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Influence of Peats of Different Origins and Decomposition Degree on Germination and Early Growth of Chinese Cabbage

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Summary

Germination and early growth (21 days) of Chinese cabbage (*Brassica pekinensis* (Lour.) Rupr.) were investigated under controlled and standardized conditions using 20 peats from different countries and decomposition degrees. As control, a commercially available growing media for propagation was used. In the peats, some chemical and physical properties as well as CO_2-evolution were determined. Differences in germination between the substrates appeared only in the early stage but not at the end. After 21 days, only seven peats had lesser shoot growth compared to the control, while root growth was reduced for 16 out of 20 peats up to 70 %. Apart from P in plants growing on the peat with worst root growth, N-, P-, and K-concentration in the dry matter of shoots was not smaller compared to the control; partly N- and K-concentrations were higher. It turned out that none of the usually analyzed chemical and physical parameters could explain root and shoot growth satisfactorily. Instead, the CO_2-evolution from the microbial activity in the peats in combination with air volumes was a better indicator for the root growth of the seedlings, though not for all peats. Reasons and consequences are discussed.

Key words. air volume – chemical properties – CO_2-evolution – nutrient concentration – physical properties – root growth – shoot growth

Introduction

Peat is one of the most preferred growing media used in horticulture. Compared to non-peat constituents, peat amounts to 86 % in the production of professional growing media (Epagma 2009). Apart from peat-mining procedures, the peat-forming environment, botanical composition and degree of decomposition influence peat properties considerably (i.e., Clymo 1983; Shotyk 1988; Bohlin et al. 1989; Steinmann and Shotyk 1997; Moore and Basiliko 2006). Since peats from different origins (Baltic countries, Germany, Ireland, Finland, Sweden) are used for the production of growing media, different properties have to be expected. Physical, chemical, and botanical characteristics of peat origins from the aforementioned countries are described in detail by Amha et al. (2010) and detailed microbial properties are given in Amha (2011). The results show differences among the investigated peats. Consequences for plant production remain open but are essential since the measured peat properties are intended to describe a possible use of these peats as growing medium. Furthermore, according to the knowledge of the authors until now, no combined evaluation of results concerning decomposition degree of peats, their air and water volume, microbial properties and plant growth is available. The experiments described in this paper will answer the question if the characterization of the peats with standardized methods is reflected in reactions of plants growing in these peats.

Materials and Methods

Germination tests according to Vdlufa (1997) were carried out with a total of 20 peats from the Baltic countries, Germany, Ireland, Sweden, and Finland. Briefly, peats were limed to reach pH values between 5.5 and 6.5. pH was measured according to Vdlufa (1991) using $CaCl_2$. Nutrients were added as 1 g PG-mix (14 % N, 16 % P_2O_5, 18 % K_2O, 2 % MgO and trace elements) L^{-1} substrate. Black plastic pots (750 cm^3) were totally filled with moistened peat and then dropped from approximately 2 cm height ten times to get a uniform settling. Each peat was replicated four times with 30 seeds per replication. Seeds were laid down on the slightly smoothened surface of the peats and then covered with a layer of approximately

2 mm fine material of the same peat type. Pots were randomized in a climate cabinet with 20 °C; lighting was 12 hours per day. Irrigation was carried out from above, according to good practice and checked daily. The test lasted for 21 days. Additionally, by the methodology described in VDLUFA (1997), root dry matter and N-, P- and K-concentrations in the shoots of the plants were determined at the end of the test.

Physical properties of the peats (air volume AV, water volume WV and easy available water EAW) were determined according to DIN EN 13041 (2000).

Nmin and Nmin-change were measured according to VDLUFA (2007). The Nmin-change is the difference between the mineral N-content at the beginning and at the end of the incubation test (after 14 days). Positive changes indicate mineralization, negative changes immobilization. According to VDLUFA (2007), a threshold of 50 mg L^{-1} substrate must not be exceeded to classify a growing medium as stable.

CO_2-evolution was measured filling the peats with their respective bulk density and a moisture content corresponding to 40 % of water filled pore space into plastic pots. Each pot was put into a 1.5 L glass jar and incubated at 25 °C. Headspace gas (20 mL) was taken from the sealed jars at the beginning and an additional 11 times within 180 days. In the headspace gas, the concentration of CO_2 was measured by gas chromatograph (AMHA 2011).

