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THE RELATION BETWEEN THE VALUES pH, V AND S (HUMUS) OF SOME HUMUS SOILS. S (HUMUS) AND V OF THESE SOILS WITH pH = 7. THE EQUIVALENT WEIGHT OF THE HUMUSSUBSTANCE

by

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This paper refers to 15 humus soils with widely varying humus-content (50,0 %—6,7 %), already more fully described in two other papers in this volume (1). They are soils in which the clay-content (mineral particles smaller than 20 microns diameter) is of little or no importance in comparison with the humus-content. The values pH, V and S (humus) of the soils were determined.

The pH was determined with the aid of the Biilmann-electrode (2) in suspensions containing 5 gms humus per 200 cc water after three days.

The degree of saturation of the soil, the value V, is defined as the ratio of the quantity of adsorbed bases (Ca, Mg, K, Na) actually present in the soil (S) to the total quantity which the soil can adsorb (T); V being 100 S : T (3). Only the content of exchangeable Ca and not that of exchangeable Mg, K and Na was, however, determined. S was therefore calculated from the content of exchangeable Ca by assuming that 80 % of the exchangeable bases consisted of Ca (4). Thus for instance B 1718 contains 1,734 % exchangeable CaO, i. e. per 100 gms soil 1734 mgms CaO or 1734 : 28 = 61,93 milligram equivalents Ca; S is then found to be 61,93 : 0,8 = 77,4. T — S has further been determined by the method given in other papers (5) by A. Dekker. For B 1718 T — S has been found = 220,8; this gives T = 77,4 + 220,8 = 298,2 and V = 100 × 77,4 : 298,2 = 26,0 (Table I).

S(humus) is defined as milligram equivalents exchangeable bases (Ca, Mg, K, Na) per 100 gms humus and is arived at by dividing S(× 100) by the content of humus; thus for B 1718 S(humus) = 100 × 77,4 : 50,0 = 154,8 = 155 (see Table I). This figure is not, however, quite exact, partly because (as already stated) Mg, K and Na were not determined, but also because a part of the exchangeable bases is fixed in the clay-substance.

In table I is also given the K(humus)-value, i. e., gms exchangeable CaO per 100 gms humus. Thus for instance for B 1718 K(humus) = 100 × 1,734 : 50,0 = 3,47. The S(humus)-value can also be calculated by dividing the K(humus)-value (× 1000) by 28 × 0,8 = 22,4; thus for B 1718 S(humus) = 1000 × 3,47 : 22,4 = 155.

In view of the method of calculating S from the content of exchangeable CaO and of the fact that the soils examined

Table I. *Values for the original soils.*

Soil sample Nº. B	pH (5 gms humus + 200 cc H_2O)	gms per 100 gms dried soil		milligram equivalents per 100 gms dried soil			$V = \frac{100\,S}{T}$	per 100 gms humus	
		Humus	Exchangeable CaO	S	T—S	T		mgm equiv. bases = S(humus)	gms exch. CaO = K(humus)
1609	7.0	35.3	1.689	75.4	133.8	209.2	36.0	214	4.78
1868/70	6.9	43.0	1.815	81.0	145.1	226.1	35.8	188	4.22
1869/71	6.4	42.6	1.715	76.1	143.9	220.0	35.0	179	4.03
1856/58	6.2	44.9	1.605	71.7	178.8	250.5	28.6	160	3.57
1718	5.7	50.0	1.734	77.4	220.8	298.2	26.0	155	3.47
1857/59	5.4	48.1	1.390	62.1	202.8	264.9	23.4	129	2.89
1690	5.4	23.6	0.657	29.3	108.4	137.7	21.3	124	2.78
1610	5.0	41.9	1.089	48.6	209.8	258.4	18.8	116	2.60
1724	5.0	50.0	1.104	49.3	242.0	291.3	16.9	99	2.21
1691	4.4	23.4	0.395	17.6	124.4	142.0	12.4	75	1.69
2061	5.2	7.7	0.111	5.0	38.7	43.7	11.4	65	1.44
2059	4.9	8.1	0.115	5.1	40.8	45.9	11.1	63	1.42
2063	4.5	8.8	0.075	3.3	43.4	46.7	7.1	38	0.85
2057	4.3	9.6	0.074	3.3	47.0	50.3	6.6	34	0.77
1396	3.3	6.7	0.009	0.4	42.9	43.3	0.9	6	0.13

