DISTRIBUTION OF EXTRACTABLE CALCIUM, MAGNESIUM, POTASSIUM, AND SODIUM IN VARIOUS DEPTHS OF SOME VIRGIN PEAT SOILS

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The distribution of plant nutrients in various layers of a peat profile depends on several factors. Among these are for example the intensity with which the nutrients are adsorbed or fixed by the peat, the quantities of nutrients carried by the water or by the air from the neighbourhood, and also the utilization of nutrients by the respective surface vegetation. In shallow peat lands the quality of the mineral subsoil is of importance, too.

Our information even of the combined effect of all these factors on the nutrient content of various peat layers is rather poor. Only very few results concerning this problem are reported in Finland. In a previous publication one of us (2) tried to elucidate the distribution and forms of phosphorus in various depths of thirty virgin peat lands. Warén (4) gives data of calcium, magnesium, potassium, phosphorus and sulphur soluble in 4 % hydrochloric acid from nine peat profiles. In addition to these only some scattered reports exist.

The authors were interested in the contents of plant available calcium, magnesium and potassium in various depths of peat lands. Therefore, an investigation was carried out in which samples from different layers of virgin peat soils were analysed, generally down to about a depth of one meter. The extraction with ammonium chloride solution was supposed to give an estimate of the available amounts of the cations. In addition to calcium, magnesium, and potassium also sodium was determined.

Material and methods

The material of the present investigation consisted of 85 samples taken from 25 peat lands. All of them were from Northern Finland and represented uncultivated soils. The surface vegetation type and degree of land quality of the sampling places were the following:

1. *Sphagnum fuscum* pine bog, Bo 1.
2. Treeless *Sphagnum fuscum* bog, Bo 1.
3. — 4. *Carex globularis* pine bog, Bo 2.
5. Oligotrophic water-logged *Sphagnum* bog occupying hollows, Bo 1—2.
6. Treeless *Sphagnum papillosum* bog, Bo 1—2.
7. — 8. Treeless *Sphagnum papillosum* — *Scirpus caespitosus* bog, Bo 2.
9. — 10. Treeless *Sphagnum papillosum* — *Carex lasiocarpa* bog, Bo 3.
11. — 15. Treeless *Sphagnum papillosum* — *Carex limosa* bog, Bo 3.
16. Mesotrophic treeless *Sphagnum papillosum* bog, Bo 6.
17. — 18. As number 16, occupying hollows, Bo 5.
19. — 20. Treeless, water-logged *Carex limosa* bog, Bo 4.
21. Flooded bog, without trees, Bo 5.
22. Mesotrophic water-logged treeless *Carex*-bog, Bo 6.
23. *Sphagnum Warnstorfianum* fen, Bo 8.
24. — 25. *Scorpidium scorpioides* fen, Bo 7.

The depths of the sampling layers and the kind of the respective peat are reported in Table 1 which also gives the degree of humification for the peat samples estimated in the field according to the method of von POST (3). In addition to the peat samples also samples of mixed surface vegetation were collected from the peat lands n:ris 6—10 and 12—18.

All the analyses described in the present paper were performed of air-dry peat ground in a Wiley mill. The pH-value was determined in a water suspension (1: 4).

The extraction of the cations was carried out with 1 N ammonium chloride solution. The ratio of soil to extractant was 1: 50, and the extraction period was two hours. The estimation of calcium, potassium, and sodium in the filtrate was performed using the flame photometer by Lange. The total calcium + magnesium content of the filtrate was determined by the versenate titration (1) and the amount of magnesium was calculated on the basis of the calcium content estimated by the flame photometer.