Plant material

The cultivar 'Kasium F_1' of Chinese cabbage (*Brassica pekinensis* (Lour.) Rupr.) was used as the test plant. Chinese cabbage is known to be sensitive with regard to various unfavorable growing conditions (VDLUFA 1997).

Peats

Some peat characteristics are given in Table 1. Four peats came from Germany. Their decomposition degree ranged from H4 to H7 on the von Post scale (VON POST 1924) with C/N-ratios varying between 47 and 56. Five Finnish and one Swedish peat were included. They had decomposition degrees between H3 and H7, C/N-ratios between 31 and 64. Three peats came from Estonia, two from Latvia and three from Lithuania. They comprise the decomposition range of H3 to H7 and have C/N-ratios of 24–101.

Table 1. Some chemical and physical properties and CO_2-evolution of 20 peats from different countries used in the germination test.

Peat number	Country	H	C/N	CO_2[1] (µg g dry peat^{-1} day^{-1})	Nmin change[2] (mg L^{-1})	A_V (% v/v)	W_V	EAW	pH in the germination test[3]
1	Latvia (La)	3	101	185 ± 9	−12.6	50.0	46.4	18.6	5.7
2	Lithuania (Li)	3	65	267 ± 10	−25.2	33.0	63.6	32.6	5.7
3	Lithuania (Li)	3	69	201 ± 16	−47.4	20.6	75.2	39.3	5.7
4	Estonia (E)	3	52	275 ± 26	−13.9	15.7	78.5	42.3	5.8
5	Finland (F)	3	64	330 ± 21	−72.5	26.0	69.7	38.9	6.0
6	Finland (F)	3	47	313 ± 16	−35.9	14.0	79.9	36.3	5.1
7	Finland (F)	3	55	362 ± 22	−75.8	16.3	79.4	40.3	5.9
8	Latvia (La)	4	53	194 ± 9	−67.7	28.7	67.2	36.9	5.8
9	Ireland (I)	4	67	90 ± 9	−52.8	52.6	43.3	17.2	5.9
10	Lithuania (Li)	4	47	273 ± 14	−38.2	14.2	80.1	39.9	5.7
11	Ireland (I)	4	61	83 ± 4	−59.7	50.3	46.2	22.0	6.3
12	Germany (G)	4	56	221 ± 13	−53.5	21.4	73.0	37.0	5.6
13	Estonia (E)	5	58	233 ± 3	−104.6	13.9	79.8	33.1	6.0
14	Sweden (S)	5	54	151 ± 6	−59.9	45.2	50.2	22.4	6.5
15	Germany (G)	5	47	300 ± 11	−44.3	10.5	82.1	19.5	5.4
16	Finland (F)	5	48	435 ± 23	−26.6	14.4	80.5	36.3	5.5
17	Germany (G)	6	51	130 ± 7	−52.5	10.4	80.5	29.2	5.6
18	Germany (G)	7	50	109 ± 11	−6.1	19.9	72.0	34.7	5.7
19	Finland (F)	7	31	407 ± 14	−124.5	10.5	76.9	27.0	5.4
20	Estonia (E)	7	24	58 ± 2	−61.4	10.4	78.3	18.9	6.1

H: degree of decomposition according to VON POST (1924); A_V: air volume at 1 kPa; W_V: water volume at 1 kPa. EAW: easily available water (1–10 kPa), from AMHA et al. 2010.

[1]: measured over six months, mean ± standard deviation, n = 3; [1, 2]: from AMHA 2011; [3]: according to VDLUFA 1991

The two Irish peats had a decomposition degree of H4 and C/N-ratios between 61 and 67.

Ratings, measurements and analyses

Germinated seedlings were counted daily in the first week of the germination test. During growth, plants were inspected daily. At the end of the test, shoots and roots were evaluated according to Table 2. Furthermore, fresh and dry matter of shoots and dry matter of roots were determined. Drying was carried out at 70 °C until a constant weight was achieved.