contained clay even if only in relatively small quantities, the figures given for V and S(humus) are not exact and are to be regarded as merely a first approximation. As soon as time allows the exchangeable Mg, K and Na will be determined. If possible the various values S and V will then also be given separately for the humus- and the clay-substance. The figures given here are therefore not to be regarded as final.

The figures for pH, humus, exchangeable CaO, S, T—S, T, V, S(humus) and K(humus) are shown in table I. The pH-, V-, S(humus)- and K(humus)-values vary widely; pH from 7,0 to 3,3; V from 36,0 to 0,9; S(humus) from 214 to 6 and K(humus) from 4,78 to 0,13.

Values of the original soils (Table I).

Table I shows a relation between the three values pH, V and S(humus) (and K(humus) of course), which is still more clearly seen in the three curves of the graph. For all the 15 soils the S(humus)- and V-curve remain at fairly equal distances from each other. This is also the case with the pH-curve for the first 10 soils. A deviation then occurs, however, for the 4 sandy soils relatively poor in humus (B 2061—2057); this part of the pH-curve, however, runs practically parallel with the first part. Soil no. 15 (B 1396), with the lowest V- and S(humus)-value, also has the lowest pH-value (pH = 3,3). This last point lies fairly well in the line of the first part of the pH-curve. The cause of the deviation of the four sandy humus soils is unknown to me.

S and V and S(humus) with pH = 7 (Table II).

In a publication included in this volume (6) is stated how much CaO the 15 humus soils require to reach a pH = 7. With the aid of this figure we can calculate the S-value of the soil with a pH = 7. Thus, for instance, 100 gms humus of B 1718 require 1,95 gms CaO to reach a pH = 7 (see table II). The humus-content of B 1718 being 50,0 %, 100 gms soil must take up 0,5 × 1,95 = 0,975 gms CaO, i.e., 975 : 28 = 34,8 mgm equivalents Ca. The S-value of the original soil B 1718 being 77,4 (see table I), the S-value with a pH = 7 will be 77,4 + 34,8

