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Occurrence of IAA auxin in some organic soils

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Abstract. The estimation of the quantities of auxin indole-3-acetic acids (IAA) and the composition of humus substances in peats and sapropels from Belarus and in secondary transformed peat-moorsh soils from Poland was demonstrated In high-moor peats the highest contents of IAA and humus substances was proved and ranged from 124.4 to 210 μg kg^{-1}. The contrary was found for low-moor peat. In these raw materials the quantities of IAA ranged from 57.9 to 134.3 μg kg^{-1}. In secondary transformed peat–moorsh soils the contents of IAA ranged from 69.3 to 186.1 μg kg^{-1}. A directly proportional relationship between the concentrations of IAA in peats and humus substances as well as total and dissolved organic carbon was observed. The correlations coefficients among these parameters ranged from 0.692 to 0.793. The concentrations of IAA in sapropels were similar to those determined in high-moor peats and ranged from 190 to 374 μg kg^{-1} μg kg^{-1}.

Key words: peat, sapropel, humic substances, auxin, indole-3-acetic acid

INTRODUCTION

Plant hormones called phytohormones or plant growth regulators represent a wide group of organic substances (auxins, gibberellins, cytokinins, abscisic acid and ethylene) which are biosynthesized in soils, plants, sediments (by microorganisms: fungi, bacteria, actinomycetes and algae) and translocate to another part of the plant or environment to impact a whole range of physiological and development processes at low quantities. Auxin is translocated in plant tissues mainly by polar transport. However, some part of endogenous and exogenously supplied auxins may transport in the plant's vascular system (Goldsmith, 1977). Biosynthesis of auxin is not limited to higher plants. The changes and the transformation as well as chemical and biochemical conversions of these substances led to their specificity and sensitivity which are responsible for their physiological effect. Many chemical, biochemical, chromatographic, enzymatic and immunological analytical methods are used to evaluate their occurrence, conversions, pathways, modes of action, biological availability, biological function in governing plant processes, etc (Kampert & Strzelczyk, 1975; Budenoch-Jones et al., 1982; Wang et al., 1982; Kaneshiro et al., 1983; Roy & Basu, 1992).

Phytohormones have been used due to their role in many chemical and biochemical cellular processes as well as influencing several pathways at the organismal level in agronomic crops such as cotton, blueberry and grape (Cothern, 1994; Oosterhuis, 1994; Crozier et al., 2000). Applications of the numbers of chemical compounds characterizing hormonal effect or hormonal-like effect have become important agricultural production practices, particularly in horticulture, agriculture, pomology, floriculture as well as for growing media. These substances are used to induce root development of vegetation cuttings, thinning of apples, or to increase the plant height of several species of greenhouse-grown flowers and nursery – produced ornamental plants. Dormancy, juvenility, sex determination, floral induction, fruit set, growth and ripening, tuberization, and rooting, as well as induction of desirable fruit color, also may be enhanced/modified with phytohormones. Phytohormones used for hormonal control of some specific process or to induce a specific effect usually have fairly narrow concentration ranges that are suitable to attain the desired effect (Reddy & Hodges, 2003).

Auxins represent a wide group of the compounds which are derivatives of the indole ring. This chemical structure explains the relationship between the quantity and the activity of their members. Since the discovering of auxins many efforts of scientists have focused on the possibility of manipulating plant growth and development. It was suggested that mycorrhizal fungi produce auxins (indole-3-acetic acid – IAA is preferred) and that these auxins affect the growth of susceptible roots by modifying apices so that they assume the structure seen in the host tissues of mycorrhizas (Strzelczyk & Pokojska-Burdziej, 1984). All the effects of other external factors on the roots, e.g. nitrogen supply or light intensity, operate through stimulation (or otherwise) of fungal growth and auxin production. It is usually assumed that auxins at concentrations that stimulate the growth of shoots inhibit that of roots, but that concentrations of lower magnitude (several orders) stimulate root growth and are essential for it. Knowledge of the processes and mechanisms controlled by plant hormones has remained elusive (Harley & Smith, 1983).