In the shoots, N, P, and K were analyzed. Nitrogen was analyzed by controlled burning with oxygen (DUMAS method, 1831) and was measured in form of the originating gas (VarioMAX CN). To measure phosphorous and potassium, the powdered plant material was ashed and then dissolved in 0.5 M HCl. Potassium was measured using the flame photometer, phosphorous was measured at 470 nm with a photometer.

Computations and statistical analyses

Fresh and dry matters, as well as nutrient concentrations, were evaluated statistically using a linear model. Differences with the control were calculated for P = 0.05. Concerning the concentration of N, P, and K in the dry matter, differences with the control were calculated for P = 0.1, 0.01 and 0.001. In both cases the Dunnet-test was used.

Concerning the ratings of the roots with regard to root quality a permutation test according to WESTFALL and YOUNG (1993) (p. 94) is used to compare the mean rooting scores of each different peat variety to the control. Adjusted p-values are reported controlling a global family-wise error rate of 5 %.

The statistical analyses were done with R (2009).

Results

Germination

Two days after sowing, germination in the different peats ranged from 13 to 83 % (data not shown). At this time, a high germination rate (76–83 %) was found for peats from Latvia, Lithuania and Finland with a decomposition degree of H3–H4. Other peats from Lithuania also having H3 showed slow germination (16, 18 %). Slow germination also took place in a peat from Germany and Estonia (13, 23 %), both grouped into the decomposition class H7. In the group with intermediate germination (38–65 %), all decomposition degrees (H3, H4, H5, H6), as well as the control (38 %), were found. Differences between the peats disappeared in the third day after sowing and germination ranged between 94 and 100 %.

Ratings and measurements at the end of the germination test

The rating of the leaf colour resulted in the highest score (9) for all peats except peats no. 4 (Estonia), 6 (Finland), 12 (Germany), 16 (Finland), 17 (Germany) with ratings between 5 and 7 (data not shown). Plants growing on peat no. 6 had chlorosis and necrosis on the leaves and little growth compared to the control was observed in just 10 days. Concerning the roots, differences between the peats were more pronounced (Fig. 1). Apart from the control, only three peats (no. 2, Lithuania, H3; no. 13, Estonia, H5; no. 18, Germany, H7) reached the highest score (9). Very bad root growth (score 1) was observed in a peat from Finland (no. 6, H3).

Shoot fresh matter for 30 seedlings ranged from 35 to 50 g, except peat no. 6 with only 25 g. Differences in fresh matter were reflected in dry matter. Plants grown on seven peats produced significantly less shoot dry matter than plants from the control (Fig. 2). These were peats from Finland (no. 6, 7, 16), Lithuania (no. 10), Latvia (no. 8), and Germany (no. 15, 17). The decomposition degree of these peats lies between H3 and H6. For peat no. 6 (Finland), the decrease in shoot dry matter compared to the control was 55 %, for the other peats it ranged between 20 and 35 %.

For all peats, root dry matter of the plants was smaller compared to the control (Fig. 3). This was statistically significant for 16 peats out of 20. For these 16 peats compared to the control, root dry matter was reduced in the range of 30–70 %; the highest reduction of 70 % was found for peat no. 6 (H3, Finland). Peats showing no dif-

Table 2. Rating of shoots and roots used in the germination test (changed from VDLUFA 1997).

Score	Parameter	
	Leaf colour	Rooting intensity
9	like control or better	like control or better
7	25 % of a leaf chlorotic or necrotic	small differences compared to control
5	50 % of a leaf chlorotic or necrotic	clear differences compared to control
3	whole leaves chlorotic or necrotic	very clear differences compared to control
1	totally little growth, chlorosis, necrosis	totally little growth, partly brown roots

