Comparison of analytical methods in testing soil fertility

RAINA NISKANEN and ANTTI JAAKKOLA

University of Helsinki, Department of Agricultural Chemistry,
SF-00710 HELSINKI, Finland

Abstract. Analytical methods for testing soil fertility were compared in a material of 430 topsoil samples. The samples were analyzed for particle-size distribution, organic carbon content, pH(CaCl$_2$), exchangeable Ca and Mg extracted with 1 M ammonium acetate (pH 7) and 1 M KCl, exchangeable K extracted with 1 M ammonium acetate (pH 7) and P extracted by the Bray 1 method. These soil properties were compared with the soil textural class and humus content class estimated visually, pH(H$_2$O) and Ca, Mg, K and P extracted with acid ammonium acetate.

The estimation of soil textural class was quite successful, but the content of organic matter was frequently underestimated. pH(H$_2$O) and pH(CaCl$_2$) were highly correlated and 95 % of the variation in pH(H$_2$O) was explained by pH(CaCl$_2$). Exchangeable Ca together with pH(CaCl$_2$) explained about 90 % of the variation in Ca extracted with acid ammonium acetate. Exchangeable Mg explained about 70 % of the variation in Mg extracted with acid ammonium acetate. Exchangeable K explained 90 % of the variation in K extracted with acid ammonium acetate. The Bray 1 P and pH(CaCl$_2$) explained 60 % of the variation in P extracted with acid ammonium acetate. pH(CaCl$_2$), clay and organic carbon content explained 72—83 % of the variation in Ca. Mg, K and P were not highly dependent on pH, particle-size distribution and organic carbon content of soil.

Introduction

For the estimation of soil fertility status, various methods have been developed. In Finland, acid ammonium acetate extraction (VUORINEN and MÄKITIE 1955) is extensively used in testing the soil nutrient status. In soil testing, soil textural class and humus content are estimated visually and soil pH is measured in water suspension. The purpose of this study was to compare the results of the adopted soil testing analysis with other soil test values. The reference methods were chosen among those widely used in other countries.

Material and methods

The research material consisted of 430 plough layer (0—25 cm) samples collected for mapping down soil characteristics at the agricultural area of the Viikki Experimental Farm. The characteristics of the soil samples have previously been described by JOKINEN (1983 and 1984).

Index words: exchangeable Ca, Mg, K, extractable P, humus content class, pH, textural class, soil testing

The samples were air-dried and ground to pass a 2-mm sieve. The particle-size distribution of the inorganic matter in the soil samples was determined by the pipette method (ELONEN 1971). The pH of the soil was measured in a stirred soil-0.01 M CaCl$_2$ suspension (1 : 2.5) (RYTI 1965). The organic carbon content of the soil samples was determined using a modified (GRAHAM 1948) ALTEN's wet combustion method. Exchangeable Ca and Mg were extracted from 10 g soil by four successive treatments with 50 ml of 1 M ammonium acetate (pH 7.0) an . with 50 ml of 1 M KCl and determined by atomic absorption spectrophotometry. Exchangeable K was extracted with 1 M ammonium acetate (pH 7.0) and determined by flame photometry. Phosphorus was extracted with Bray 1 extractant (0.03 M NaF, 0.025 M HCl) (BRAY and KURTZ 1945), the extraction ratio being 1 : 10 w/v (KAILA 1965) and determined by a molybdenum blue method (KAILA 1955). The pH of the soil-H$_2$O suspension (1 : 2.5), and Ca, Mg, K and P extractable with acid ammonium acetate (0.5 M acetic acid, 0.5 M ammonium acetate, pH 4.65, ratio 1 : 10 v/v) (VUORINEN and MÄKITIE 1955) were determined at a commercial soil testing laboratory (Viljavuuspalvelu Oy). The textural class and the humus content of the soils were estimated visually at the same laboratory.

The particle sizes of soils were classified as follows:

Particle-size fraction	Diameter, mm
Clay	< 0.002
Silt	0.002—0.02
Finer finesand	0.02—0.06
Coarser finesand	0.06—0.2
Sand	0.2—2

The textural classes aimed at were as follows:

Textural class	Proportion of particle-size fractions, %		
	Clay	Silt	Coarser fractions
Heavy clay	> 60		
Silty clay	30—60		< 20
Sandy clay	30—60		> 20
Silt	< 30	> 50	
Loam	< 30	< 50	< 50
Coarser soils	< 30		> 50

Coarser soils are classified according to the dominating coarser fraction. Gyttja clay is a soil with a clay content over 30 % and with a 3—6 % organic matter content in the subsoil. Soils with a clay content under 30 % may be defined as clayey if the clay content is considerable. Coarser soils with a considerable silt content may be defined as silty and silt soils with considerable content of coarser fractions as sandy.