Obviously, the data obtained by this method do not correspond to the content of exchangeable cations in these soils. A more reliable estimation of their amount could have been gained if barium chloride instead of ammonium chloride had been used and if the extraction had been completed by some thorough washings. The disturbing effect of barium on the flame photometric determination of the other cations prevented its employment, and it was necessary to resort to ammonium chlo-

Table 1. Calcium, magnesium, potassium and sodium extracted by 1 N ammonium chloride from various layers of the peat lands

No	Depth dm	Kind of peat	H	pH	w/v	Ash %	Ca	Mg	K	Na
								kg/ha		
1.	0—3	S	1	4.2	0.08	5.9	660	180	30	20
	4—6	S	1	4.4	0.08	3.9	750	150	10	10
	6—8	CS	5	4.5	0.25	5.8	220	450	30	10
2.	0—2	S	1	4.5	0.11	4.9	1080	310	140	10
	2—4	CS	2	4.6	0.23	5.0	2000	340	170	20
	4—6	CS	4	4.6	0.25	4.3	1750	270	70	10
3.	1—2	S	1	4.5	0.11	4.2	1500	80	230	100
	2—3	S	2	4.6	0.17	4.5	2300	120	280	120
	3—4	CS	5	4.6	0.39	5.5	3000	150	210	80
4.	0—3	LCS	2	4.2	0.09	3.4	410	400	470	40
	3—5		4	4.4	0.25	9.7	860	750	320	670
	7—10		6	4.3	0.36	6.2	850	850	130	300
5.	0—2	S	1	3.7	0.05	1.4	180	150	90	40
	2—5		3	3.6	0.09	1.5	410	220	40	30
	5—9		5	3.8	0.21	2.9	710	350	50	50
	9—11		7	4.2	0.32	2.4	1130	580	60	30
6.	Plant matter			4.3	0.07	7.2	350	320	490	30
	0—2	S	1	3.9	0.29	5.7	1200	1000	150	10
	3—5	S	3	4.0	0.34	4.0	1000	580	30	10
	8—10	SC	5	4.1	0.30	3.1	780	410	20	0
7.	Plant matter			4.4	0.06	6.9	280	190	310	40
	0—3	S	1	4.5	0.12	5.2	480	350	10	10
	5—7	CS	4	4.3	0.30	3.5	960	660	10	20
	8—10	CS	5	4.1	0.35	4.0	1260	850	10	10
8.	Plant matter			4.3	0.10	5.8	480	240	740	150
	1—3	CS	3	3.8	0.33	7.8	1000	280	140	70
	3—5	SC	7	4.2	0.42	11.0	920	280	60	40
9.	Plant matter			4.5	0.07	7.9	620	320	620	30
	0—2	S	1	4.4	0.28	10.8	1800	780	360	20
	3—5	C	3	4.5	0.29	10.0	1200	500	110	20
10.	Plant matter			4.5	0.09	8.5	620	360	760	130
	1—3	SC	4	4.3	0.34	6.2	1800	350	240	200
	3—5	LC	7	4.6	0.31	5.3	1300	320	60	60
11.	0—1	S	1	4.2	0.09	5.0	850	290	50	40
	2—3	SC	3	4.9	0.34	6.1	2300	610	120	20
	4—6	C	5	4.9	0.34	6.1	2500	750	40	10