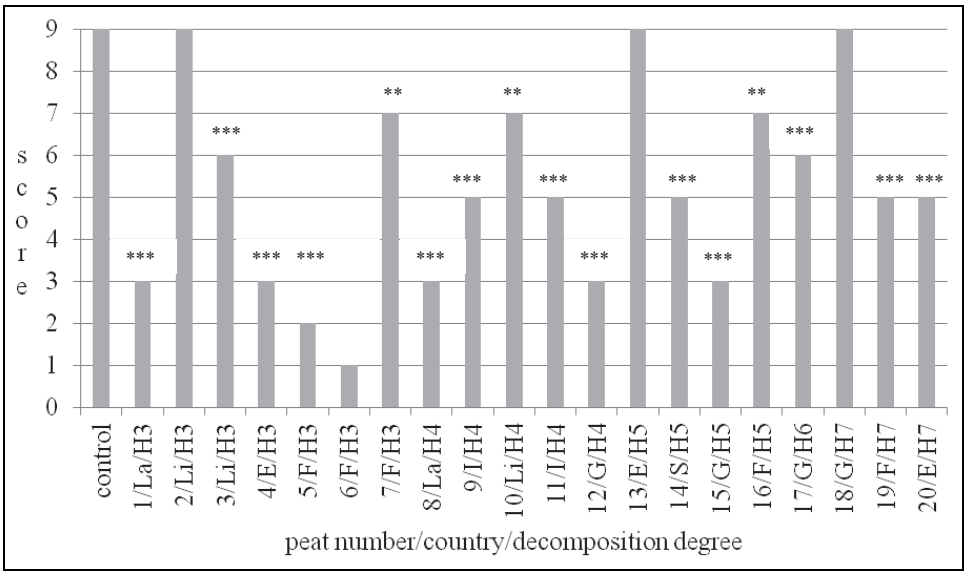


Fig. 1. Rating of the root system of Chinese cabbage grown on peats from different countries[1] and decomposition degree[1] after 21 days of growth in a germination test. 9 = best score, 1 = worst score. [1]: Abbreviations according Table 1. ***, **, * indicate significant differences compared to the control for P = 0.001, P = 0.01, P = 0.1, respectively, permutation test according to Westphal and Young (1993).

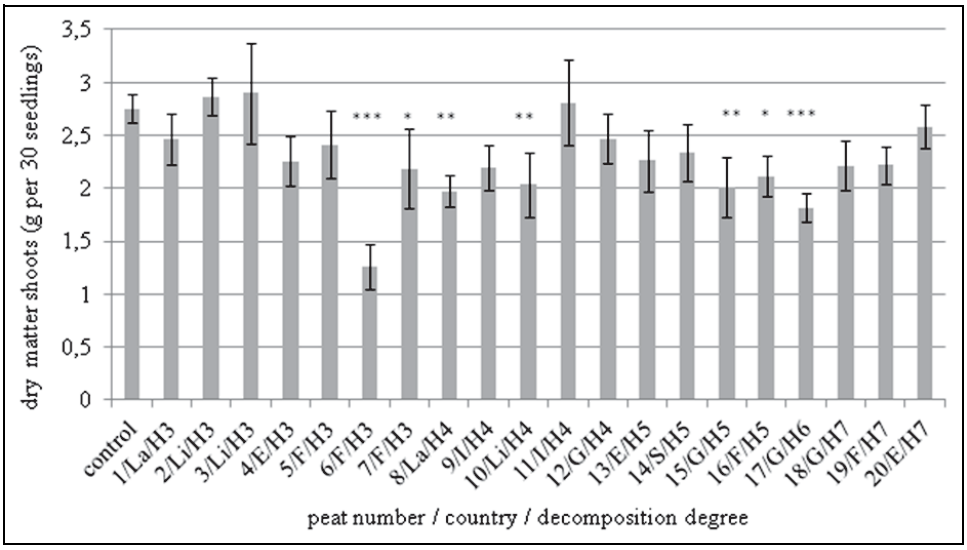


Fig. 2. Dry matter of shoots of Chinese cabbage grown on peats from different countries[1] and decomposition degree[1] after 21 days of growth in a germination test. Means with ± standard deviation, n = 4 replications with each 30 seedlings. [1]: Abbreviations according Table 1. ***, **, * indicate significant differences compared to the control for P = 0.001, P = 0.01, P = 0.1, respectively, Dunnet-test.

ference to the control came from Estonia (no. 13, H5; no. 20, H7), Sweden (no. 14, H5) and Germany (no. 17, H6).

N-, P-, K-concentration in shoots

The N-concentration in the dry matter of shoots ranged between 3.23 and 5.66 % (Table 3). Plants in eight out of 20 peats had a significant higher % N in the dry matter of shoots compared to the control. These peats came from Latvia (no. 1), Lithuania (no. 2, 3), Estonia (no. 4), Finland (no. 5, 6), Ireland (no. 11), and Germany (no. 15). They constitute a decomposition degree between H3 and H5. For the other peats, there was no difference with the control.