The soils were classified according to the content of organic matter as follows:

Content of organic matter in the soil, %	Corresponding content of organic carbon, %	Humus content class
< 3	< 1.7	low
3— 6	1.7— 3.5	medium
6—12	3.5— 7.0	rich
12—20	7.0—11.6	very rich
20—40	11.6—23.3	mould

The content of organic matter is obtained by multiplying the organic carbon content (%) with the coefficient 1.72.

Results

Soil textural class (visual estimation) and particle-size distribution. Particle-size distribution is presented in Table 1. The particle-size distribution varied greatly in different fields. However, the proportion of sand fractions was low in the whole area and finesand fractions averaged 20 and 28 % of the particle-size distribution. The mean clay and silt contents were 31 and 17 % of the inorganic material.

The greatest group consisted of 169 coarser finesand samples (Table 2). In this group the mean content of coarser finesand fraction was 47 % of the inorganic material, the contents ranging from 28 % to 81 %. The group of finer finesand samples included only 15 samples in which the content of finer finesand fraction averaged 25 %. In addition, 12 samples were identified as finesand soils without a more accurate classification. In these samples the proportions of finer and coarser

Table 1. Particle-size distribution and organic carbon content in the research material.

Field	Number of samples	Particles, %															Org. C, %		
		<0.002 mm			0.002—0.02 mm			0.02—0.06 mm			0.06—0.2 mm			0.2—2 mm					
		x̄	s	R	x̄	s	R	x̄	s	R	x̄	s	R	x̄	s	R	x̄	s	R
49	45	20	1	6—52	11	5	4—35	16	5	8—38	47	11	17—68	7	5	2—33	4.5	2.8	1.8—14.6
54	99	21	2	6—65	12	4	3—24	20	6	3—42	43	12	14—81	4	2	1—12	4.6	1.9	2.2—11.2
84	42	30	1	19—47	18	4	12—27	24	6	11—35	24	14	7—49	4	2	2—11	4.6	0.8	2.2—5.9
86	46	36	2	7—62	13	4	6—22	14	6	6—45	33	13	16—65	4	1	2—9	3.6	0.6	2.1—5.1
88	34	28	2	9—49	12	4	6—20	15	3	8—21	41	16	14—68	3	1	2—8	4.5	1.7	2.5—9.4
89	31	39	1	14—50	16	3	7—21	25	5	14—37	16	9	7—56	4	3	2—12	8.2	1.8	3.5—11.7
94	6	42	3	30—50	28	8	23—43	20	5	17—29	8	3	3—12	3	1	2—4	8.5	3.3	5.2—14.4
96	66	42	1	27—50	27	3	16—34	23	3	18—32	6	3	2—26	3	2	1—11	7.0	1.3	2.6—9.5
97	23	33	3	14—50	27	9	8—37	23	6	13—38	13	14	2—43	4	3	2—13	6.1	2.1	2.5—9.2
98	38	33	3	9—51	27	6	15—39	24	9	14—55	12	8	3—37	3	2	1—8	4.1	1.6	2.3—8.5
All	430	31	3	6—65	17	8	3—43	20	7	3—55	28	19	2—81	4	3	1—33	5.2	2.2	1.8—14.6

Table 2. Particle-size distribution (%) by textural classes.

Textural class	Number of samples	Particles, %														
		<0.002 mm			0.002—0.02 mm			0.02—0.06 mm			0.6—0.2 mm			0.2—2 mm		
		x̄	s	R	x̄	s	R	x̄	s	R	x̄	s	R	x̄	s	R
Heavy clay	4	63	2	61—65	11	3	9—15	6	2	3—8	16	2	14—17	4	1	3—4
Silty clay	40	41	4	33—49	31	3	25—39	21	3	14—29	4	2	2—9	2	1	1—4
Sandy clay	154	40	6	28—59	19	6	9—32	20	7	8—37	18	10	3—44	4	2	2—11
Gytja clay	23	44	3	40—50	26	2	20—29	21	2	17—26	6	2	4—10	3	1	1—6
Silt	1	14	—	—	37	—	—	33	—	—	12	—	—	4	—	—
Loam	3	24	5	20—29	35	4	31—37	28	5	22—31	9	4	6—14	5	1	4—6
Finer finesand	15	19	10	7—34	25	3	19—35	37	8	27—55	16	6	6—27	4	3	2—11
Coarser finesand	169	18	6	6—31	11	3	3—24	19	5	6—31	47	10	28—81	5	3	1—19
Finesand*	12	25	5	14—31	15	2	13—22	24	5	18—33	28	6	19—39	7	3	2—12
Mould	3	26	13	11—36	23	17	10—43	18	5	12—23	20	13	6—33	13	17	2—33
Attribute																
clayey	54	25	4	17—34	15	4	8—32	20	5	12—33	35	10	6—55.	5	3	2—13
silty	23	35	4	9—49	27	3	21—35	26	8	16—47	9	5	4—20	3	1	2—8
sandy	32	41	9	11—62	27	7	9—43	20	4	8—33	7	6	3—33	4	5	2—33