1	2	3	4	5	6	7	8	9	10	11
12.	Plant matter			4.9	0.07	22.6	920	320	590	70
	0—2	SC	3	4.9	0.26	16.7	1250	570	90	20
	3—5	SC	2	4.8	0.25	4.0	2250	860	40	20
	8—10	SC	2	4.8	0.20	6.5	1550	760	70	20
13.	Plant matter			4.4	0.09	12.9	650	340	740	50
	2—4	SC	4	4.3	0.34	6.5	1550	750	90	20
	6—8	SC	3	4.5	0.30	3.7	1150	880	10	20
	8—10	C	5	4.1	0.31	5.5	1250	650	130	30
14.	Plant matter			4.5	0.07	7.3	640	320	1230	70
	1—3	SC	2	5.0	0.25	12.3	3000	880	210	90
	4—6	SC	4	4.2	0.30	5.8	1750	840	70	30
	8—10	C	7	5.8	0.37	7.2	6700	3400	70	20
15.	Plant matter			4.8	0.09	5.9	900	610	680	20
	1—3	SC	2	4.7	0.38	8.0	3200	1060	210	40
	5—6	LC	3	5.0	0.34	5.5	2500	1160	10	10
	8—9	C	6	5.1	0.37	8.7	3000	1250	10	10
16.	Plant matter			4.8	0.09	8.3	1000	130	750	70
	0—2	C	3	4.7	0.30	5.5	2000	820	250	20
	3—5	C	3	4.8	0.25	5.1	1400	600	30	30
	8—10	C	4	4.9	0.23	4.2	1400	480	60	60
17.	Plant matter			5.0	0.11	10.7	1170	460	220	50
	1—3	SC	4	5.0	0.26	5.6	2500	900	60	20
	4—6		5	5.2	0.37	5.5	4100	1440	40	70
	8—10		6	5.3	0.40	5.0	5100	1840	30	50
18.	Plant matter			5.0	0.12	22.9	1200	500	550	40
	1—3	SC	3	5.1	0.26	16.9	2000	620	70	20
	4—6		5	5.1	0.35	7.9	4200	700	50	70
	8—10		7	5.2	0.37	7.4	7100	1440	50	40
19.	0—1	SC	3	4.4	0.27	9.8	2800	700	90	10
	1—3	C	4	4.9	0.28	5.1	2200	620	10	10
	5—7	C	4	5.1	0.26	4.9	1750	570	10	10
20.	0—2	SC	4	5.5	0.27	15.4	1800	400	30	10
	3—5	C	7	5.4	0.46	8.1	3100	650	20	10
	6—8	C	6	5.4	0.30	4.8	2300	780	10	10
21.	0—2	SC	3	3.6	0.23	24.4	760	970	280	120
	3—9		5	3.5	0.32	3.5	1060	1300	160	120
	10—13		7	4.2	0.40	13.2	1560	1430	100	290
22.	1—3	C	3	4.6	0.21	4.5	1400	360	10	5
	5—7	C	3	4.2	0.20	3.1	1400	560	10	5
	11—14	LC	4	4.4	0.23	5.3	1300	640	10	5

1	2	3	4	5	6	7	8	9	10	11
23.	0—2	EuSC	3	4.4	0.18	18.4	2800	1150	550	160
	3—5		5	4.7	0.32	4.9	6100	1500	110	130
	8—10		7	4.3	0.38	5.1	4000	1800	90	120
24.	0—1	BC	1	4.9	0.16	9.9	1700	290	90	60
	2—3	BC	2	5.2	0.24	15.6	1800	170	40	60
	5—7	BC	7	5.0	0.37	10.6	3000	540	10	140
25.	0—2	BC	1	5.5	0.14	9.0	2900	310	100	110
	3—5	BC	3	5.2	0.28	7.5	4800	620	170	160
	7—9	BC	7	5.3	0.34	4.4	4600	500	110	100

ride. It is known to be a less effective exchanger in peat soils than barium chloride and it appears to be able to dissolve some calcium sulphate. On the other hand, it may be possible that the amounts of cations extracted by any solvent from the air-dried and ground samples markedly differ from those exchangeable from fresh samples. In any case, the results obtainable by the method employed probably yield a rough estimate of the fairly easily available amounts of calcium, magnesium and potassium in the peat samples. Since more attention was paid to the relative contents than on the absolute amounts it did not appear to be desirable to use any constant coefficient to improve the possibly too low results obtained by using only one extraction.

Results

The data in Table 1 show that the kind of peat in the various layers of the same peat land is almost equal or only slightly tends to improve with the depth. Generally the degree of humification and the volume weight increase on going deeper but changes in the pH values are fairly small and irregular. The ash content of all the samples is rather low indicating no marked presence of mineral matter in these virgin peat soils.

The amounts of the extractable cations are reported as kilograms per hectare in a layer of 2 dm. Thus, the markedly varying volume weight of the samples was taken into consideration and the comparison of the cation content could occur on a basis better corresponding to the natural conditions than if the results were presented per weight. These values are, of course, somewhat artificial, since volume weights estimated on air-dry and ground peat are used for the calculation, but they can be supposed to give a fairly reliable picture of the relative amounts of the extractable cations in the different layers.

In almost all the samples calcium appears to be the dominating cation, although also the content of magnesium may often be of the same order. The potassium and sodium contents of the peat samples are far lower and, on the average, nearly equal to each other. Only in samples of undecomposed plant material the potassium content, even when expressed on the volume basis, can be higher than the calcium and magnesium contents of the respective samples.