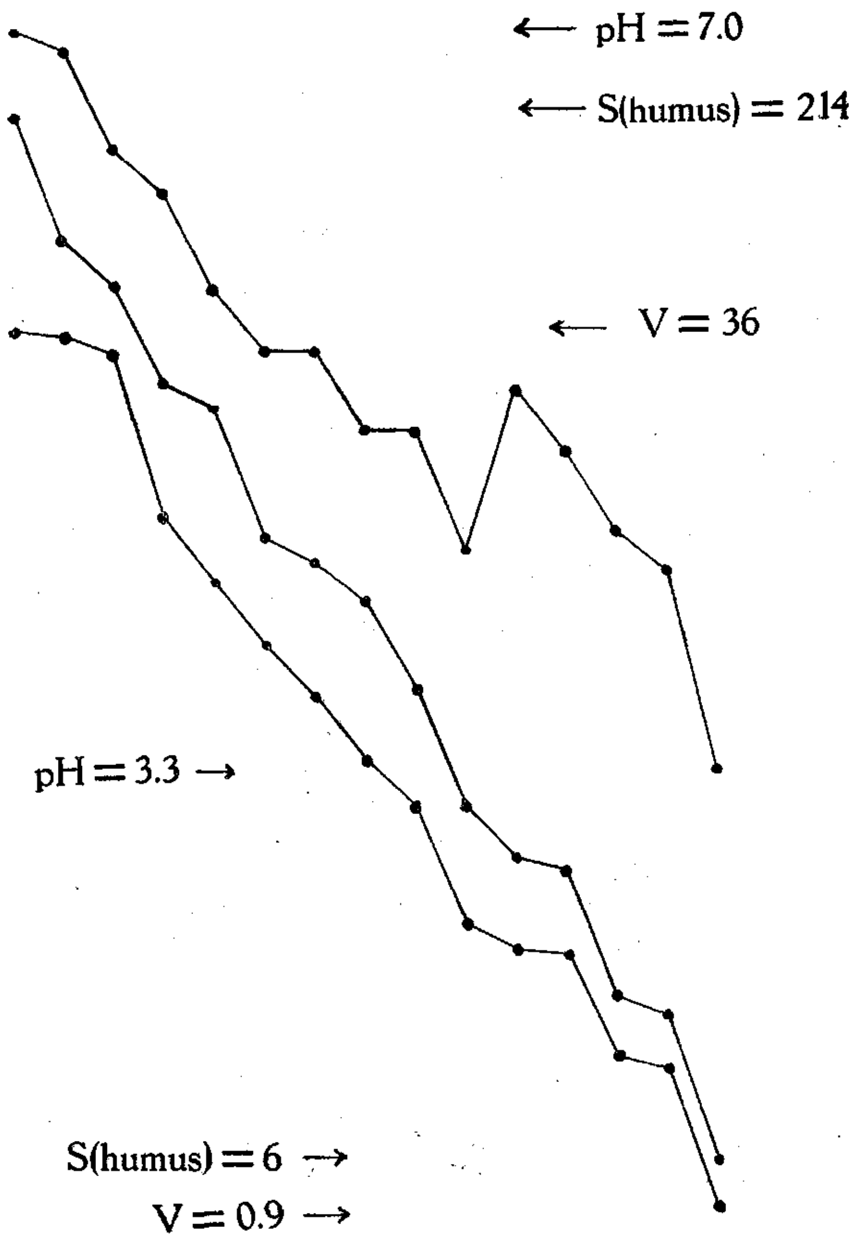
= 112,2. And since T = 298,2, the degree of saturation V of soil B 1718 with a pH = 7 is 100 × 112,2 : 298,2 = 37,6.

Further the S(humus)-value with a pH = 7 is calculated by dividing S with a pH = 7 (× 100) by the humus-content; thus, for instance for B 1718, this value is found to be 100 × 112,2 : 50,0 = 224.

Table II.

Soil sample N⁰. B	CaO required to reach pH = 7			S with pH = 7, i. e., milligm. equivalents bases per 100 gms dried soil	V with pH = 7, i. e., 100 S (pH=7) / T	Per 100 gms hums		Equivalent weight of the humus-substance
	gms per 100 gms humus	gms per 100 gms dried soil	milligm. equivalents per 100 gms dried soil			S with pH = 7 and an average V = 35,8	S with V = 100 and pH about 11	
1609	0	0	0	75.4	36.0	214	593	169
1868/70	0.38	0.163	5.8	86.8	38.4	202	526	190
1869/71	n. d.	n. d.	n. d.	n. d.	n. d.	n. d.	516	194
1856/58	1.22	0.548	19.6	91.3	36.4	203	558	179
1718	1.95	0.975	34.8	112.2	37.6	224	596	168
1857/59	2.17	1.044	37.3	99.4	37.5	207	551	181
1690	2.22	0.524	18.7	48.0	34.9	203	583	172
1610	2.99	1.253	44.7	93.3	36.1	223	617	162
1724	3.30	1.650	58.9	108.2	37.1	216	583	172
1691	3.91	0.915	32.7	50.3	35.4	215	607	165
2061	3.32	0.256	9.1	14.1	32.3	183	568	176
2059	3.63	0.294	10.5	15.6	34.0	193	567	176
2063	4.08	0.359	12.8	16.1	34.5	183	531	188
2057	4.42	0.424	15.2	18.5	36.8	193	524	191
1396	6.15	0.412	14.7	15.1	34.8	225	646	155
Average					35.8	206	568	176