IAA seems to play an important function in nature as a result of its influence in the regulation and development of plant growth (Cohen & Bandurski, 1982). A principal feature of IAA is its ability to affect the growth, development and health of plants (Sanderson et al., 1987; Dahm et al., 1997) by activating root morphology and metabolic changes in the host plant (Bandurski & Schulze, 1977). The physiological impact of this substance is involved in cell elongation, apical dominance, root initiation, parthenocarpy, abscission, callus formation and respiration (Tena et al., 1986; Strzelczyk et al., 1997). IAA is formed in soils from tryptophan by enzymatic conversion (Chalvignac & Mayaudon, 1971; Tena et al., 1986; Sarwar et al., 1992; Martens & Fankenberger, 1993).

Soil organic matter represents the reservoir of the nutrients for plants (Power, 1994). The stimulatory effect of humic substances on plant growth has been observed and extensively documented in many investigations and review papers (Chen, 1996; Nardi et al., 1996; Musculo & Nardi, 1997; Cesco et al., 2002). Natural processes of organic matter transformation in peat and sapropel lead to the formation of humic substances (Anderson & Hepburn, 1986; Lishtvan et al., 1989; Bambalov et al., 2000; Schaumann et al., 2000; Leinweber et al., 2001; Nieder et al., 2003). The chemical composition and molecular structure of humic substances depend on genetic

peculiarities of peatland and depth of sampling. Therefore, the investigation of IAA and the chemical properties of humic substances are most important. However, it is commonly known that plants uptake low molecular weight humic substances such as free amino acids, aminosugars, amides, alkaloids, phenols, vitamins, derivatives of purine and pirymidines bases, terpenoids and steroids, glycosides, etc (Gorowaja et al., 1995; Szajdak, 2003). These chemical compounds represent a wide group of stimulators and nutrients. The effectiveness of these stimulators on agricultural usage depends basically on the initial peat properties and biological activity of its components (Kasimova & Kravets, 2000).

Some kinds of peat and sapropel are commonly used for the preparation of organic fertilizers for agriculture and horticulture, floriculture, pomology as well as for growing media (Bielkowskij & Gorosko, 1991; Crouch et al., 1992; Crouch & van Staden, 1993; Szajdak & Sokolov, 1997; Szajdak et al., 2002). Peatlands are commonly used for growing crops – cloudberry, cranberry and blackberry. In addition, they are used for forestry and agriculture and as a source for horticulture. Unfortunately, despite these benefits, peatlands have been heavily utilized or degraded. However, large scale drainage of peatlands for agriculture has often created major problems related to deterioration in soil quality. It is important to identify possible ways to minimize the consumption of limited natural resources and to establish sustainable systems, based on principles of ecology, in the exploitation of peatland.

The objective of the present study was to evaluate the quantity of IAA in different kinds of peats and sapropels from Belarus and Poland.

MATERIALS AND METHODS

Samples of peat and sapropel were taken from locations in Belarus: high-moor peats of low decomposition degree (magellanicum and angustifolium) from the peatland Orekhovskiy Mohk) and low-moor pine-sphagnum and eriophorum sphagnum peats from peatland Dukora. These raw materials represent sampling from different depths (Table 1). Samples of secondary transformed peat-moorsh soils were also taken from Czarna Wieś, Otoczne, and Kwatera 17 (North-East of Poland located in the Biebrza River Valley) (Table 4). Samples represent two depths, 5–10 cm, and the range 45-80 cm. At present they are being utilized as meadows. Sapropel samples were taken from 4 Belarussian lakes.

Soils were sampled from 10 sites at each location. Samples were air-dried and crushed to pass through a 1 mm-mesh sieve. These 10 sub-samples were mixed to prepare a "mean sample" which was used for the potentiometric determination of pH (in H_2O and in 1M KCl), and for the measurements of dissolved organic carbon (DOC) and total organic carbon (TOC).