Table 2. The relative contents of extractable cations in various depths of the peat lands.

No	Depth dm	Kind of peat	Per volume				Per weight			
			Ca	Mg	K	Na	Ca	Mg	K	Na
1.	0—3	S	100	100	100	100	100	100	100	100
	4—6	S	115	85	40	30	115	85	40	35
	6—8	CS	330	250	100	55	105	80	30	15
2.	0—2	S	100	100	100	100	100	100	100	100
	2—4	CS	185	110	120	500	90	55	55	200
	4—6	CS	160	90	50	125	70	40	20	50
3.	1—2	S	100	100	100	100	100	100	100	100
	2—3	S	150	150	120	120	95	100	80	80
	3—4	CS	200	185	90	80	55	50	25	25
4.	0—3	LCS	100	100	100	100	100	100	100	100
	3—5		210	190	70	1700	75	70	25	560
	7—10		210	210	30	750	50	55	5	170
5.	0—2	S	100	100	100	100	100	100	100	100
	2—5		230	150	45	75	130	80	20	40
	5—9		400	230	55	125	95	55	15	30
	9—11		630	390	65	65	100	60	10	10
6.	Plant matter		30	30	330	600	120	135	1400	2300
	0—2	S	100	100	100	100	100	100	100	100
	3—5	S	85	60	20	140	70	50	20	100
	8—10	SC	65	40	15	0	60	40	10	0
7.	Plant matter		60	55	3100	400	115	110	6500	900
	0—3	S	100	100	100	100	100	100	100	100
	5—7	CS	200	190	60	200	80	75	25	75
	8—10	CS	260	240	140	70	90	85	50	25
8.	Plant matter		50	85	530	210	155	280	1760	730
	1—3	CS	100	100	100	100	100	100	100	100
	3—5	SC	90	100	45	60	70	75	35	50
9.	Plant matter		35	40	170	150	140	160	680	500
	0—2	S	100	100	100	100	100	100	100	100
	3—5	C	70	65	30	100	70	65	30	75
10.	Plant matter		35	100	320	65	130	380	1210	240
	1—3	SC	100	100	100	100	100	100	100	100
	3—5	LC	70	90	25	30	80	100	30	35
11.	0—1	S	100	100	100	100	100	100	100	100
	2—3	SC	270	210	240	35	70	55	60	100
	4—6	C	290	260	80	15	80	70	20	50

1	2	3	4	5	6	7	8	9	10	11
12.	Plant matter		75	55	650	440	280	210	2340	1600
	0—2	SC	100	100	100	100	100	100	100	100
	3—5	SC	180	150	45	125	190	150	45	125
	8—10	SC	125	135	80	125	160	170	85	165
13.	Plant matter		40	45	820	250	155	175	3160	970
	2—4	SC	100	100	100	100	100	100	100	100
	4—6	SC	75	120	15	100	85	120	15	100
	8—10	C	80	85	145	125	85	95	160	135
14.	Plant matter		20	35	590	80	75	130	2140	300
	1—3	SC	100	100	100	100	100	100	100	100
	4—6	SC	60	95	35	35	50	80	25	30
	8—10	C	220	390	35	20	150	260	20	20
15.	Plant matter		30	60	320	50	115	240	1350	260
	1—3	SC	100	100	100	100	100	100	100	100
	5—6	LC	80	110	5	20	80	120	5	20
	8—9	C	95	120	5	20	95	120	5	20
16.	Plant matter		50	80	350	200	170	270	1200	720
	0—2	C	100	100	100	100	100	100	100	100
	3—5	C	55	75	15	85	70	90	20	120
	8—10	C	55	65	30	170	75	90	35	220
17.	Plant matter		50	50	350	250	110	120	900	550
	1—3	SC	100	100	100	100	100	100	100	100
	4—6		165	160	65	350	115	110	45	225
	8—10		205	205	50	250	130	130	35	150
18.	Plant matter		60	80	790	200	130	175	1750	380
	1—3	SC	100	100	100	100	100	100	100	100
	4—6		210	115	70	350	160	85	55	250
	8—10		355	230	70	200	250	160	55	150
19.	0—1	SC	100	100	100	100	100	100	100	100
	1—3	C	80	90	10	80	75	85	10	15
	5—7	C	65	80	5	70	65	85	5	15
20.	0—2	SC	100	100	100	100	100	100	100	100
	3—5	C	170	160	70	100	100	95	30	50
	6—8	C	130	195	40	60	115	175	30	50
21.	0—2	SC	100	100	100	100	100	100	100	100
	3—9		140	135	55	100	105	100	40	75
	10—13		210	145	35	240	120	85	20	145
22.	1—3	C	100	100	100	100	100	100	100	100
	5—7	C	100	155	90	100	105	165	100	100
	11—14	LC	95	180	110	100	85	165	100	100