These figures are shown in table II. Whilst the V-values of the original soils vary very widely (table I), we see in table II that there is not a great divergence in the V-values with a pH = 7 (from 32,3 to 38,4), the average being 35,8. This is likewise the case with the S(humus)-values with a pH = 7 and an average V = 35,8, which vary from 183 to 225, the average being 206. This means that with a pH = 7 100 gms humus of all the 15 soils examined contain an average of 206 mgm equivalents bases. Assuming that these bases are only Ca,



pH, S(humus) and V for the 15 original soils this gives 206 × 28 = 5768 mgms CaO = 5,77 gms CaO per 100 gms humus. This is our K(humus)-value with a pH = 7. In several publications (7) we have given this value as 5,2, but this latter figure does not take into account the content of exchangeable Mg, K and Na. It is of course better to work with the S(humus)-value than with the K(humus)-value.

The equivalent weight of the humus-substance.

With the aid of the T-value and the humus-content of the soil we can calculate how many milligram equivalents of base are required for the complete saturation of 100 gms humus-substance; this is S(humus) with V = 100. For B 1718 this is 100 × 298,2 : 50,0 = 596. In this completely saturated condition (V = 100) the pH of all soils examined is found to be about 11 (8).

The equivalent weight of the humus-substance has been calculated in the following manner. 100 gms soil B 1718 contain 50,0 gms = 50000 milligrams humus-substance, whilst the humus acids in this 100 gms soil are completely saturated by 298,2 milligram equivalents of bases (T). One milligram equivalent of base therefore binds 50000 : 298,2 = 168 milligrams humus-substance. This figure is shown in table II as the equivalent weigt of the humus-substance. It can of course also be arrived at by dividing 100000 by S(humus) with V = 100; for instance for B 1718 the equivalent weight of the humus-substance = 100000 : 596 = 168.

As we see in table II, the equivalent weights vary from 155 to 194, the average being 176. It is hardly necessary to point out that the same errors which are inherent in the S- and V-values, also inhere in the equivalent weights.

In my Faraday Society paper I calculated the equivalent weights of the clay-substance in some clay soils; the average is about 1225 (9). I should be the last person to deny that the two figures 176 and 1225 are open to criticism. But, although they are only provisional, they do show very clearly that the humus-substance has a far greater power of base adsorption than the clay-substance. This follows also from the K-values of the humus-substance and the clay-substance. As already stated in another paper in this volume (10), in well-saturated soils (pH = 7) in a natural condition 100 gms humus contain about 5,2 gms CaO and 100 gms clay about 1,1 gms CaO. It should be borne in mind that 5,2 and 1,1 are the K(humus)-values which refer only to exchangeable CaO. The S(humus)-values include also the content of exchangeable Mg, K and Na and are therefore greater than the K(humus)-values.

Summary.

1. The pH, the degree of saturation (V) and the S(humus), i. e., mgm equivalents of exchangeable bases per 100 gms humus, of 15 humus soils with widely varying humus-content (50,0 % —6,7 %) have been determined. The pH varies from 7,0 to 3,3; the V from 36,0 to 0,9 and the S(humus) from 214—6 (Table I).

2. There is a relation between the three values pH, V and S(humus), which is still more clearly seen in the three curves of the graph. Only in the case of the 4 humus sandy soils does a deviation in the pH-curve occur.

3. By means of the values of the amount of CaO required to reach pH = 7 (6) the V- and S(humus)-values of the soils with a pH = 7 have been determined (Table II). Both these values are found to vary but slightly, the averages for the 15 soils examined being V = 35,8 and S(humus) = 206. If this latter figure is expressed in CaO, 100 gms humus (with pH = 7) are seen to contain an average of 206 × 28 : 1000 = 5,77 gms CaO.