For the investigation of DOC, soil samples were heated in redistilled water in 100°C for two hours in a reflux condenser. Extracts were separated by the mean filter paper and analyzed on TOC 5050A facilities (Shimadzu, Japan) (Smolander & Kitunen, 2002).

Humus substances were extracted (Bambalov et al., 2000) and investigated by the methods of Schnitzer (1977) and Maryganova (2000). The investigations of IAA were conducted using the spectrofluorimetric method with $\lambda_{excitation}$= 290 nm and $\lambda_{emission}$= 368 nm (Szajdak, unpublished date).

According to Chen, et al., (1977), 3 mg of HA were dissolved in 10 ml of 0.05 M $NaHCO_3$. Absorbances at 464 nm (E_4) and 665 nm (E_6) of HA in this solution were measured and E_4/E_6 ratios were calculated from spectrums in the visible region. BECKMAN DU®-68 spectrophotometer with a 1 cm thick layer was used for spectrometric measurements.

Twice distilled water from silica glass equipment was used. All the experiments were run in triplicate, and the results were averaged. All the chemicals used in this study were of analytical grade.

RESULTS AND DISCUSSION

Histosols contain more than 30% organic matter. Accumulation of organic matter in these soils represents a geological sink for nitrogen and carbon. Organic matter exerts a significant influence on chemical properties of the soil and the availability of biologically active substances as well as cation exchange capacity. Organic matter also imports desirable physical environments to soils by favorably affecting soil structure expressed through soil porosity, aggregation and bulk density, and water storage (Nieder et al., 2003).

Peat samples under study differ significantly in the chemical composition of organic matter depending on genetic peculiarities of peatlands and the depth of sampling. High-moor peats of a low degree of decomposition (magellanicum and angustifolium) from peatland Orekhovskiy Mohk are characterized by the lowest percentage of total nitrogen (1.1–1.2%), a low proportion of humic substances (HS) (17–22%), and non-hydrolysable compounds (non-hydrolysable residue), and the highest percentage of easily- and difficultly-hydrolysable substances (Table 1 and 2).

High-moor Pine Sphagnum and Eriophorum Sphagnum peats from peatland Dukora reveal the highest content (56–57%) of organic carbon and HS (33–37%). Sedge, reed, and wood-reed peats from low-moor peat bogs have the highest content of total nitrogen and non-hydrolysable residue, and the lowest percentage of hydrolysable substances. Peat samples from the depth 0.75–1.00 m of peatlands are characterized by a higher content of organic carbon and lower proportion of total nitrogen as compared with peat samples from the upper peat-forming layer, resulting in a wider C/N ratio. Among peats from different depths there are also differences in the group chemical composition and the content of acidic functional groups, which are more pronounced for low-moor peat bogs. For all peat bogs, peat samples from the depth 0.75–1.00 m are characterized by lower content of HS and higher content of non-hydrolysable residue compared with those from the peat-forming layer. The content of hydrolysable substances changes not so much with the depth of sampling, but the percentage of reducing compounds are usually a little higher in peats from the depth 0.75–1.00 m, than in the peat-forming layer. Acidic functional groups, especially carboxylic, are connected mainly with HS, so their decrease along with the depth of peatlands correlates very well with lowering the content of HS.

It was observed that the content of IAA for peat samples depends on the kind of peat (Table 3). The highest amount of IAA content was determined for high-moor Pine Sphagnum and Eriophorum Sphagnum peat with the decomposition degree (R) of 30–35% (185.2–210.2 $\mu g\ kg^{-1}$). The lowest IAA content was measured for Reed peat

with R = 40% (57.9 μg kg^{-1}) and hyphum peat with R = 5–10% (74.1 μg kg^{-1}). In all other peat samples the IAA content ranged from 108.6 to 144.2 μg kg^{-1}. For some peatlands a decrease in the IAA content with an increase in the depth of sampling was observed. For others, there were no significant differences in the IAA concentration between peat samples as related to the depth of sampling.