1	2	3	4	5	6	7	8	9	10	11
23.	0—2	EuSC	100	100	100	100	100	100	100	100
	3—5		220	130	20	80	125	70	10	50
	8—10		140	155	15	75	70	75	10	40
24.	0—1	BC	100	100	100	100	100	100	100	100
	2—3	BC	105	60	45	100	70	40	30	70
	5—7	BC	175	185	10	230	75	80	5	100
25.	0—2	BC	100	100	100	100	100	100	100	100
	3—5	BC	165	200	170	145	80	100	90	70
	7—9	BC	160	160	110	100	65	65	45	40

In peat lands of better quality the amount of extractable calcium tends to be somewhat higher than that of the peat lands of lower quality. The corresponding differences in the contents of other cations seem to be less marked.

Considerable variations exist in the distribution of calcium in different layers of the peat soils. Generally, an increase in the calcium content with the depth can be noted. The same seems also to hold true with the magnesium extracted by this procedure, but the distribution of potassium is reverse. Particularly the potassium content of undecomposed plant material appears to be far higher than that of the lower peat layers. The distribution of sodium seems to be less regular.

The general trends in the distribution of the extractable cations in various depths may be easier to observe if instead of the absolute amounts the relative contents are examined. Therefore, the cation contents of the surface samples were given the value of 100, and the respective relative values for the other layers were calculated. These results are listed in Table 2.

The relative calcium and magnesium contents calculated on the basis of the kg/ha-values seem most often to increase with the depth, although there also are profiles in which the surface layer appears to be the richest one. In most of the cases potassium is concentrated in the surface vegetation and also the surface layer of peat generally contains a higher amount of extractable potassium than the lower ones. The distribution of sodium in some profiles resembles that of potassium, whereas in other cases an increase in the sodium content with increasing depth may be found.

If the relative values calculated on the basis of the cation content expressed per weight are examined the concentration of potassium and sodium in plant matter is the most striking feature. Also the magnesium content in all the cases and the calcium content in most of them are highest in the surface vegetation. Generally, the potassium content is very low in the deeper layers, but the distribution of the other cations appears to be fairly variable in the different profiles.

An approximate general view of these results may be presented by the average values of the respective relative cation contents in various layers. Owing to the fact that the sampling depths were not equal in all the peat lands only a rough

estimation can be gained. The relative distribution of the extractable cations in four peat layers and fresh plant material appears, on the average, to be the following:

	Per volume				Per weight			
	Ca	Mg	K	Na	Ca	Mg	K	Na
Plant material	40	60	690	240	140	200	2030	790
0—3 dm	100	100	100	100	100	100	100	100
3—6 dm	150	130	60	200	110	80	30	100
6—10 dm	170	170	50	140	100	110	40	80
10—14 dm	310	240	70	140	100	100	40	80

The effect of depth on the relative amounts of extractable cations was also studied by computing the correlation coefficients between these quantities. The 12 samples of plant material were excluded, and only the peat layers were examined. The following total correlation coefficients were obtained for the depth and the relative content of cations:

	Cation content per volume	Cation content per weight
Ca	$r = 0.22$	$r = 0.18$
Mg	$r = 0.54$***	$r = 0.30$*
K	$r = - 0.27$*	$r = - 0.48$***
Na	$r = 0.09$	$r = 0.04$

According to these figures no correlation exists between the depth and the content of extractable calcium or sodium in these peat lands. The correlation coefficients between the depth and the magnesium content appear to be somewhat higher than could have been expected on the basis of the average values reported above, particularly if the data concerning the magnesium content per weight are examined. The negative correlation between the content of extractable potassium and the depth is distinct, although not very close.