* without a more accurate classification

finesand fractions were almost equal (on the average 24 % and 28 %, respectively). Four clay soils were also included in the finesand soil groups in which the clay content was 34 % at its highest.

The second greatest group included 154 sandy clay soils with a mean clay content of 40 % (Table 2). The content of clay fraction ranged from 28 % to 59 %. The clay content of two samples was under 30 %, thereby these samples were not clay soils. The group of samples identified as silty clay soils included 40 samples in which the mean contents of clay and silt fractions were 41 and 31 %, respectively. However, the content of coarser fractions was over 20 % in all samples, and all the samples in this group should be classified as sandy clays.

Four samples were identified as heavy clays, and their content of clay fraction was over 60 %. The group of gyttja clays consisted of 28 samples, average clay content 44 %. Only one sample was identified as silt soil. In this soil the content of silt fraction was under 50 % as well as the content of coarser fractions. So, this soil belongs to the group of loam soils.

Fifty-four samples the clay content of which averaged 25 %, range 17—34 %, were defined as clayey (Table 2). The clay content was over 30 % in four samples of this group. These samples should be classified as clay soils. Twenty-three samples (excl. silty clays) the silt content of which averaged 27 %, range 21—35 %, were defined as silty. Thirty-two samples (excl. sandy clays) in which the finer and coarser finesand fractions ranged from 8 to 33 % and from 3 to 33 %, respectively, were defined as sandy.

Organic carbon content and humus content class. Organic carbon content averaged 5.2 %, range 1.8—14.6 % (Table 1). The mean organic carbon content was highest (7.0 %) in gyttja clays and was high also in the silty and sandy clays (6.6 % and 5.4 %, respectively) (Table 3). The humus content class »medium» included 327 samples in which the organic carbon content averaged 4.4 %, range 1.9—11.2 % (Table 3). On the basis of organic carbon content 186 samples of this group should be classified as »rich» and 25 samples as »very rich». The humus content class »rich» included 88 samples of an average organic carbon content of 7.4 %, range 2.5—13.2 %. On the basis of organic carbon content 57 samples should be classified as »very rich», one sample as mould soil and one sam-

Table 3. Organic carbon content in textural and humus content classes.

Soil class	Number of samples	Org. C, %		
		x̄	s	R
Heavy clay	4	3.5	0.5	2.8— 3.8
Silty clay	40	6.6	1.6	2.8— 9.2
Sandy clay	154	5.4	2.1	2.5—11.2
Gyttja clay	28	7.0	1.5	4.1— 9.5
Silt	1	2.4	—	—
Loam	3	3.4	0.2	3.2— 3.6
Finer finesand	15	3.7	1.8	1.8— 7.0
Coarser finesand	169	4.4	1.8	1.9—14.2
Mould	3	13.6	1.6	11.7—14.6
Humus content:				
Low	1	1.8	—	—
Medium	327	4.4	1.6	1.9—11.2
Rich	88	7.4	1.8	2.5—13.2
Very rich	10	9.2	2.0	6.9—14.2

ple as »medium». The humus content was considered very rich in 10 samples, one of them should be included in mould soils. Three samples were classified as mould soils.

Soil pH. The pH measured in water suspension ranged from 4.2 to 7.1, mean 5.8 (Table 4). The mean pH measured in 0.01 M $CaCl_2$ suspension was 5.3, range 4.0—6.8. The pH values measured in water and 0.01 M $CaCl_2$ suspensions were highly correlated (r = 0.98***). The regression equation $pH(H_2O)$ = 0.94 + 0.91$pH(CaCl_2)$ explained 95 % of the variation in $pH(H_2O)$.

The applicability of the regression equation in predicting the mean $pH(H_2O)$ values in different fields was tested so that $pH(H_2O)$ values were calculated using the mean $pH(CaCl_2)$ values in different fields. The predicted $pH(H_2O)$ was equal to the mean $pH(H_2O)$ in the fields 54, 84 and 89. In the fields 49, 94, 96 and 98 the predicted value was 0,1 pH unit higher, in the fields 88 and 97 0.1 and in the field 86 0.2 pH units lower than the mean $pH(H_2O)$.