4. The equivalent weight of the humus-substance has been found by dividing the humus-content (in mgms) by T and represents therefore mgms humus-substance per mgm equivalent of base in the completely saturated condition (V = 100). The values obtained vary from 155 to 194, the average being 176 (Table II). In an earlier publication (9) the average of the equivalent weight of the clay-substance in clay soils was stated to be 1225. This means that the humus-substance has a far greater power of base adsorption than the clay-substance.

In view of the method of calculating S from the content of exchangeable CaO and of the fact that the humus soils examined contained clay even if only in relatively small quantities, the figures given in this paper are to be regarded as merely a first approximation.

DIE BEZIEHUNG ZWISCHEN DEN GRÖSSEN pH, V UND S(HUMUS) BEI EINIGEN HUMUSBÖDEN. S UND V DIESER BÖDEN BEI EINER REAKTIONSZAHL pH = 7. DAS ÄQUIVALENTGEWICHT DER HUMUSSUBSTANZ.

Zusammenfassung.

1) Es wurden pH, Sättigungszustand (V) und S(Humus) (d.h. die Menge Milligramaequivalenten austauschfähiger Basen auf 100 g. Humus) von 15 humosen Böden mit sehr verschiedenem Humusgehalt (50,0 %—6,7 %) bestimmt. Die pH-Werte schwanken zwischen 7,0 und 3,3; die V-Werte zwischen 36,0 und 0,9; und die S(Humus)-Werte zwischen 214 und 6 (Tabelle I).

2) Es besteht eine Beziehung zwischen den drei Werten pH, V und S(Humus), welche in der graphischen Darstellung noch klarer hervortritt. Nur bei den vier Humussandböden tritt eine Abweichung in der pH-Kurve auf.

3) Mittels der Kalkmenge, die erforderlich ist, um pH = 7 zu erreichen, sind die V- und S(Humus)-Werte der Böden bei pH = 7 bestimmt worden (Tabelle II). Es zeigt sich, dass diese beiden Werte nur sehr wenig variieren. Die Mittelwerte bei den 15 untersuchten Böden waren für V = 35,8 und für S(Humus) = 206. Wenn der letztere Wert in CaO ausgedrückt wird, dann erweist es sich, dass 100 g. Humus (pH = 7) im Mittel 206 × 28 : 1000 = 5,77 g. CaO enthalten.

4) Das Aequivalentgewicht der Humussubstanz wurde gefunden aus dem Quotienten Humusgehalt in mg. durch T und bedeutet also Humussubstanz — in völlig gesättigtem Zustand (V = 100) — in mg. auf ein Milligramaequivalent Base. Diese Aequivalentgewichte der Humussubstanz schwanken zwischen 155 und 194; der Mittelwert ist 176 (Tabelle II). In einer früheren Arbeit (9) ist das mittlere Aequivalentgewicht der Tonsubstanz in Tonböden zu 1225 gefunden worden. Das heisst, dass die Humussubstanz ein weitaus grösseres Basenbindungsvermögen besitzt als die Tonsubstanz.

Im Hinblick auf die Methode, nach der S aus dem Gehalt an austauschfähigem CaO errechnet wurde, und mit Rücksicht darauf, dass die untersuchten Humusböden Ton, wenn auch nur in relativ geringen Mengen enthielten, sind die in dieser Arbeit gegebenen Daten nur als eine erste Annäherung zu betrachten.

LA RELATION ENTRE LES VALEURS pH, V (DEGRE DE SATURATION) ET S(HUMUS) DANS QUELQUES SOLS HUMIQUES. S ET V DE CES SOLS AVEC pH = 7. LE POIDS EQUIVALENT DE L'HUMUS.

Résumé.