Concerning P apart from peat no. 6 (Finland), which had a smaller concentration, there were no significant differences compared to the control. The level of P was apart from plants in peat no. 6 approximately 0.70 % (Table 3).

K in the dry matter ranged from 2.5–4.9 % (Table 3). Plants in seven out of 20 peats showed a significantly higher K concentration than in the control (2.9 %). Apart from three peats (no. 4, Estonia, no. 8, Latvia; no. 15, Germany), these were the same which showed higher N concentration compared to the control.

Apart from peat no. 15 (H5), the decomposition degree of the peats leading to higher N- and K-concentrations compared to the control covered the range H3 and H4.

Discussion

Germination

Not until two days after sowing was the germination different for the peats. There was not a clear relationship with decomposition degree. Also looking at the conditions for

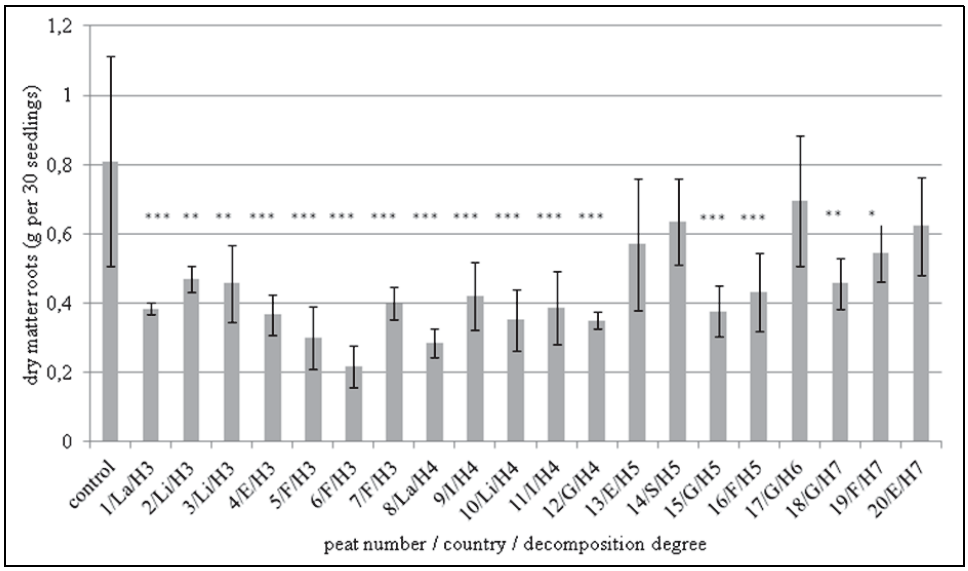


Fig. 3. Dry matter of roots of Chinese cabbage grown on peats from different countries[1] and decomposition degree[1] after 21 days of growth in a germination test. [1]: Abbreviations according Table 1. Means with ± standard deviation, n = 4 replications with each 30 seedlings. ***, **, * indicate significant differences compared to the control for P = 0.001, P = 0.01, P = 0.1, respectively, Dunnet-test.

Table 3. N-, P-, K-concentrations (% in dry matter) in shoots of Chinese cabbage grown on peats from different countries and decomposition degrees[1] and on a commercial peat based growing medium for propagation.