The pH measured in water or 0.01 M $CaCl_2$ suspensions was not highly related to particle-size distribution or organic carbon content of soil. The organic carbon content explained 42 % of the variation in $pH(H_2O)$ and 32 % of the variation in $pH(CaCl_2)$. When the effect of silt fraction was also considered, 46 % and 36 % of the variation in $pH(H_2O)$ and $pH(CaCl_2)$, respectively, was explained.

Exchangeable calcium. The mean content of calcium extracted with acid ammonium acetate was 1779 mg/l, range 275—3850 mg/l soil (Table 5). The contents of calcium extracted with 1 M ammonium acetate (pH 7) and 1 M KCl averaged 2374 and 2174 mg/kg soil, respectively. Calcium extracted with 1 M ammonium acetate (pH 7) explained 68.7 % of the variation in acid ammonium acetate-extractable calcium, the regression equation being Ca = 348 + 0.60Ca(Acet.pH 7). Calcium extracted with 1 M KCl explained 55.8 % of the variation in acid ammonium acetate-extractable calcium, and the regression equation was Ca = 507 + 0.59Ca(KCl).

The $pH(CaCl_2)$ and neutral ammonium acetate- or potassium chloride-extractable calcium together explained most of the variation in acid ammonium acetate-extractable calcium. Acid ammonium acetate-extractable calcium was dependent on $pH(CaCl_2)$ and calcium extracted with 1 M ammonium acetate (pH 7) according to the equation Ca = —2039 + 506pH + 0.47Ca(Acet.pH 7). The coefficient of determination was 91.2 %. In different fields the values of acid ammonium acetate-extractable calcium calculated on the basis of the mean $pH(CaCl_2)$ and calcium extracted

Table 4. pH values measured in water and 0.01 M $CaCl_2$ suspensions.

Field	Number of samples	pH(H₂O)			pH(CaCl₂)		
		$\bar{x}$	s	R	$\bar{x}$	s	R
49	45	6.3	0.5	4.8—7.1	6.0	0.6	4.6—6.8
54	99	6.0	0.5	4.8—7.0	5.6	0.5	4.5—6.6
84	42	5.8	0.3	5.3—6.9	5.3	0.4	4.8—6.6
86	46	6.2	0.2	5.7—6.6	5.6	0.3	4.9—6.1
88	34	5.5	0.4	4.8—6.2	4.9	0.4	4.2—5.6
89	31	5.5	0.3	5.1—6.1	5.0	0.3	4.5—5.6
94	6	5.2	0.5	4.2—5.5	4.8	0.4	4.0—5.1
96	66	5.5	0.4	4.9—6.9	5.1	0.6	4.4—6.5
97	23	5.2	0.3	4.7—5.7	4.6	0.3	4.2—5.2
98	38	5.7	0.5	4.9—6.9	5.3	0.5	4.3—6.6
All	430	5.8	0.5	4.2—7.1	5.3	0.6	4.0—6.8

with 1 M ammonium acetate (pH 7) according to the regression equation deviated from the mean values as follows:

Field (No. of samples)	Deviation, %	Field (No. of samples)	Deviation, %
49(45)	+5.0	89(31)	—0.6
54(99)	+0.9	94(6)	+2.2
84(42)	—3.9	96(66)	+1.9
86(46)	—9.3	97(23)	+4.5
88(34)	0.0	98(38)	+4.2

Calcium extracted with 1 M KCl and pH($CaCl_2$) together explained 89.9 % of the variation in calcium extracted with acid ammonium acetate, the regression equation being $Ca = -2442 + 597pH + 0.48Ca(KCl)$. In different fields the values of acid ammonium acetate-extractable calcium calculated by means of the regression equation deviated from the mean values as follows:

Field (No. of samples)	Deviation, %	Field (No. of samples)	Deviation, %
49(45)	+4.1	89(31)	—0.2
54(99)	+1.1	94(6)	+2.3
84(42)	—3.3	96(66)	+2.8
86(46)	—6.0	97(23)	—0.2
88(34)	+0.8	98(38)	+6.6

The dependence of the exchangeable calcium on soil properties was studied using clay and silt content (%), organic carbon content (%) and pH($CaCl_2$) as independent variables in the regression analysis. The pH($CaCl_2$) of soil alone explained 54 % of the variation in calcium extracted with acid ammonium acetate. Adding the clay content to the variables increased the coefficient of determination to 74 %. Adding the organic carbon content to variables increased the coefficient of determination to 82.5 %, the regression equation being $Ca = -4744 + 16.8clay\text{-}\% + 1037pH + 93org.C\text{-}\%$. Including silt content to the variables increased the coefficient of determination only to 84 %.

