Dr. G. W. HARMSEN

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Dr. G. W. HARMSEN, former Head of the Department of Soil Microbiology, Institute of Soil Fertility, Groningen, the Netherlands, died on June 2, 1981. He was one of the Executive Editors of 'Plant and Soil' from 1957 to 1969.

The son of a merchant, Georg Wilhelm HARMSEN was born in Leningrad, at that time called St. Petersburg, on June 20, 1903. His father was Dutch, although he was born and worked in Russia, and his mother was from the Baltic republic of Latvia. He started secondary education in his native town but did not complete the program because of the outbreak of the Russian Revolution. The family moved to the Netherlands where the young HARMSEN completed secondary school. Thereafter he enrolled at the Agricultural University at Wageningen where he started to study agricultural science with microbiology as his specialization.

He had a good command of the Russian language owing to the fact that he spent the greater part of his youth in Russia; this facilitated his contacts with Russian colleagues and enabled him to read the Russian literature.

After finishing his studies at Wageningen, where he obtained his training in microbiology from Söhngen and Wieringa, HARMSEN moved to the small town of Medemblik on the west coast of the Zuiderzee. The gradual reclamation of part of this inland sea had started there, resulting in the completion of the first big polder, the Wieringermeer (20,000 ha), in 1930. This project had been preceded by the formation of a small experimental polder where soil scientists and agronomists studied various characteristics of the reclaimed soil. As several of the problems they encountered had a microbiological origin, the Research Department of the Zuiderzee Reclamation Authority founded a microbiological laboratory and HARMSEN became the first soil microbiologist of this laboratory.

One of the first major subjects that attracted the attention of the soil scientists, including HARMSEN, was the formation of pyrite (FeS_2), which occurred in moderate amounts in the reclaimed soils. Up to that time pyrite formation had been thought to take place only under strictly anaerobic conditions in deep layers of the water-soaked soils. Extensive analytical work by HARMSEN and his colleagues made it clear that pyrite is (also) produced in young marine formations in the presence of organic residues. In addition to anaerobic conditions required for the microbiological production of hydrogen sulphide from sulphate, oxygen is temporarily required for oxidizing part of the sulphide to sulphur which makes up part of the pyrite.

Much attention was also paid to the oxidation of pyrite in the reclaimed soils. This is an important phenomenon because the resulting sulphuric acid formation leads to acidification of the soil and deterioration of soil fertility. Extreme

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examples of such phenomena are known from estuaries in tropical regions where the conditions for pyrite oxidation are more favourable (higher pyrite contents and higher soil temperatures).

From their experiments, HARMSEN and his colleagues concluded that pyrite oxidation starts with non-biological oxidation of the iron component of the mineral, followed by biological oxidation of the sulphide and sulphur components by *Thiobacillus thiooxidans* as the most important sulphur-oxidizing bacterium. It is now known that pyrite is not oxidized by *T. thiooxidans*, but by *T. ferrooxidans*. In addition to oxidizing reduced S compounds, this organism readily oxidizes ferrous iron. The oxidation of pyrite starts with the biological oxidation of the iron component of the mineral. The S components are oxidized directly by *T. ferrooxidans* or indirectly by ferric ions; the reduced iron is then reoxidized by the bacterium. The existence of *T. ferrooxidans* as a soil organism was unknown when HARMSEN studied pyrite in the Zuiderzee polders. It was impossible, therefore, to decide if the sulphur- and sulphide-oxidizing bacterium, found by HARMSEN in large numbers in the pyrite-containing marine deposits of the Zuiderzee polders, was a representative of *T. thiooxidans* or of *T. ferrooxidans*. It would be interesting to repeat HARMSEN's experiments in order to answer this question. HARMSEN's observation that low pH values favoured the oxidation of pyrite is consistent with the requirement of *T. ferrooxidans* for very low pH values to allow iron oxidation.