There is some relationship between the concentration of IAA and the content of humic substances in different kinds of peat. The significant value of correlation between the contents of humic substances and the concentrations of IAA was equal to r = 0,692. In some cases lowering of the IAA concentration along with increasing the depth of sampling correlates well with the decrease of humic substances in peats (peatlands Dukora and Rusakovichi). In other cases the IAA concentration in peats does not depend on the depth of sampling (nameless peatland near village Dukora), despite lowering the humic substances content with an increase in the depth of sampling. Probably, the concentrations of IAA in peats depend not only on the content of HS, but also on other reasons, one of which may be the biochemical pathways of humic substances.

All samples representing Biebrza River Valley (Table 4) were taken from secondary transformed peat-moorsh soils. The oscillation of the water level results in increased release of dissolved organic matter when remoistening dry soil. Swelling and shrinking, a high water uptake, and hysteresis during water uptake and release are typical gel properties which can be found in soil organic matter (Schaumann et al., 2000).

Samples taken from the upper compared with the deeper layer characterized lower contents of TOC ranging from 37.19 to 38.20% and higher DOC contents ranging from 10.80 to 19.39%. These differences may result from drainage, which affects the degradation and mineralization of peat organic matter (Kalbitz et al., 1999; Leinweber et al., 2001.). Anderson & Hepburn, (1986) suggest that the significant loss of volatile products and some phenolic compounds and fulvic acid components by natural drainage of the bog waters may account for the apparent changes in organic content with humification.

It was observed that all samples of peat-moorsh soils from the depth 45–80 cm were characterized by higher contents of TOC than from the depth 5–10 cm. The concentration of TOC from the depth 45–60 cm ranged from 40.23 to 45.58%. The highest amount of TOC was determined in the sample from Otoczne (45.58%) and the lowest from Kwatera 17 45.58% and 40.23%, respectively. Generally, the sample from the upper depth of Kwatera 17 characterized the highest content and from 70–80 cm the lowest concentration of TOC from all investigated peat-moorsh samples.

Dissolved organic matter can contribute significantly to the cycling of soil nutrients. It can be a substrate for microbial growth and represents a major vehicle for the leaching of many elements. Depending on the geobotanical content there are differences in chemical properties of peat organic matter (Smolander & Kitunen, 2002).

Table 1. Some characteristics of peats.

Depth of sampling cm	Peat species, decomposition degree, %	Ash content, %	pH		C	N	C/N
			in H_2O	in KCl	% on organic matter		
		High-moor peatlands					
		Orekhovskiy Mokk					
0–25	Angustifolium, 15	6.90	3.3	2.6	51.1	1.21	42.1
75–100	Magellanicum, 15–20	1.82	3.5	2.8	53.6	1.05	50.6
		Dukora					
0–25	Pine Sphagnum, 30	7.40	3.3	2.3	56.7	1.32	43.0
75–100	Eriophorum Spagnum, 30–35	2.80	3.2	2.4	56.4	1.18	47.7
		Low-moor peatlands					
		Nameless peatland near village Dukora					
0–25	Sedge, 30	26.80	6.2	5.9	53.2	3.38	15.7
75–100	Sedge, 25	9.50	6.0	5.8	55.9	2.98	18.7
		Nameless peatland near village Rusakovichi					
0–25	Wood-Reed, 60–65	32.95	6.0	5.3	49.5	4.51	11.0
75–100	Reed, 40	11.80	6.1	5.8	54.9	3.42	16.1

Table 2. Chemical composition of peats.

