Leaching of Sodic Soils as Influenced by Application of Gypsum

B. VERHOEVEN

Soils Department, Zuiderzeepolders Development and Settlement Authority, Kampen, Netherlands

Inundations with seawater — as a result of stormfloods or due to war actions — never have been rare in the Netherlands. In the flooded areas the salt-concentration of the soil moisture may amount to 500 me. per litre, of which NaCl covers more than 400 me. But not only concentration and composition of the soil moisture change, also the relations between the various adsorbed cations are influenced by the inundation (Table 1.).

Due to this high exchangeable sodium percentage the flooded soils get the character of sodic soils and a decline of structure of these soils is observed as soon as the excess of electrolytes has been leached. The exchangeable Na^+ indeed is replaced later by Ca^{2+} but this process takes time (annual downward waterpassage in normal soils equals about 200 mm) and cases have reported that full regeneration of structure took 20 years.

Measures to prevent or to reduce the deterioration of structure always roused the interest of scientists and of practical farmers. After the floods of 1906 HISSINK [2] — but he was not the first Dutchman dealing with the subject — carried out in his laboratory some leaching experiments with saline soils. Judging from these experiments HISSINK applied gypsum on some experimental fields after the floodings of 1916. It was only after the small scale war inundations of 1939 and 1940 that gypsum was applied in practice. After the inundations of 1944/1945 and the disaster of 1953 application of large amounts of gypsum was a general use.

Time of application of gypsum

About 20 years ago (DOMINGO [1], ROWAAN [4]) it was thought that gypsum should be applied only after the bulk of the salt had been leached and the concentration of the soil moisture in the top layers had been lowered down to ±110 me. per litre. At that concentration the collapse of structure would not yet start on the one side, but on the other hand the exchange of Ca^{2+} with adsorbed Na^+ would be favoured by the lower NaCl-content of the soil moisture. Even other arguments for a late application of gypsum could have been adduced (exchange of adsorbed Na^+ with Ca^{2+} due to the dilution effect or due to the slow but undeniable natural regeneration process).

These arguments are not so strong as they perhaps seem to be. First of all VAN DER MOLEN [3] pointed out that the leaching of the salt in the few

Table 1.

Ionic composition of normal and flooded Dutch soils

Exchangeable cations in %	Na^+	K^+	Mg^{2+}	Ca^{2+}
Normal soil	1	2	4	93
Soil flooded with seawater	25	7	26	42
Soil in frequent contact with seawater	32	8	36	24

topmost centimeters proceeds so fastly and the gypsum dissolves so slowly, that the Ca^{2+}-ions mainly enter layers which have already lost a good deal of the salts. Another difficulty lies in the fact that there is no sharp point of collapse, the swelling of the clay particles (the first beginning of the decline of structure) proceeding, below a relatively high threshold value, gradually with decreasing salt concentration, and, moreover, leaching intensity varies considerably over short distances. A practical objection against use of gypsum after partial leaching is that the "right" moment in Holland generally is reached during the first winter after drainage and then the land is too wet to be treated with heavy dressings of gypsum. Last but not least, experiments showed that application of gypsum after leaching of the main part of the salt caused a delay in the regeneration of the structure, which delay is unacceptable with regard to the intensively used Dutch soils.

On the contrary, the present opinion with respect to the time of applying gypsum is: the earlier the better. In this way temporary decline of structure is prevented or at least reduced substantially and hence the intake rate and the capillary conductivity of the top layers is kept to the mark. The better the intake rate of the soil, the less rain is lost by runoff. Dressing with gypsum