Peat number	Country/decomposition degree	N	P	K
		(% in dry matter)		
Control		3.28 ± 0.17	0.70 ± 0.02	2.89 ± 0.16
1	Latvia/H3	4.91 ± 0.36***	0.69 ± 0.00	4.75 ± 0.29***
2	Lithuania/H3	4.43 ± 0.33**	0.70 ± 0.00	3.95 ± 0.20**
3	Lithuania/H3	4.39 ± 0.62**	0.69 ± 0.00	4.11 ± 0.76***
4	Estonia/H3	4.17 ± 0.59*	0.69 ± 0.00	3.58 ± 0.68
5	Finland/H3	5.66 ± 0.26***	0.69 ± 0.00	4.97 ± 0.10***
6	Finland/H3	4.87 ± 0.18***	0.65 ± 0.02***	3.89 ± 0.26**
7	Finland/H3	3.48 ± 0.98	0.68 ± 0.00	3.07 ± 0.78
8	Latvia/H4	4.09 ± 0.19	0.69 ± 0.00	4.07 ± 0.31***
9	Ireland/H4	3.43 ± 0.50	0.69 ± 0.00	3.16 ± 0.35
10	Lithuania/H4	3.39 ± 0.18	0.69 ± 0.00	2.91 ± 0.25
11	Ireland/H4	4.75 ± 0.53***	0.69 ± 0.01	4.26 ± 0.38***
12	Germany/H4	3.38 ± 0.28	0.68 ± 0.01	3.44 ± 0.22
13	Estonia/H5	3.23 ± 0.60	0.69 ± 0.01	2.93 ± 0.47
14	Sweden/H5	3.85 ± 0.36	0.70 ± 0.02	3.52 ± 0.35
15	Germany/H5	4.79 ± 0.20***	0.69 ± 0.00	3.20 ± 0.10
16	Finland/H5	3.31 ± 0.22	0.69 ± 0.00	2.91 ± 0.17
17	Germany/H6	3.82 ± 0.26	0.70 ± 0.01	3.10 ± 0.18
18	Germany/H7	3.64 ± 0.16	0.68 ± 0.03	2.35 ± 0.16
19	Finland/H7	3.74 ± 0.15	0.68 ± 0.00	2.98 ± 0.15
20	Estonia/H7	4.06 ± 0.26	0.68 ± 0.00	2.56 ± 0.16

Means with ± standard deviation, n = 4 replications with each 30 seedlings.
[1]: Abbreviations according Table 1. ***, **, * indicate significant differences compared to the control for P = 0.001, P = 0.01, P = 0.1, respectively, Dunnet-test.

air and water, the peat with H7, having simultaneously the lowest air volume (10.4 %, v/v) and a high water volume (78.3 %, v/v), turns out to be the one with the lowest germination rate (peat no. 20). According to the International Substrate Manual (2000), for sowing into peat substrates an air volume of 15–20 % (v/v) is recommended.

The air volume of the peats used here covers a range of 10–53 % (v/v) (Table 1). Apart from peat no. 20, the germination does not seem to be influenced by air volume nor by water volume. Furthermore, late germination did not lead to less growth and fast germination did not result in better growth at the end of the germination test.

Ratings and measurements at the end of the germination test

In general, differences for plant growth between the peats were much more pronounced for roots compared to shoots.

Only in four out of twenty peats was root dry matter not statistically different from the control. These four peats had a decomposition degree of H5, H6 and H7. Compared to recommendations from the INTERNATIONAL SUBSTRATE MANUAL (2000) for air volume (15–20 %, (v/v)), these peats are surprisingly far out of the recommended range on both sides (45.2, 13.9, 10.4, 10.4 %, (v/v)). On the other hand, plants grown in peats which show the recommended air volume had less root dry matter than the control. A comparable growing medium (TKS2®) to the control showed an air volume of 14.6 % (v/v) (WREDE 2001). As well as air volume, water volume and easily available water cannot explain the differences in root growth. Both parameters cover a broad range (Table 1) which is not related to root dry matter. Anyway, taking into account that irrigation was optimal, the amount of easily available water is not expected to be the essential parameter for growth in this experiment.

For roots, peats with a higher decomposition degree (H5–H7) showed comparable growth with the control, though, for shoots in all decomposition classes, there were peats without significant difference to the control. Furthermore, differences in root growth were only partly reflected in shoot growth.

Nutrient uptake was not constrained by insufficient root growth. Concerning N and K, plants in some peats even showed higher concentrations than the control (Table 3), and only in peat 6 and peat 15 this can be attributed to reduced dry matter compared to the control. Obviously, also high C/N ratios of the peats did not affect N uptake negatively. According to the N-stability-test (VDLUFA 2007), the N-household can be considered to be stable (< 50 mg N L^{-1}) or only slightly unstable (51–125 mg N L^{-1}). The level of N-, P-, and K-concentrations lay in a range found in fertilization experiments during two years (MAGNUSSON 2002). For N, concentrations varying between 2 and 6 %, for P between 0.5 and 0.9 %, and for K between 3 and 8 % in dry matter were found.