Depth of sampling cm	Peat species, decomposition degree, %	C organic, %	Humic substances, %	Easily hydrolysable compounds, %		Difficultly hydrolysable compounds, %		Non-hydrolysable compounds, %	Acidic functional groups, meq g^{-i}		
				Suma	Reducing substances	Suma	Reducing substances		CO_2H	OH Phenolic	Suma
				High-moor peatlands							
				Orekhovskiy Mokk							
0–25	Angustifolium, 15	51.1	22.37	24.13	15.56	15.88	3.50	37.82	1.45	1.85	3.30
75–100	Magellanicum, 15–20	53.6	17.40	25.23	14.42	16.96	4.66	40.42	1.35	1.88	3.23
				Dukora							
0–25	Pine Sphagnum, 30	56.7	36.76	9.57	5.96	7.66	2.27	46.01	1.87	2.13	4.00
75–100	Eriophorum Sphagnum, 30-35	56.4	32.54	11.45	7.55	7.39	2.70	48.62	1.68	1.80	3.48
				Low-moor peatlands							
				Nameless peatland near village Dukora							
0–25	Sedge, 30	54.2	32.50	8.81	4.03	4.02	0.41	54.67	0.82	2.35	3.17
75–100	Sedge, 25	55.9	15.25	9.01	6.12	5.67	0.64	70.07	0.44	2.14	2.58
				Nameless peatland near village Rusakovichi							
0–25	Wood-Reed, 60–65	49.5	28.95	13.46	5.21	5.05	0.80	52.54	0.96	2.04	3.00
75–100	Reed, 40	54.9	16.13	9.60	5.95	5.97	1.36	68.30	0.46	1.99	2.45

Table 3. The content of IAA (μg kg^{-1}) in peats.

No	Depth of sampling cm	Peat species	Decomposition degree, %	IAA
		High-moor peatlands		
		Orekhovskiy Mokh		
1	0–25	Angustifolium	15	124.4±4.7
2	30–50	Magellanicum	10	144.2±4.6
		Dukora		
3	0–25	Pine Sphagnum	30	203.4±7.7
4	30–50	Eriophorum Sphagnum	35	210.2±7.6
5	75–100	Eriophorum Sphagnum	35	185.2±7.0
		Low-moor peatlands		
		Nameless peatland near village Dukora		
6	0–25	Sedge	30	131.2±4.6
7	30–50	Wood-Sedge	40–45	128.4±4.4
8	75–100	Sedge	25	134.3±4.7
		Nameless peatland near village Rusakovichi		
9	0–25	Wood-Reed	60–65	133.3±5.1
10	30–50	Reed	40–45	108.6±3.8
11	75–100	Reed	40	57.9±1.9
		Ptich		
12	-	Hypnum	5–10	74.1±2.7

(μg kg^{-1} of IAA +/– 95% confidence interval)

It was shown for all peat-moorsh soils that the concentrations of DOC, in comparison with TOC, decrease with increase of the depth of the profile (Table 4). The amounts of DOC for 0–10 cm depth ranged from 10.80% to 19.39%. The highest content of DOC was determined for the sample from Kwatera 17, and the lowest from Otoczne. The samples taken from the depth 45–80 cm revealed low contents of DOC ranging from 5.34% to 7.55%. Contrary to TOC, measurements of the sample from Kwatera 17 representing 0–10 cm depth characterized the highest concentration of DOC, but samples from the 75–80 depth showed the lowest content.

Table 4. pH and concentrations of TOC, DOC, IAA and E_4/E_6 ratios for investigated peats.

Place of sampling, depth in cm	Type of soil	Degree of decomposition in von Post scale	pH		TOC [%]	DOC [%]	IAA μg kg^{-1}	E_4/E_6
			in H_2O	in 1 N KCl				
Czarna Wieś 5–10	Moorsh	-	5,54	5,19	37.19	12.81	186.10 ±8.37	6.968
Czarna Wieś 50–70	Sedge-moorsh peat	H_1	5.66	5.16	44.02	5.80	110.86 ±4.85	6.244
Otoczne 5–10	Moorsh	-	6.02	5.46	38.10	10.80	87.10 ±3.96	6.887
Otoczne 45–50	Sedge-reed peat	H_5	6.10	5.63	45.58	7.55	122.70 ±5.58	5.677
Kwatera 17; 5–10	Moorsh	-	5.05	4.70	38.20	19.39	128.70 ±5.11	6.981
Kwatera 17; 70–80	Alder peat	H_6	5.88	5.39	40.23	5.34	69.30 ±3.16	5.691

TOC – total organic carbon, DOC – dissolved organic carbon, IAA - concentration, E_4/E_6 ratios, μg·kg^{-1} of IAA +/- 95% confidence interval.