Calcium extracted with 1 M ammonium acetate (pH 7) was not highly correlated with pH, clay nor organic carbon content alone, but pH($CaCl_2$) and organic carbon content together explained 63 % of the variation in calcium. Addition of clay content to the variables increased the coefficient of determination to 75 %, the regression equation being $Ca(Acet.pH\ 7) = -6104 + 22.8clay\text{-}\% + 1205pH + 261org.C\text{-}\%$. The silt content was an insignificant explainer.

The organic carbon content and pH($CaCl_2$) of soil explained 55 % of the variation in

Table 5. Exchangeable calcium extracted by acid ammonium acetate, 1 M ammonium acetate (pH 7) and 1 M KCl in the research material.

Field	Number of samples	Acid NH_4OAc extractable Ca mg/l soil			1 M NH_4OAc extractable Ca mg/kg soil			1 M KCl extractable Ca mg/kg soil		
		$\bar{x}$	s	R	$\bar{x}$	s	R	$\bar{x}$	s	R
49	45	2177	595	1250—3700	2757	862	1275—5845	2344	696	1130—5132
54	99	1830	465	1025—3850	2238	556	1035—4325	1975	476	836—3542
84	42	1742	367	1075—3100	2195	439	1495—3930	2005	343	1364—2970
86	46	2074	550	700—3000	2312	658	750—3550	2186	604	690—3290
88	34	1197	277	725—2100	1610	337	1000—2700	1507	352	826—2502
89	31	1799	347	1400—3225	2760	439	1775—3730	2608	504	780—3444
94	6	1617	688	275—2100	2688	1139	502—3537	2564	1066	546—3394
96	66	2006	569	1000—3700	3198	779	1136—5603	3042	690	1060—4732
97	23	991	288	600—1900	1593	285	1215—2269	1426	416	0—2178
98	38	1493	327	900—2200	1941	437	950—3190	1810	421	368—2798
All	430	1779	560	275—3850	2374	773	502—5845	2174	716	0—5132

calcium extracted with 1 M KCl. Addition of clay content to the variables increased the coefficient of determination to 72 %. With these variables the regression equation was Ca(KCl) = —4888 + 24.8 clay-% + 953pH + 235org.C-%.

Exchangeable magnesium. The content of magnesium extracted with acid ammonium acetate averaged 163 mg/l soil, range 25—1850 mg/l soil (Table 6). The mean contents of magnesium extracted with 1 M ammonium acetate (pH 7) and 1 M KCl were 187 and 167

mg/kg soil, respectively. Magnesium extracted with 1 M ammonium acetate (pH 7) explained 72.4 % of the variation in magnesium extracted with acid ammonium acetate, the regression equation being Mg = —23.6 + 1.0 Mg(Acet.pH 7). Considering the effect of pH($CaCl_2$) the coefficient of determination which was in this case 73.3 % did not essentially increase. In different fields the values of acid ammonium acetate-extractable magnesium calculated on the basis of the mean values of magnesium extracted with 1 M am-

Table 6. Exchangeable magnesium extracted by acid ammonium acetate, 1 M ammonium acetate (pH 7) and 1 M KCl in the research material.

Field	Number of samples	Acid NH$_4$OAc extractable Mg mg/l soil			1 M NH$_4$OAc extractable Mg mg/kg soil			1 M KCl extractable Mg mg/kg soil		
		$\bar{x}$	s	R	$\bar{x}$	s	R	$\bar{x}$	s	R
49	45	226	274	50—1850	204	120	44—585	171	105	35—526
54	99	180	158	60— 950	199	160	69—952	172	146	49—864
84	42	134	58	65— 335	160	62	84—373	137	57	65—352
86	46	352	209	40— 800	364	211	55—810	337	191	32—720
88	34	98	54	25— 235	124	52	48—261	107	54	24—246
89	31	97	28	55— 180	145	36	73—224	141	80	71—528
94	6	138	41	75— 185	205	60	137—298	190	52	134—269
96	66	94	50	40— 345	144	60	70—357	127	60	60—341
97	23	67	50	35— 245	94	50	45—277	77	52	0—256
98	38	145	94	40— 500	172	103	36—598	165	99	48—552
All	430	163	161	25—1850	187	137	36—952	167	128	0—864

Table 7. Exchangeable potassium extracted by acid ammonium acetate and 1 M ammonium acetate (pH 7) in the research material.

