status of the soils of the Latin American countries, observations to date indicate that sulphur deficiency is likely to be rather widespread, no doubt more so than in the United States. There are at least four reasons for this: first, many of the soils are low in organic matter and much of the sulphur in the surface zone occurs in the organic fraction; second, there is little sulphur in the atmosphere; third, many of the soils are of volcanic origin and contain considerable amounts of allophane and weathered kaolinite which tightly sorb sulphate; and fourth, the total sulphur content of many of the soils is relatively low to begin with.

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RECENT DISSERTATIONS

■ *As an experiment, The Sulphur Institute Journal will publish the titles of recent Doctoral and Masters dissertations in sulphur related fields. Department heads and professors are invited to supply the title, author, etc. of such dissertations for listing.*

"A Theoretical Investigation of the Nature of the Bonding in Sulphur Containing Molecules." Ph.D. David James Miller, Tulane Univ., La.

"Determination of the Optimum Nitrogen-to-Sulfur Ratio Using Plant Protein and Urea as Nitrogen Sources with Organic and Inorganic Sulfur." M.S. Michael John Mehren, La. State Univ. (Jan., 1970).

"Temperature Effects on the Response to Sulphur of Barley (*Hordeum Vulgare* L.), Peas (*Pisum Sativum* L.) and Rape (*Brassica Campestris* L.)." Ph.D. H. M. W. Herath, Univ. of British Columbia (March, 1970).

"Some Factors Affecting the Extraction of Sulphate from Selected Lower Fraser Valley and Vancouver Island Soils." M.S. Aldwyn L. Bart, Univ. of British Columbia (Dec., 1969).

"A Study of the Supply-Demand Relationship of Sulphur in an Autumn Sown, Nitrogen Fertilized Oats Fodder Cropping Program on the Central Tablelands of New South Wales." Ph.D. Graeme John Blair, Univ. of Sydney (Aug., 1969).

SULPHUR DEFICIENCY in the Netherlands

A. E. R. MES AND K. W. SMILDE

■ SULPHUR DEFICIENCY has been reported in various crops in many countries (6). As only few data were available for the Netherlands (1, 3), it was felt necessary to study the sulphur supply of some crop plants grown on soils likely to be deficient in this nutrient.

The aim of the present work was to investigate whether sulphur deficiency does occur on poor sandy soils in the Netherlands and to what extent the sulphur contained in rain water can supply the crop's requirements. In addition, the value of soil and plant analysis in determining the sulphur status of the crops were investigated.

Experimental procedures

In pot experiments 27 Pleistocene sandy soils varying in pH-KCl (3.9-5.4), organic matter (1.2-5.8%) and sulphur (1-22 ppm; extraction in reducing solution according to Johnson and Nishita (4)) were used. The soils were specially selected to avoid correlations between these factors. They were collected at sites not in the neighborhood of industrial and residential areas and where no large quantities of sulphur-containing fertilizers had been applied in preceding years.

Each pot received adequate quantities of N, P, K, Ca, Mg, Cu and B, and half the pots of each soil received sodium sulphate at the equivalent rate of 250 kg S/ha. The pots were placed in a glasshouse and seeded with turnips, which are known to have a high sulphur requirement. The crop was harvested after five weeks. A further dressing of N, P, K, Ca, Mg and Mo was given to each pot, and a second crop of turnips seeded. No further sulphur was added to any of the pots.

In the following year, the soils in the pots were cropped with spring wheat. Again, all the pots received

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a dressing of N, P, K, Ca, Cu, B and Mo, but no sulphur. Half the pots were placed in a glasshouse, and the other in an outside cage, not protected from rainfall. Analysis of the rain water indicated that each pot received the equivalent of 10.5 kg S/ha from this source during the growing period.

The yield of each crop was determined, and the leaves analyzed for total N, NO_3-N, total S and SO_4-S. Soil samples were taken before sowing the second crop of turnips and the wheat crop, and water soluble sulphur determined, using a procedure similar to that developed by Sissingh (5) for water soluble phosphorus.

Results and discussion

In the first crop of turnips sulphur deficiency appeared on most of the minus-sulphur pots about one month after sowing. Leaves turned pale green to yellow, standing somewhat erect. Young leaves were small and stiff, the edges curling upwards. In severe cases petioles and veins turned purple. The symptoms resembled those of severe nitrogen deficiency. The severity of the symptoms was related to the soil sulphur content (4), very severe symptoms occurring at less than 5 ppm S. Yellowing and growth inhibition were less marked at concentrations up to 12 ppm S and at higher levels sulphur deficiency symptoms could hardly be distinguished if at all.

For each soil the yield was expressed as a percentage of the yield obtained with sulphur, and plotted against the soil sulphur content (Figure 1). On soils with less than 16 ppm S yield reductions of up to 30% occurred if no sulphur was added.

In the second crop of turnips sulphur deficiency symptoms developed at an earlier stage and were more serious than in the first crop. Even on soils originally rather high in sulphur there was a marked response to this nutrient. This can be attributed to depletion of the sulphur supply by the first crop.

