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THE AMELIORATION OF THE STRUCTURE OF CLAY SOILS BY LIMING

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1. Introduction

Many scientists studied the influence of lime on the physical soil conditions and generally the results obtained were rather variable. Baver (1) doubts if lime has a favourable influence on soil structure for he could find no difference in physical behaviour between a hydrogen clay and a calcium clay and he could show no correlation between exchangeable calcium and aggregation. Bradfield (3) was coming to the same conclusion. On clay soils rich in chalk he could not find a better aggregation. In our country we mostly find on heavy clay soils with a great percentage of chalk a rather good physical condition and we know that following loss of chalk an unfavourable soil structure is obtained. Lastly we could show on several experimental fields that liming improved a poor or maintained a good soil structure. However, some clay soils show a very poor soil structure, in spite of the fact that a great percentage of chalk is present.

Now it is well known in practice that sugar factory lime sludge has a more favourable influence on the structure of a heavy clay soil than marl and similar agents. The question arises in which way lime is affecting soil structure and what is the cause of the mentioned differences. In the following we shall try to answer that question.

2. Supposed mechanism

All the scientists agree that a calcium clay has a much better structure than a sodium clay. We know that a sodium clay after the greater part of the soluble Na-ions has drained away, has a very poor structure and that we can improve this structure by treating the soil with gypsum. Then the adsorbed Na-ions are exchanged against Ca-ions.

There were however indications that not only the exchangeable cations are important for soil structure, but also the cations present in the soil solution. Well known is the phenomenon, that a clay

soil with enough Na-ions in the soil solution has a good soil structure. L a a t s c h (4), asserts that in the same way an excess of Ca-ions in the soil solution improves the physical condition of a clay soil which was saturated with exchangeable Ca-ions.

3. Experiments and results

On some experimental fields we have checked the importance of the nature and quantity of the soluble cations.

In the first place this occured on an experimental field with lime and gypsum on a heavy clay soil in the province of Groningen. Originally the purpose of this experimental field was to study the need of potassium at different levels of liming. The gypsum was applied to prevent the counteraction of the direct favourable influence of potassium on plant growth by an indirect and unfavourable influence due to a decrease in soil structure caused by the potassium.

However, we studied only the influence of lime and gypsum on the chemical and physical properties of the soil. It is wel known, and we found it here again, that lime has another influence on the soil than gypsum. Lime increases the pH and that means that a part of the exchangeable H-ions is replaced by Ca-ions. Gypsum does not increase the pH and also does not replace

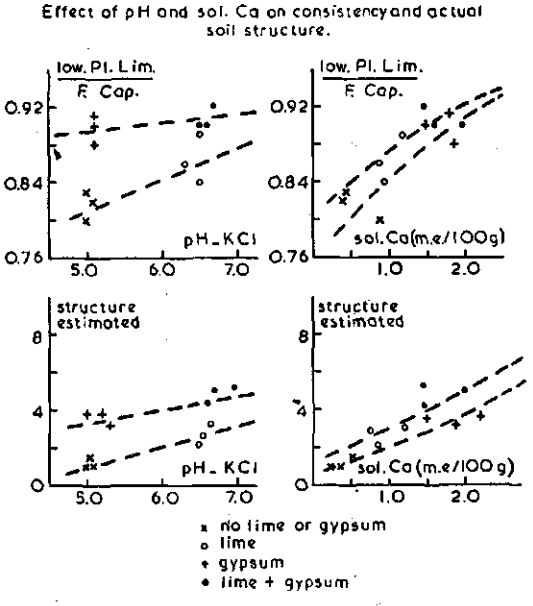

Fig. 1

Effect of pH and soluble Ca on consistency and actual soil structure
Erratum : read „lower" plastic limit instead of „iower" pl. lim.

H-ions by Ca-ions. It increases however strongly the quantity of soluble cations.

On this experimental field, we measured :

a. the pH, as a parameter for the exchangeable cations,

b. the quantity of soluble cations and

c. soil structure by means of a visual method (P e e r l k a m p, 5) and a consistency determination (B o e k e l. 2).

Then we checked separately the influence of pH and quantity of soluble Ca-ions on soil structure. The result is shown in fig. 1.