A second microbiological topic studied by HARMSEN in his Medemblik laboratory concerned the aerobic decomposition of cellulose in soil. As cellulose is the polymer form in which the majority of plant residues occur, cellulose breakdown by micro-organisms represents one of the most important reactions of the carbon cycle which finally leads to the formation of carbon dioxide and water.

After the methods for counting and isolating cellulolytic micro-organisms had been improved, a survey was made of the various types of these organisms in different soils. Newly reclaimed soils in the Wieringermeer, differing in clay content, were compared with old clay soils and with sandy soils. Large numbers of cellulose-decomposing actinomycetes were counted in the old and new soils. This was particularly true of the autochthonous microflora. Upon the addition of cellulose to the soil, other bacterial types multiplied much more rapidly than the actinomycetes, indicating that their contribution to the breakdown of added cellulose was more important than that of the actinomycetes. In the clay soils, the cellulose decomposers that responded to the added cellulose included nocardias, pseudomonads, cytophagas and myxobacteria of the genus Polyangium. Fungi played a major part in the decomposition of cellulose in marine sandy soil in the polders as well as in old sandy soil. This was particularly true of the old sandy soil which had a low pH and therefore enabled only fungi to develop on the added cellulose. In the marine sandy soil, which had a high pH, fungi also belonged to the dominating cellulose-decomposing micro-organisms. But here, in addition, pseudomonads and actinomycetes responded abundantly to the added cellulose.

In studying isolated cellulolytic micro-organisms, attention was paid to the requirement of these organisms for traces of growth-promoting compounds, apparently vitamins. These compounds were supplied by non-cellulolytic bacteria that utilized the degradation products of cellulose breakdown and thus gave rise to a sort of symbiotic association between the two types of bacteria. In some cases this association led to the formation of mixed colonies from which the two components were separated only with difficulty.

When HARMSEN started these investigations it was decided that the report would serve as a thesis for obtaining a doctoral degree at Wageningen. However, in 1939, when the manuscript was almost completed, World War II broke out so that publication of the thesis and the defence had to be postponed until 1946. The thesis is an extensive publication; unfortunately it was written in Dutch and no separate papers have appeared in an international journal. As a result, the contents of the thesis are largely unknown to most workers dealing with cellulolytic micro-organisms.

The fixation of elementary nitrogen by symbiotic nitrogen fixers was the third important topic of HARMSEN's study of the reclaimed soils of the former Zuiderzee. A number of other aspects of the nitrogen cycle were studied as well. Nodulation of leguminous plants in the reclaimed soils was poor during the first years of cultivation due to the absence of adequate numbers of the various Rhizobium spp. This was particularly true of legumes nodulated by *R. lupini* (lupines and serradella) which hardly formed any nodules. Lucerne and Phaseolus beans were also very poorly nodulated but in clover crops about 20% of the plants were nodulated and in pea, Vicia and Lathyrus plants (nodulated by *R. leguminosarum*) even half of the plants formed nodules. These results showed clearly that various Rhizobium spp. should be introduced into reclaimed soils. An extensive seed inoculation program had to be set up for that reason. Rhizobium strains were selected and large amounts of inoculation material were produced by HARMSEN's laboratory.

The demand for Rhizobium cultures increased considerably when the North-East polder (48,000 ha) was completed. The need to inoculate leguminous crops in these new areas was almost as great as it had been in the Wieringermeer.

When the reclamation of the North-East polder was close to completion, the Zuiderzee Reclamation Authority, together with its research laboratories, was transferred to the town of Kampen at the mouth of the river IJssel near the east coast of the former Zuiderzee. Here the laboratories were ideally situated between the North-East polder and the South-East polder (54,000 ha), reclaimed between 1950 and 1957.