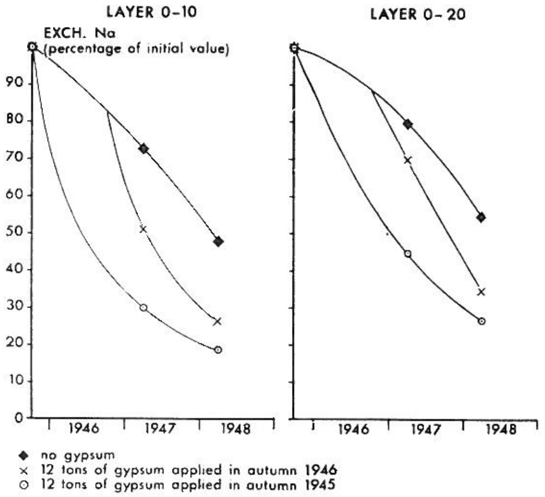

Fig. 1

Decrease of exchangeable Na^+ on untreated and gypsumtreated plots (mean values of 8 experimental fields) has two effects: The concentration of Ca^{2+}-ions in the soil moisture is increased and the downward passage of rainwater is facilitated. Thus the exchange of adsorbed Na^+ is promoted as well by the presence of more Ca^{2+}-ions and by a faster removal of the reaction products. As shown in Figure 1. gypsum given before the decline of structure starts, gives a faster lowering of exchangeable Na^+-figures than gypsum given after collapse of structure.

If the quantity of gypsum given is the same for both treatments, the stronger lowering of the adsorbed Na^+ after an early application can be caused only by a larger water passage. More water passage through sodic soils as a result of a better structure of the soil surface has been demonstrated by VERHOEVEN [6] and e.g. in the fields of Figure 1. (as far as sampled at the right time) the downward passage of water during the winter 1946–1947 was 89 mm for the zero plots and 115 mm for the plots which got an early dressing of 12 tons gypsum (for the method of calculating water passage from salt values see VERHOEVEN [5]).

Leaching as influenced by structure

A bigger downward passage of water (in consequence of a better structure) must involve a more substantial removal of salt from the soil. Indeed, the salt content (down to 80 cm) of the plots treated in good time with 12 tons of gypsum was during three subsequent years always 40–60% lower than that of the untreated plots.

Even more interesting were the data obtained on fields where various chemical amendments had been applied (Figure 2).

The effect of these amendments on structure and hence on water passage and desalinization depends upon two factors, viz. the amount of Ca^{2+}-ions applied and the solubility of the related chemical. It has to be mentioned that the ratio between the Ca^{2+}-ions brought on the soil with respectively $CaSO_4 \cdot H_2O$, $CaCl_2$, $Ca(OH)_2$, and S was as 1 : 0.7 : 1 : 1.5.

The largest water passage could be expected in the $CaCl_2$-treated plots, but the relatively low quantity of $CaCl_2$ used and the Cl^--ions brought into the soil (salt content was measured via chloride determinations) allowed only for a second place in leaching. The gypsum effected the fastest leaching, the solubility indeed being lower than of the $CaCl_2$, but the quantity used being higher and anyhow high enough to keep the permeability of the topsoil up to the mark. The leaching of the slaked lime plots lagged behind, due to the low solubility of the $CaCO_3$ in which the slaked lime is changed largely, soon after application. The zero-plot where regeneration of structure was completely dependent upon the slow dissolving of the $CaCO_3$ present in the soil, showed the tardiest progress of leaching.

Most interesting was the effect of the S. This amendment only works after microbiological oxidation and reaction with the $CaCO_3$ present in the soil, resulting in the formation of gypsum. The S had been applied in autumn 1946. Autumn and winter temperatures hardly allow for any oxidation hence an influence on rate of leaching was only slight. But during the winter after the warm summer of 1947 the meanwhile oxidized S promoted leaching as could be expected from a comparable (high) dressing of gypsum.

Table 2.

Relative salt content of topmost 40 cm in 1947.
(mean values of 7 experimental fields)

Treatment		No gypsum	12 tons of gypsum applied in	
			autumn 1945.	autumn 1946.
Relative salt content	Spring	100	48	75
	Autumn	141[1]	83	125

[1] This corresponded with 0.55 g NaCl per kg of dry soil, being too much for sensitive crops.

Due to the low salt values water passage could not be computed accurately for the second winter, but during the first one, water passage for the zeroplot, the $CaSO_4$-, the $CaCl_2$-, the $Ca(OH)_2$- and the S-treated plot was respectively 46, 120, 76, 59 and 63 mm.