Discussion

The results reported in this paper do not reveal any clear picture of the distribution of plant-available cations in various depths of virgin peat lands. The only distinct feature seems to be the accumulation of extractable potassium in the living surface vegetation and also, although in a less degree, in the surface layers of peat. Almost in every case, also the percentic content of sodium, magnesium, and calcium in the surface vegetation was somewhat higher than that of the peat below.

The accumulation of the easily extractable potassium in surface vegetation may be taken to arise from the scanty occurrence of this important plant nutrient in peat lands. Since it was found that also in the peat layers almost all of the total potassium was extractable by 1 N ammonium chloride, there is probably no reason to suppose that potassium would be markedly more tenaceously adsorbed in the lower and more humified peat layers than in the plant material and in the surface layers.

Of course, the possibility of the washing out of potassium from the lower layers of peat lands can not be excluded. On the basis of the present material it is impossible to conclude which of these phenomena, the most economical utilization of the poor sources of potassium in the peat lands or the washing out of this nutrient, is the more important one. According to the opinion of the authors, the former reason seems to be more probable than the latter one.

If the potassium content of the surface layers of these peat lands is compared to the uptake of this nutrient by a medium crop of oats or timothy, it will be found that most of these peat lands contain enough easily available potassium for the growth of one or two crops. However, there are peat lands, such as the numbers 1, 7, 20 and 22 in which the lack of available potassium probably prevents the growth of a satisfactory crop. If the amounts of calcium and magnesium extracted by the present method are available for plants, these nutrients do not generally play the role of minimum factors in peat soils.

Summary

It has been attempted in the present paper to study the distribution of plant-available calcium, magnesium, and potassium in various depths of 25 virgin peat lands. The amounts of these cations extractable by 1 N ammonium chloride are supposed to give a rough estimation on the available content of the nutrients. Also the quantities of extracted sodium are reported.

It has been found that the percentic content of these cations in the surface vegetation are higher than in the peat. Particularly marked is the accumulation of potassium in living plants and, although in a less degree, in the surface layers of peat. The variation in the distribution of the extractable amounts of the cations in various depths of the peat lands is considerable. A significant correlation exists between the depth and the magnesium content, and a negative correlation between the depth and the amount of extractable potassium.

So far as the amount of cations extracted by 1 N ammonium chloride represents nutrients available for plants, calcium and magnesium are not generally minimum factors in peat soils, whereas in most soils the sources of potassium probably will be depleted by the first crops.

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SELOSTUS:

UUTTUVAN KALSIUMIN, MAGNESIUMIN, KALIUMIN JA NATRIUMIN MÄÄRISTÄ ERÄITTEN LUONNONTILAISTEN SOITTEN ERI SYVYYKSISSÄ

ARMI KAILA ja JAAKKO KIVEKÄS

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Tutkimuksessa on esitetty 1 n ammonium kloridin uuttamat kalsiumin, magnesiumin, kaliumin ja natriumin määrät 25 luonnontilaisen suon eri kerroksista pinnasta noin 1 m:n syvyyteen. Lisäksi analysoitiin 12 suon pintakasvustoa.

Todettiin kasvien sisältävän enemmän uuttuvia kationeja kuin alla olevan turpeen. Etenkin kasviaineksen kaliumin pitoisuus oli erittäin suuri verrattuna turpeen vastaavaan arvoon. Turpeen uuttuvan kaliumin määrä aleni tavallisesti syvemmälle mentäessä, mutta muitten kationien kohdalla muutokset olivat epäsäännöllisempiä. Uuttuvan magnesiumin pitoisuus näytti lisääntyvän syvemmissä kerroksissa.

Sikäli kuin saadut tulokset kuvastavat soitten käyttökelpoisia ravinnevarastoja, näyttää siltä, että kalsium ja magnesium vain harvoin ovat minimitekijöinä. Kalium sen sijaan riittänee tavallisesti tyydyttämään vain ensimmäisten satojen tarpeen.