The mineralization of organic soil nitrogen was one aspect of the nitrogen cycle that had attracted HARMSEN's interest for much of his scientific career. Reclamation of young marine soils mostly results in an abundant supply of soil nitrogen so that agricultural crops can give optimum yields with only low or moderate amounts of fertilizer nitrogen. Such a situation will often continue for several years. It is thought to be due to the presence of fresh residues of plants and animals that lived in the partly flooded soil before reclamation.

In contrast to what happened in this more or less normal type of marine soil, far lower amounts of soil nitrogen became available to the agricultural vegetation in the newly reclaimed marine soils of the Zuiderzee polders that were studied by HARMSEN and his colleagues. Relatively large amounts of nitrogen had to be supplied even shortly after reclamation in order to obtain maximum yields. This was thought to be due to (a) the relatively low content of organic matter of these soils, and (b) the resistance of the organic material to microbial breakdown.

In contrast to most marine clays which have been gradually built up and contain more or less young residues of plants and animals, most clay soils of the Zuiderzee polders were formed several thousand years ago. Young sediments, which might have contained younger organic residues, hardly cover the old soils. During their long conservation under the sea bottom, the more readily available components of these residues have probably been removed, leaving resistant humus.

In 1947, HARMSEN emigrated with his family to Canada where he had accepted a position as a microbiologist with the National Research Council in Ottawa. The Canadian period lasted a relatively short time and HARMSEN returned to the Netherlands in 1950. He joined the Koninklijke Nederlandsche Gist en Spiritusfabriek N.V. (now Gist-Brocades) at Delft as a microbiologist. He stayed there less than two years and succeeded Gerretsen when the latter retired as Head of the Microbiological Laboratory of the Institute for Soil Fertility at Groningen in 1952. The work on soil nitrogen, which had been started in the laboratories of the Zuiderzee (now IJsselmeer) polders, was continued and extended during the subsequent period. Methods were developed and applied to estimate the amount of plant-available soil nitrogen. The 'indirect' incubation method, an entirely microbiological method, was applied with some success. This method depends on the estimation of the CO_2 production of the soil sample supplied with an excess of cellulose and incubated under laboratory conditions. The carbon dioxide produced is closely related to the development of cellulolytic micro-organisms which in turn depends on the available nitrogen liberated during the incubation period. Consequently, the CO_2 production is a measure of the mineralization of the soil organic matter.

Another topic studied by HARMSEN and his colleagues of the Institute for Soil Fertility was the mobility and leaching out of nitrate, phenomena that are important to the farmer as well as to the environmentalist.

The Groningen group also isolated many Rhizobium strains from various legumes growing in different regions of the Netherlands. These strains were tested for their efficiency of nitrogen fixation. In the case of *R. trifolii* one strain gave excellent results with all types of clover tested. This strain did especially well on slightly acid soil where all the other strains tested were much inferior. Most of the isolates from nodulated clover plants growing on fertile soils belonged to the strains with high efficiency. This was in contrast to plants from poorly drained acid peat and clay soils where more than one-third of the isolates either had poor efficiency or did not fix nitrogen at all. The variation in efficiency of isolates of lucerne and black medic was less pronounced. Almost all of these isolates were excellent nitrogen fixers; no ineffective strains were detected. The efficiency of *R. leguminosarum* isolated from nodules of pea and vetch plants from different regions varied greatly. In addition to strains with high efficiency, there were many isolates with poor efficiency and ineffective strains were also frequently isolated.

With his retirement on November 1, 1968, HARMSEN entered a new (10-year) period of enthusiastic activity as an ornithologist and a defender of the environment, particularly in connection with the protection of birds. The northern part of the Netherlands including the Wadden islands and the shallow Waddenzee, a region that stretches all along the north-west coast of Germany to Denmark, is one large bird sanctuary. In addition to many birds dwelling there permanently, large numbers of waterfowl from northern and eastern countries winter in that region.

HARMSEN was not only active in the observation of birds during this period, but also played an important role in the functioning of several organizations on nature conservation and bird protection.

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