Field	Number of samples	Acid NH$_4$OAc extractable K mg/l soil			1 M NH$_4$OAc extractable K mg/kg soil		
		$\bar{x}$	s	R	$\bar{x}$	s	R
49	45	144	98	20— 330	198	127	53— 510
54	99	233	142	75—1250	306	165	130—1440
84	42	323	108	115— 580	436	157	168— 838
86	46	310	78	180— 570	356	109	210— 700
88	34	183	44	118— 290	234	71	129— 374
89	31	161	114	60— 695	246	158	114— 970
94	6	169	63	100— 285	296	143	174— 561
96	66	174	55	85— 325	276	73	155— 480
97	23	232	87	90— 450	357	139	125— 765
98	38	265	82	50— 405	356	139	65— 643
All	430	224	115	20—1250	305	147	53—1440

monium acetate (pH 7) deviated from the mean values as follows:

Field (No. of samples)	Deviation, %	Field (No. of samples)	Deviation, %
49(45)	— 20.0	89(31)	+ 25.2
54(99)	— 2.6	94(6)	+ 31.4
84(42)	+ 1.8	96(66)	+ 28.1
86(46)	— 3.3	97(23)	+ 5.1
88(34)	+ 2.4	98(38)	+ 2.3

Magnesium extracted with 1 M KCl explained 68.6 % of the variation in acid ammonium acetate-extractable magnesium, the regression equation being $Mg = -10.0 + 1.0Mg(KCl)$. Considering the effect of $pH(CaCl_2)$, the coefficient of determination increased to 70.2 %.

Exchangeable magnesium was not highly related to the particle-size distribution, organic carbon content nor $pH(CaCl_2)$ of soil. Clay and silt content together explained only 28 % of the variation of acid ammonium acetate-extractable magnesium. These variables together with $pH(CaCl_2)$ explained 50 % of the variation and adding the organic carbon content to the variables increased the coefficient of determination only to 52 %.

Clay content and $pH(CaCl_2)$ together explained 56 % of the variation in the content of magnesium extracted with 1 M ammonium acetate (pH 7) and 52 % of the variation in the content of magnesium extracted with 1 M KCl. Clay and silt content together with $pH(CaCl_2)$ explained 64 % of the variation in acetate-extractable magnesium and 60 % of the KCl-extractable magnesium. Adding the content of organic carbon to the variables increased the coefficient of determination to 66 % (1 M acetate-extractable Mg) and 62 % (1 M KCl-extractable Mg).

Exchangeable potassium.. The content of potassium extracted with acid ammonium acetate averaged 224 mg/l soil, range 20—1250 mg/l soil (Table 7). The content of potassium extracted with 1 M ammonium acetate (pH 7) averaged 305 mg/kg soil, range 53—1440 mg/kg soil. Potassium extracted with

acid ammonium acetate was highly correlated with potassium extracted with 1 M ammonium acetate (r = 0.95***). The regression equation was $K = -3.07 + 0.75K(Acet.pH 7)$ and the coefficient of determination 90.3 %. Addition of $pH(CaCl_2)$ to variables increased the coefficient of determination to 92.3 %. In different fields the values calculated from the regression equation deviated from the mean content of potassium extracted with acid ammonium acetate as follows:

Field (No. of samples)	Deviation, %	Field (No. of samples)	Deviation, %
49(45)	+ 0.7	89(31)	+ 12.7
54(99)	— 2.8	94(6)	+ 29.5
84(42)	+ 0.3	96(66)	+ 17.2
86(46)	—14.9	97(23)	+ 14.1
88(34)	— 5.8	98(38)	— 0.4

The dependence of exchangeable potassium on soil properties was weak. The content of clay and organic carbon together with $pH(CaCl_2)$ explained only 19 % of the variation in potassium extracted with 1 M ammonium acetate (pH 7). The content of clay, silt and organic carbon together explained 22 % of the variation in potassium extracted with acid ammonium acetate.

Extractable phosphorus. Phosphorus extracted with acid ammonium acetate averaged 23 mg/l soil and ranged from 4 to 92 mg/l soil (Table 8). Phosphorus extracted by the Bray 1 method averaged 112 mg/kg soil, range 2—355 mg/kg soil. The correlation between phosphorus extracted by these two methods was not very close (r = 0.62***). Phosphorus extracted by the Bray 1 method explained only 37.7 % of the variation in phosphorus extracted with acid ammonium acetate. When the effect of $pH(CaCl_2)$ was considered, the coefficient of determination increased to 59.5 %, the regression equation being $P = -42.4 + 9.9pH + 0.11P(Bray)$. Adding the content of clay and organic carbon to the variables increased the coefficient of determination only to 62.1 %.

