%. C/N values are approximately 9.0. 30% of the fields have a low Corg and therefore humic substance content.

A look at the field history index provides information of the use of organic fertilizers. 25% of the companies don't use organic fertilizer but under-ploughing plant residues or straw of crops. 5 of 13 companies used manure (horse, cattle, chicken) as a fertilizer, 4 of 13 liquid manure, 3 fermentation residues and only one company compost as a long term fertilizer. As recommendation they should use more effective organic additives in most of the fields. All companies use intercrops (e.g., yellow mustard, phacelia, Terra Life, sand oats, sudan grass, oil radish, cereal varieties). This is good for the water balance, microorganisms and soil organic matter. As recommended measure they should further cultivate them as well as use longer growing times, especially over winter time.

A theoretical calculation of the humus balance can also be carried out using the field index. This provides information on the development of soil organic matter. Over 60% of farms have too long fallow periods (>25%) and a negative humus balance (<-75 HÄQ/ha, according to VDLUFA). Our analyses revealed good values for the microbiome. The maximum values of microbial biomass in C are 365 mg C/kg in vegetable crop fields, the minimum value was 58 mg C/kg, respectively. Approximately 20% of the fields have a lack of microbial biomass (Figure 1).

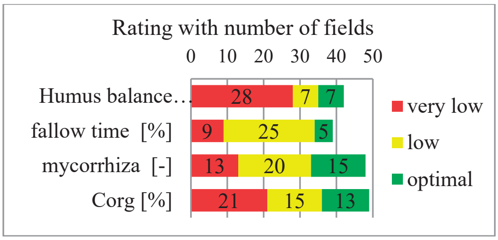

Figure 1. Evaluation of calculated parameters of the field history and soil parameters

Some relationships between soil properties are shown in Table 2. In general, sand content is negatively correlated with pH, total nitrogen (TN) and microbial parameters. However, no significant linear correlation was found between the sand content and the SOC in the soil. There is a close correlation between the total nitrogen content and soil organic matter and the microbial (especially bacterial) biomass in the soil. The revealed relationship between soil organic matter (SOC) and microbial biomass in carbon (MBC) highlights the important role of SOC in soil fertility, such as nutrient availability and the contribution of microorganisms to soil structure. Specifically, soils with SOC enrichment have more microbes to promote nutrient availability and soil structure development (Liddle et al., 2020).

Table 2. Correlation between measured parameters

	Corg	pH	MBC	BBC	FBC	TN	Clay	sand	Mg-CAT
Corg	1.0								
pH	-0.12	1.0							
MBC	0.61	0.34	1.0						
BBC	0.62	0.36	0.99	1.0					
FBC	0.51	0.38	0.97	0.96	1.0				
TN	0.87	0.25	0.81	0.82	0.74	1.0			
clay	0.4	0.62	0.78	0.78	0.72	0.74	1.0		
sand	-0.18	-0.66	-0.62	-0.61	-0.63	-0.52	-0.80	1.0	
Mg-CAT	0.37	0.36	0.61	0.59	0.62	0.57	0.62	-0.46	1.0
B-CAT	0.32	0.75	0.56	0.68	0.57	0.63	0.71	-0.71	0.45

The high correlations between microbial biomass and magnesium and boron CAT contents are also of interest. However, despite the importance of the soil microbial community for soil fertility, the effects of boron are still unknown (Vera et al., 2019). Boron has a noticeable effect on the soil nitrogen cycle. According to their study, the analysis of PLFAs showed that the effect of B on soil microbial biomass was dependent on the chemical form of fertilizers used. The correlation coefficients between boron and TN in our samples were 0.63 in vegetable crop fields. According to Vera et al. (2019), high B doses reduce soil microbial respiration, and fungal diversity is reduced. This was confirmed by our analyses. The correlation between boron and fungal biomass in carbon was between 0.54.

However, microbial biomass in vegetable fields correlates strongly (0.59-0.62) with Mg-CAT-content. According to Yang et al. (2021), who studied the short-term application of Mg fertilizers on soil microbial biomass and functions, the application of $MgSO_4$ significantly increases the C-mic content (MBC).

CONCLUSIONS

Due to frequently too low humus content and microbial biomass, the following measures are recommended for vegetable farms: more use of organic fertilizers, use of microbial soil additives and use of (new) intercrops. After consultation with the farmers of all 13 farms, a total of 71 measures were defined for the individual fields (Table 3).

Table 3. Measures resulting from the deficits

Measure	N=71
Addition of organic fertilizers	19
Calcification	18
Addition of micronutrients	16
an/ a new intercrop	10
Addition of microbial organisms	8
only observation	4

Thus, studies with altered management practices and the influence of micronutrient fertilizers, limes, and organic soil amendments are planned. The derivation of individual area-specific measures to maintain and increase soil fertility and biodiversity is to be based on the actual state determined here.

Soil organic carbon is an important parameter that determines soil fertility and maintains soil health. Chemical fertilization alters the soil nutrient status, which indirectly affects the soil carbon balance, while organic fertilization replenishes the soil carbon balance by directly adding organic carbon to the soil.

Various measures were implemented 2022 on a subplot of the pilot farms, and their success in improving and maintaining good soil vitality will be analysed and documented 2024. Maintaining and improving soil quality requires an understanding of how soils respond to agricultural and horticultural practices over time and the ability to quantitatively measure or monitor changes (Goh et al., 2001).

The results are summarized with theoretical knowledge in a catalogue of measures and made available to the farmers.

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