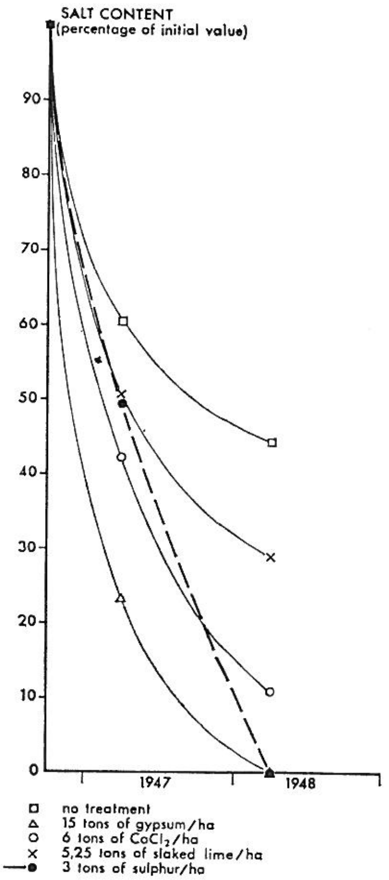

Fig. 2
Lowering of salt content in the topmost 40 cm of plots treated with various amendments (mean values of 2 experimental fields)

Another example of the advantage of a fast leaching due to an early application of gypsum may be cited for the dry summer of 1947. During summer the total salt content in the topmost 40 cm (being the most density rooted part) of the soil increased as a result of the capillary rise of more or less saline water from the subsoil. The more leached the subsoil the lower the increase and the final value of the salt content of the topsoil. The advanced subsoil-desalinisation of the plots treated with gypsum in 1945 (as compared with the 1946-treatment) was reflected in the low salt content of the topsoil (Table 2).

Discussion and conclusion

A good structure of the topsoil being of predominant importance with respect to the leaching of flooded soils, it is a step forward to abandon the former idea of applying gypsum after partial leaching and instead, now to apply gypsum as soon as possible. In practice this means that the first dressing is given before the first leaching period (winter). It is not recommended to give more than 7 tons at once, this being the amount which is solved during a Dutch winter (VAN DER MOLEN [3]). In case the flooded land is drained in spring, a small amount of gypsum is given shortly after reclamation. The effect of an early application of gypsum as compared with a late one depends also upon the distribution of rainfall during the leaching periods. Very equable distribution of rainfall lowers the advantage of an early dressing.

Summary

Never in history flooding with seawater (due to stormfloods or to war action) of low lying Dutch areas was rare. After recession of the seawater and after lowering of the salt content of the soil by leaching, the flooded soils show some typical features of sodic soils (ESP values up to 30, bad structure and in case of repeated floodings sometimes even formation of a textural B-horizon).

The improvement of structure is brought about by large dressings of gypsum. About twenty years ago it was recommended to apply gypsum only after the bulk of the salt had been leached. However, experimental fields showed that decline of structure was prevented easier by application of gypsum on fully salinized soils than on partly leached soils. Moreover leaching efficiency of the precipitation proved to be larger on the early treated plots than on plots which got a late dressing of gypsum.

References

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Выщелачивание засоленных почв в результате применения гипса

Б. ВЕРХОЕВЕН

Почвенный отдел Управления Развития и Заселения Зуйдерзеепольдерс, Кампен, Голландия

Резюме

В ходе истории много раз случалось, что голландские территории, лежащие ниже уровня моря, затоплялись морем (в результате бурь или военных действий). После отхода моря и следующего за этим снижения содержания солей путем промывания почвы, бывшие под затоплением почвы приобретают некоторые характерные для засоленных почв свойства. (Количество обменного натрия до 30%, неблагоприятная структура, а при повторяющемся затоплении и образование оструктуренного горизонта B.)

Улучшение структуры проводится путем внесения большого количества гипса. Около 20 лет тому назад гипс в практике применяли только после промывки основной массы солей. Результаты, полученные на опытных делянках, показали, что легче воспрепятствовать разрушению структуры, если вносить гипс на насыщенных солями, а не на уже частично промытой почве. Кроме того, на делянках, где гипс вносили раньше, выщелачивающее действие осадков также оказалось более действенным, чем там, где гипс вносился позже.