Table 8. Phosphorus extracted by acid ammonium acetate and the Bray 1 method in the research material.

Field	Number of samples	Acid NH₄OAc extractable P mg/l soil			Bray 1 P mg/kg soil		
		$\bar{x}$	s	R	$\bar{x}$	s	R
49	45	26	14	4—54	82	49	5—206
54	99	32	10	13—65	173	66	53—355
84	42	15	6	9—40	94	34	44—196
86	46	32	9	18—60	131	54	64—292
88	34	22	8	13—39	109	36	50—176
89	31	17	4	12—27	114	33	53—194
94	6	9	2	8—12	18	11	2— 30
96	66	12	11	6—92	55	28	14—151
97	23	18	4	13—27	128	45	63—228
98	38	23	11	9—64	100	43	32—197
All	430	23	12	4—92	112	62	2—355

Extractable phosphorus was only weakly related to soil properties. The content of silt and organic carbon together with pH(CaCl₂) explained 31.5 % of the variation in acid ammonium acetate-extractable phosphorus. The variable which explained the variation in phosphorus extracted by the Bray 1 method was primarily the clay content. However, it explained only 26.7 % of the variation in phosphorus. When the effects of pH(CaCl₂) and the content of silt fraction were also considered, the coefficient of determination increased to 30 %.

Discussion

In the visual classification of soil textural class, clay soils were well distinquished from coarser soils. In the present material of 430 samples only four clay samples were included in coarser soil groups. However, classification of clay soils into groups of silty and sandy clays was not equally successful. According to the estimation, these clay soil groups included a total of 194 samples. About 20 % of them were estimated as silty clays which was not a true classification. If the criterion of silty clay is a content of coarser fractions under 20 %, all 194 samples are sandy clays.

In the visual humus content classification, the content of organic matter was frequently underestimated. Only 36 % of 327 samples classified in the humus content class »medium» truly belonged to this class. On the basis of organic carbon content the majority of these samples should be classified as »rich». The humus content class »rich» included 88 samples of which 33 % truly belonged to this class, while nearly all other samples should be classified as »very rich». A factor rendering the humus content classification more difficult is the relatively high content of organic matter in the present material. If soils with greater variation in the content of organic matter are not included for comparison, the possibility of faulty estimations increases.

The values of pH(H₂O) and pH(CaCl₂) were highly correlated, which is in agreement with previous results of RYTI (1965), MÄNTYLAHTI and YLÄRANTA (1980) and SILLANPÄÄ (1982). In the material of RYTI (1965) the mean difference between pH(H₂O) and pH(CaCl₂) was 0.5 pH units. Also in the present study the pH(H₂O) values were about 0.5 pH units higher than the pH(CaCl₂) values. The regression equation between pH(H₂O) and pH(CaCl₂) obtained in this study agreed fairly well with the regression

equation obtained by RYTI (1965) for sand and finesand soils (pH(H$_2$O) = 0.81 + 0.94 pH(CaCl$_2$), n = 109, r = 0.97***). The mean pH(H$_2$O) values of different fields were well predicted with the regression equation calculated from the whole material. The difference between measured and calculated value was no more than 0.1 pH units excluding field No. 86 where the content of organic carbon was lower than in most other fields. The values of pH(H$_2$O) and pH(CaCl$_2$) were not closely related to the soil particle-size distribution or organic carbon content. This could also be expected on the basis of a previous study with nearly the same material (JOKINEN 1984).

In cultivated soils, the majority of the cation exchange capacity is saturated with exchangeable calcium. According to KAILA (1972), the degree of saturation with calcium varies from 60 % to 80 %. Under these circumstances it was not surprising that pH(CaCl$_2$), clay content and organic carbon content, factors on which the cation exchange capacity is highly dependent (HEINONEN 1960, MARTTILA 1965, KAILA 1971), explained more than 70 % of the exchangeable calcium extracted by three methods. More than 90 % of the variation in acid ammonium acetate extractable-calcium was explained by pH(CaCl$_2$) together with calcium extracted with 1 M ammonium acetate (pH 7) or 1 M KCl. The mean values of acid ammonium acetate-extractable calcium in different fields were predicted rather well on the basis of pH and calcium extracted by the comparative methods. However, the contents were not similar. The acid acetate extracted much less calcium from the soil than did the neutral acetate or KCl. The different extraction method explains part of the difference. According to the regression analysis, an increment of one unit of the latter values corresponded to 0.6 unit of the former.