It turns out that none of the usually analyzed physical and chemical parameters can explain root and shoot growth satisfactorily. Since root growth was much more affected than shoots, in search of an additional parameter the rooting environment seems to be promising. In addition to total air volumes, air exchange properties are correlated with plant growth (i.e. ALLAIRE-LEUNG et al. 1999). They affect the concentration of O_2 and CO_2 in the rooting environment, which is crucial for root growth (i.e. HANDRECK and BLACK 2005). Additional to gas exchange, oxygen concentrations depend on source-sink relationships due to root and microorganism respiration (NAASZ et al. 2008). In a simulation model, NAASZ et al. (2008) demonstrate that rapid and strong decreases in the oxygen concentration in a peat occurred when the microbial respiration rate is high.

The peats differ in their daily CO_2-evolution measured over six months (Table 1). Peats showing no significant differences in root growth compared to the control (no. 13, 14, 17, 20) have low or medium CO_2-evolution and a broad range of air volumes (10.4–45.2). Low air volume combined with low CO_2-evolution as found for peats no. 17 and 20 (10.4 %, (v/v)) did not lead to restricted root growth. Hence, in this case low air volume alone did not impair root growth. Although a definite classification is not possible, almost all peats with plants showing at least 50 % less root growth than the control have medium or high CO_2-evolution and again a broad range of air volumes (11–53 % (v/v)).

Surprisingly, root dry matter in two peats with low (no. 9, 11) or medium (no. 1) CO_2-evolution and very high air volume (52.6, 50.3 and 50.0 % (v/v)) is also very low. These peats have a decomposition degree of H4, indicating weakly humified organic matter. AMHA (2011) showed that evolved CO_2 increased with increasing pH. The effect of increased CO_2-evolution with an increase in pH was stronger in weakly humified peats compared to moderately or strongly humified peats and indicates decomposition of organic matter and degradation of structure. For the germination test, the peats were limed according to VDLUFA (1997). Hence, it is questionable if under growing conditions CO_2-evolution really was low and high air volume was maintained. Accordingly, plants with root growth less than 50 % compared to the control are found – apart from peat no. 15 – independent from CO_2-evolution in weakly decomposed peats, which are susceptible to decomposition of organic matter and breakdown of structure under the conditions of the germination test. Extremely bad root growth was observed for peat no. 6, which is characterized by medium air volume (14.0 %, (v/v)) and high CO_2-evolution. In this peat, plants showed early chlorosis and necrosis and little shoot and root growth (Fig. 2, 3) compared to the control, and at the end of the germination test, the roots were brown and rated with the smallest score (Fig. 1). Additionally, pH was lowest in this peat. Rhizotoxicity involves, beside H^+, the action of Al^{3+} and Mn^{2+} as well, which can be excluded in peats being almost free of minerals. Hence, it is assumed that pH – though being lower compared to the other peats – is not the major cause for bad root growth. It is supposed that low oxygen concentrations will have contributed to the restriction of root growth. Oxygen deficit leads – among other symptoms – to chlorosis, poor growth and

final root death (Levitt 1972 in: Strojny et al. 1998, Taiz and Zeiger 2007). Gislerod and Baas (1997) found a reduction in root growth of rose cuttings of about 50 % in unaerated compared to aerated nutrient solutions. Similar to the results given here, under unfavourable oxygen conditions, root growth was more affected than shoot growth.

Conclusion

Differences in chemical and physical properties of 20 peats from different countries and decomposition degrees could not explain differences in root and shoot growth of Chinese cabbage. Only when taking daily CO_2-evolution as a measure of microbial activity into account do some trends get obvious. Though with exceptions, there are parameters which indicate possible unfavourable conditions for plant growth. These are (a) high CO_2-evolution from the peat, (b) low decomposition degree of the peat, and (c) low air volume. The effect of these parameters depends on their combination and on cultivation conditions like pH and irrigation. Irrigation technique (from above, ebb- and flow, drip irrigation) influences the O_2-disitribution in pots and containers (Strojny et al. 1998, Anlauf et al. 2012), and might also favour risky situations.

The results reported here are based on methods used to characterize the general quality of growing media and can only give a rough insight into possible interactions. With the background of these results, more cause-oriented investigations have to be carried out to clarify the relations discussed here.

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