1) Les valeurs pH, degré de saturation (V) et S(humus), c'est à dire la quantité de milligrammes equivalents de bases échangeables par 100 gr d'humus, ont été déterminées dans 15 sols humiques d'une teneur en humus très différente (50,0 %—6,7 %). Les valeurs pH varient entre 7,0 et 3,3; les valeurs V entre 36,0 et 0,9 et les valeurs S(humus) entre 214 et 6 (table I).

2) Il existe une relation entre les trois valeurs pH, V et S(humus) qui est encore plus évidente si l'on examine le graphique. Il y a seulement une différence dans la ligne pH des 4 sols sabloneux pauvres en humus.

3) Au moyen de la quantité de chaux, nécessaire pour atteindre le pH = 7, les valeurs V et S(humus) des sols avec un pH = 7 sont déterminées (table II). Ces deux valeurs paraissent ne varier que peu. La moyenne dans les 15 sols examinés est V = 35,8 et S(humus) = 206. Quand cette dernière valeur est exprimée en CaO, alors il parait que 100 gr humus (avec pH = 7) contiennent en moyenne 206 × 28 : 1000 = 5,77 gr CaO.

4) Le poids équivalent de l'humus a été calculé du quotient humus (en mgr) par T et signifie donc la quantité d'humus en mgr — dans une condition de saturation complète (V = 100) — par un milligramme équivalent de base. Ces poids équivalents de l'humus varient de 155 à 194; la valeur moyenne est 176 (table II). Dans une autre publication (9) j'ai trouvé que le poids équivalent moyen de l'argile était de 1225. Cela signifie que la capacité de l'humus d'adsorber les bases est plus grande que celle de l'argile.

A cause du calcul de S du contenu de CaO échangeable et parce que les sols humiques examinés contenaient de l'argile, quoiqu'en petite quantité, les conclusions données dans ce travail doivent être considérées comme approximatives.

REMARKS.

1) This Volume, page 76 and page 175.
2) This Volume, page 29.
3) Base Exchange in Soils. A general discussion held by the Faraday Society.

December 1924. Transactions of the Faraday Society, volume XX, page 556.
4) Faraday Society paper, page 555.
5) Faraday Society paper, page 560; also Zeitschrift für Pflanzenernährung und Düngung, Teil A, 4. Jahrg., Heft 3.
6) This Volume, page 72—93.
7) This Volume, page 183.
8) Zeitschrift f. Pflanzenernährung und Düngung, Teil A, 4. Jahrg., Heft 3, page 143.
9) As can be seen in table VII on page 563, Base Exchange in soils (Faraday Society Transactions 1924), there is a great difference between the equivalent weight 1755 of B 1458 and those of the other clay soils. As stated above, S was calculated from the content of exchangeable Ca by assuming that 80 % of the exchangeable bases consisted of Ca, and found to be 12,2. Now Prof. von 'Sigmond has determined the content of exchangeable Mg, K and Na in my soil sample B 1458 and found very high values, so that S becomes 29,3 in place of 12,2 This gives T = 64,4 and V = 100 × 29,3 : 64,4 = 45,5 and the equivalent weight of the clay substance 83000 : 64,4 = 1290. This figure comes fairly close to the average 1225. Table VII also gives the equivalent weight of the loam substance of two loamy soils, 2061 and 2017 respectively. The difference between the equivalent weights of the clay-substance and the loam-substance must be due to a difference in the compostion of these two substances (see Verslagen Proefstations, no. XXX (1925), page 198—202, On the Nomenclature and Classification of the mineral soils in Holland. I Definition of the terms Clay, Loam and Sand).
10) This Volume, pag. 183.

POSTSCRIPTUM.

With reference to the „Nachschrift" on page 39 of these Transactions (Volume A) it should be mentioned that the pH's given in this paper are about 0,1—0,2 too low. As already stated in the „Nachschrift" on page 93 the amounts of CaO given in table II are those required to reach pH = 7,17 (and not pH = 7,0). The S- and V-values of table II are accordingly also those for pH = 7,17 (and not for pH = 7,0). The general results are not affected hereby.