The magnesium status fluctuated more than did calcium status in the experimental area. Exchangeable magnesium, a minor component in saturation of cation exchange capacity, was not very highly related to soil characteristics which explained 52—66 % of the variation in exchangeable magnesium. According to KAILA (1972), 10—30 % of the cation exchange capacity of cultivated soils is saturated with magnesium. The mean values of acid ammonium acetate-extractable magnesium in different fields were not predicted as well as calcium values on the basis of comparative methods. At its highest the deviation was about 30 %. On the average, the contents determined by different methods did not deviate very much from each other. According to the regression analysis, the mean differences between samples were equal irrespective of the method used.

As previously observed (JOKINEN 1984), exchangeable potassium was poorly related to soil pH, particle-size distribution and organic carbon content. Potassium extracted with acid ammonium acetate was highly related to potassium extracted with 1 M ammonium acetate. With the exception of one field (94, 6 samples), the mean values of acid ammonium acetate-extractable potassium were rather well predicted on the basis of the comparative method. The acid acetate extracted on an average 75 % of the potassium extracted by the neutral acetate.

Phosphorus extracted with acid ammonium acetate, representing relatively well available phosphorus in soil, was not highly related to phosphorus extracted by the Bray 1 method, which indicates the capacity factor of the soil phosphorus status (KAILA 1965). More phosphorus was extracted by the Bray 1 method than with acid ammonium acetate. In the study of AURA (1978) with 30 soils and in the study of SIPPOLA and JAAKKOLA (1980) with 20 soils, a 5-fold amount of phosphorus per liter of soil on the average was extracted by the Bray 1 method as compared with phosphorus extracted with acid ammonium acetate. The relationship between the methods in this study was also of the same magnitude. An accurate comparison was not possible because the former content was expressed on a

volume basis, the latter on a weight basis. In the study of Aura (1978), the phosphorus uptake of oats in four growings in pots was better explained by phosphorus extracted with acid ammonium acetate (77 %) than by phosphorus extracted by the Bray 1 method (48 %). Phosphorus extracted by any method was not very well explained by pH, organic carbon or clay and silt content, which is in agreement with the study of Sippola and Jansson (1979) on soil phosphorus extractable with acid ammonium acetate.

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SELOSTUS

Maan viljavuuden määrittämiseen käytettyjen analyysimenetelmien vertailu

Raina Niskanen ja Antti Jaakkola

Helsingin yliopisto, Maanviljelyskemian laitos,
00710 Helsinki 71

Tutkimusaineisto koostui 430 Viikin opetus- ja koetilan peltojen muokkauskerroksesta otetusta maanäytteestä. Näytteistä määritettiin lajitekoostumus, orgaaninen hiili, pH($CaCl_2$), vaihtuva Ca ja Mg uutettuna 1 M ammoniumasetaatilla (pH 7) sekä 1 M KCl:lla, vaihtuva K uutettuna 1 M ammoniumasetaatilla (pH 7) ja P uutettuna Bray 1 -menetelmällä. Näitä maan ominaisuuksia verrattiin Viljavuuspalvelu Oy:ssä tehdyn viljavuusanalyysin tuloksiin.

Aistinvaraisella määrityksellä pystyttiin maalaji tunnistamaan tyydyttävästi, mutta multavuus arvioitiin usein vähäisemmäksi kuin orgaanisen hiilen pitoisuuden perusteella saatiin. Vesilietoksesta mitatun pH:n vaihtelusta 0.01 M $CaCl_2$-lietoksesta mitattu pH selitti 95 %. Vesilietoksesta mitattu pH oli suunnilleen 0.5 pH-yksikköä korkeampi kuin pH($CaCl_2$). Happamella ammoniumasetaatilla uutetun kalsiumin vaihtelusta vaihtuva kalsium yhdessä pH($CaCl_2$):n kanssa selitti noin 90 %. Happamella ammoniumasetaatilla uutetun magnesiumin vaihtelusta vaihtuva magnesium selitti noin 70 %. Happamella ammoniumasetaatilla uuttuvan kaliumin vaihtelusta vaihtuva kalium selitti 90 %. Happamella ammoniumasetaatilla uutetun fosforin vaihtelusta Bray 1 -menetelmällä uutettu fosfori yhdessä pH($CaCl_2$):n kanssa selitti 60 %. Eri menetelmillä uutetun kalsiumin vaihtelusta pH($CaCl_2$) yhdessä saveksen ja orgaanisen hiilen pitoisuuden kanssa selitti 72—83 %. Uuttuvan magnesiumin, kaliumin ja fosforin riippuvuus maan pH:sta, lajitekoostumuksesta ja orgaanisen hiilen pitoisuudesta oli varsin heikko.