In the left half is shown the influence of pH on soil structure (consistency measurement above and visual evaluation below) at two different concentrations of soluble ions, in the right half the influence of soluble Ca on soil structure at two pH-levels.

It will be clear that by increasing pH an improvement of soil structure is obtained, but that an increase of the quantity of soluble Ca-ions can improve soil structure more strongly.

On another experimental field, lying on a heavy clay soil with some chalk in it, the soil was treated with several quantities of sulfur. The result of this treatment was, that the pH decreased, the amount of soluble salts and especially the quantity of Ca-ions increased strongly and soil structure was improved significantly.

It was clear that this improvement must be due to the increase of the quantity of soluble Ca-ions.

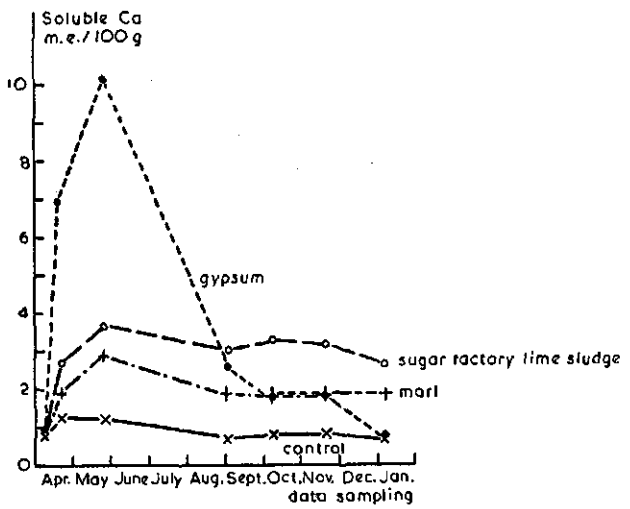

Fig. 2

Course of the quantity of soluble Ca on an experimental field with severa Ca-holding agents

Lastly we laid out an experimental field with several Ca-holding materials such as gypsum, marl and sugar factory lime sludge on a rather heavy clay soil with a very poor soil structure.

Regularly the quantity of soluble cations, especially Ca-ions, was measured and soil structure was estimated.

The results of the first measurements are given in fig. 2. A few months after application of the Ca-fertilizers, the concentration of soluble Ca was greatest in the plots with gypsum, somewhat lower in the plots with lime sludge, and rather low in the plots with marl and the untreated plots.

After 7 or 8 months however the situation was quite else. Almost all the Ca-ions of the gypsum were washed away, while in the plots with lime sludge the concentration of soluble Ca-ions remained at a rather constant level, higher than those of gypsum and marl.

Soil structure was adapting itself to the quantity of soluble Ca-ions. The first month soil structure was best on the plots with gypsum, but after a longer period the plots with lime sludge had the best soil structure. On the plot with marl, soil structure was poorer than on the plots with lime sludge, but better than on the untreated plot.

4. Conclusion

The results mentioned above show clearly that the solubility of Ca-holding materials plays an important part on improving soil structure. Marl and similar agents are influencing the pH strongly, but to improve structure of clay soils significantly, solubility is usually too small. This depends however somewhat on the soil condition, particularly on the development and the concentration of carbonic acid.

The solubility of gypsum is so great that it affects soil structure strongly, but only during a short period as the Ca-ions are washed away very quickly.

Apparently the solubility of lime sludge is sufficient to cause a favourable influence on soil structure, but not great enough to be washed away in a short time.

Hence we may conclude that the effect of Ca-holding agents on soil structure depends principally on the solubility in soil moisture and on the increases in the concentration of the soil solutions.

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SAMENVATTING

Grondverbetering van kleigronden door bekalking

De uitwerking op de bodemstructuur van het bekalken hangt grotendeels af van ieder geval afzonderlijk. De bevinding van Amerikaanse onderzoekers dat er geen verschil is in fysische eigenschappen tussen een Ca- en een H-klei konden we in het laboratorium door eigen onderzoek bevestigen.