The HA from all sampling locations showed a decrease of E_4/E_6 with an increase in depth, which indicates the increase in the degree of polyconjugation in their molecules (Chen et al., 1977) (Table 4).

High values of the correlation coefficient between DOC and values of E_4/E_6 equal to r = 0.793, and between TOC and E_4/E_6 equal to r = -0.777 reflect significant participation of the concentrations of TOC and DOC in the values of E_4/E_6. It indicates that TOC and DOC concentrations influence the chemical properties of HA from secondary transformed peat - moorsh soils.

IAA represents free amino acid in soil. The fraction of free amino acids participates in biochemical conversions and is responsible for physiological and biological effects. Free amino acids are included in the fraction of DOC in soils.

IAA contents of all peat soils from Biebrza River Valley ranged from 69.3 to 186.1 μg kg^{-1}. The highest amounts of IAA were measured in samples from Czarna Wieś and ranged from 110.86 to 186.1 μg kg^{-1} (Table 4). The ranges of IAA concentrations in the sites from Otoczne and Kwatera 17 were similar and ranged from 69.3 to 128.7 μg kg^{-1}. A similar decrease of the contents of IAA with increase in the depth for samples taken from Czarna Wieś and from Kwatera 17 was observed.

Sapropels are finely-dispersed deposits found in fresh-water lakes. These organic substances are mainly formed of dead aquatic organisms and include peptides, bitumen, lipids (hydrophobic compounds such as carbonic acids, steroids, triacetin, etc), alkali-soluble humic substances consisting of humic and fulvic acids, and humin. Inorganic components are represented by various minerals of both allochtonus and autochthonous types (Kireicheva & Khokhlova, 2000). The best quality sapropels are used in the production of soil improvers and fertilizers. Organic substances constitute not less than half their composition; they also include various mineral substances of biogenic origin and thus are well assimilated by plants (Sokolov & Bambalov, 2000).

Table 5. The content of IAA (μg kg^{-1}) in sapropels.

No	Lake	District	IAA
1	Sominskoje	Brest	189.9±7.2
2	Kwietino	Minsk	192.2±7.0
3	Maloje Swino	Vitebsk	373.9±13.1
4	Lukowo	Brest	292.5±9.9

(μg kg^{-1} of IAA +/- 95% confidence interval)

The concentrations of IAA were determined for 5 samples of sapropel from Belarus lakes.

It was shown that the contents of IAA ranged from189.9 to 373.9 μg kg^{-1} (Table 5), which is the highest from all investigated organic soils.

In general, the chemical composition of peats revealed good agreement with the IAA concentration. The Reed peat sample from the depth of 0.75–1.00 m with the lowest content of humic substances showed the lowest IAA concentration. It was also shown that secondary transformed peat-moorsh soils contained high concentrations of IAA.

CONCLUSIONS

The results of our study indicate the following:

1. The quantities of IAA in peats were shown to depend on the kind and depth of sampling.
2. The highest content of IAA was determined in Pine Sphagnum and Eriophorum Sphagnum peat samples from the peatland Dukora. The lowest concentration of IAA was found in Reed peat from the depth of 0.75–1.0 m (Rusakovichi) and in Hypnum peat (Ptich).
3. The contents of IAA in the secondary transformed peat - moorsh soil ranged from 69.3 to 186.1 μg kg^{-1}.
4. Some directly proportional relationship was found between the concentration of IAA and the content of humic substances, between IAA and the contents of total and dissolved organic carbon, and between the concentrations of IAA and properties of humic substances.
5. The amounts of IAA in sapropels (189.9–373.9 μg kg^{-1}) were determined to be higher than in peats (57.9–210.2 μg kg^{-1}).

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