Op enkele proefvelden werd nochtans een gunstige invloed van de bekalking op de bodemstructuur van een kleigrond, zonder reserve aan $CaCO_3$ en met een lage pH, waargenomen. Op een andere kleigrond, ditmaal met 2 % $CaCO_3$ en een hoge pH, vonden we dat een behandeling met zwavel een gunstige uitwerking had op de structuur. Klaarblijkelijk verhoogde door deze behandeling in beide gevallen de hoeveelheid oplosbare Ca-ionen in de bodem, met als gevolg een verbetering van de bodemstructuur. Deze verbetering in bodemstructuur was zeer groot voor de kleigronden.

De uitwerking van gips op normale kleigronden kan eveneens verklaard worden door een stijging van de hoeveelheid oplosbare Ca-ionen in de bodem. Het verschil in uitwerking tussen mergel en schuimkalk (afvalproduct bij de suikerfabricatie) ligt ook in het verschil in oplosbaarheid van het aanwezige calcium.

Het in schuimkalk aanwezige organisch materiaal verhoogt bovendien de oplosbaarheid van Ca, waardoor de structuurverbeterende werking van schuimkalk groter is dan van gewone kalk.

RESUME

L'amélioration de la structure du sol par le chaulage

L'influence du chaulage sur la structure du sol semble varier pour chaque cas.

Des recherches américaines ont montré qu'il n'y a pas de différence dans les propriétés physiques d'une argile saturée de Ca et d'une autre saturée de H; nos propres déterminations de laboratoire ont confirmé cette opinion.

Cependant, sur certaines parcelles d'expérimentation on a observé une influence favorable du chaulage sur la structure d'un sol argileux sans réserve de $CaCO_3$ et à réaction nettement acide. Sur un autre sol argileux ayant 2 % de $CaCO_3$ et un pH élevé, nous avons constaté l'effet favorable d'un traitement au souffre sur la structure. Il est évident que dans ces deux cas la teneur en ions Ca solubles a augmenté et que l'amélioration de la structure est due à cette augmentation de concentration.

L'amélioration signalée est très importante sur une terre argileuse lourde. L'action favorable du gypse sur des terres argileuses normales peut s'expliquer d'une façon analogue. Cette même explication d'une différence dans la solubilité des ions Ca est valable pour expliquer les effets différents de la marne et de l'écume de sucrerie sur la structure du sol. Dans ce dernier cas, il faut tenir compte aussi de la teneur en matière organique, qui augmente la solubilité du calcium et de ce fait l'écume s'avère plus efficace que la chaux ordinaire.

ZUSAMMENFASSUNG

Die Verbesserung der Struktur toniger Böden durch Kalkung

Der Einfluss der Kalkung auf die Bodenstruktur scheint von Fall zu Fall zu wechseln.

Amerikanische Untersuchungen haben ergeben, dass es keinen Unterschied in den physikalischen Eigenschaften eines Ca- und eines H-Tons gibt. Diese Ergebnisse wurden durch unsere Laboratoriumexperimente bestätigt.

Auf Versuchsparzellen aber wurde ein günstiger Einfluss auf die Bodenstruktur durch die Kalkung eines Tonbodens ohne $CaCO_3$-Reserve und mit niedrigem pH festgestellt. Auf einem anderen Tonboden mit 2 % $CaCO_3$ und einem hohen pH-Wert ergab die Behandlung mit Schwefel eine bedeutende Verbesserung der Bodenstruktur.

Es ist klar, dass, in beiden Fällen die Menge der löslichen Ca-ionen zugenommen und dass diese Vermehrung der Konzentration die Verbesserung hervorgerufen hat. Auf schweren Tonböden ist diese Strukturverbesserung sehr gross.

Der Einfluss einer Gipsdüngung auf normalen Tonböden kann auch durch eine Zunahme der Menge an löslichen Ca-ionen erklärt werden. Die Unterschiede in der Strukturverbesserung durch eine Kalkung mit Mergel oder mit Scheideschlamm (sekundäres Produkt der Zucker-Fabrikation) sind in ähnlicher Weise durch einen Unterschied in der Löslichkeit des Calciums zu erklären. Man darf aber nicht vergessen, dass der Scheideschlamm auch organisches Material enthält, das die Löslichkeit des Calciums erhöht, sodass das Produkt schneller strukturverbesserend wirkt als eine normale Kalkung.