Losses in leaf dry matter yields of up to 50% occurred if no sulphur was applied (Figure 2). Even on some soils where the first crop did not respond to this nutrient a distinct effect was noticed. The minimum sufficiency level appeared to be about 16 γ water-soluble sulphur per cm^3 of soil.

Although root dry weights were low because of the high plant density, they also showed a marked response to sulphur. Without sulphur roots were thin and had many root hairs. In some plants a typical blue discoloration in the transitional zone between root and petioles was apparent, in contrast with the violet color in healthy plants.

Spring wheat grown in the glasshouse showed the first signs of sulphur deficiency about one month after sowing. Growth was somewhat restricted and leaves were paler and smaller than normal, sometimes showing interveinal chlorosis. In the cage (no protection from rain water) growth was more profuse and plant color was darker than in the glasshouse. Sulphur deficiency

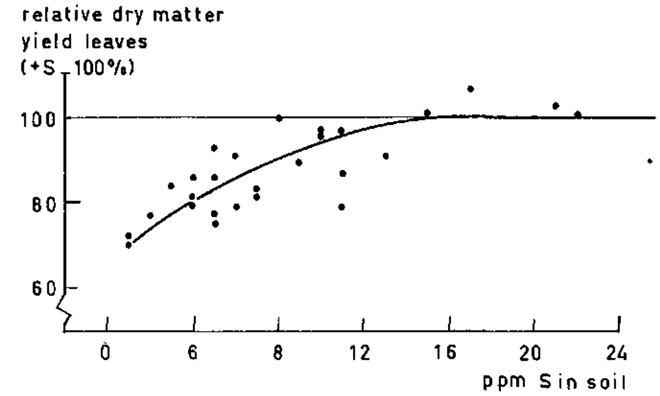

Fig. 1 Effect of soil sulphur on relative dry-matter yields of turnip leaves (first crop) grown in glasshouse (4).

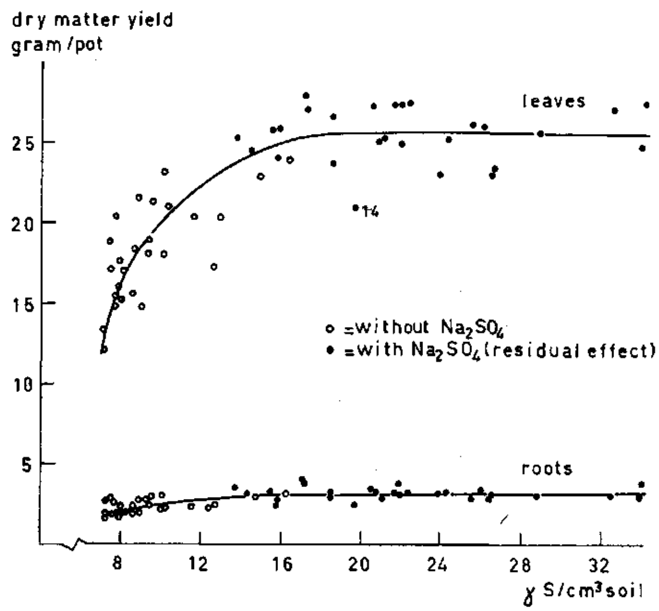

Fig. 2 Effect of water-soluble soil sulphur on leaf and root dry-matter yields of turnips (second crop) in a glasshouse.

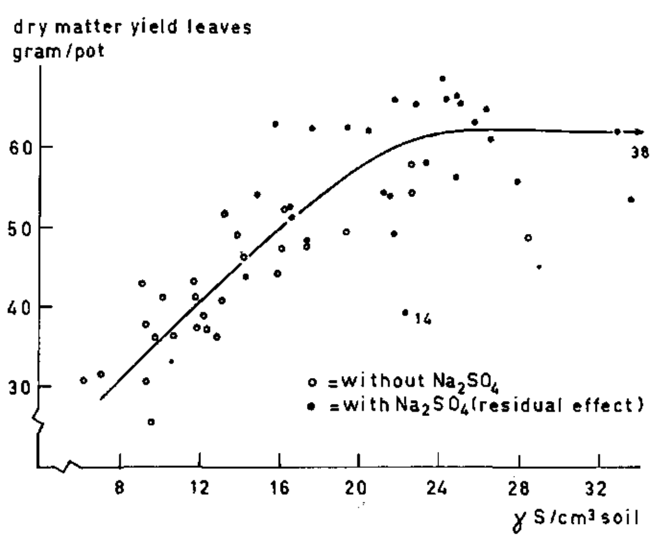

Fig. 3 Effect of water-soluble soil sulphur on leaf dry-matter yields of spring wheat grown in glasshouse.

symptoms did not appear until two months after sowing and were less severe than in the glasshouse. The difference in visible response to sulphur between plants growing in these different environments increased with time.

The effect of sulphur deficiency on leaf dry matter yields is shown in Figure 3. In the glasshouse severe losses occurred on all untreated and most of the treated soils. In the cage, yield depressions resulting from sulphur deficiency were smaller and were restricted to some of the soils not supplied with sodium sulphate (Figure 4). Minimum water-soluble soil sulphur sufficiency levels of about 22 and 14 γ S/cm³ were found for glasshouse and cage respectively. Apparently, the unfavorable effect of a low soil-sulphur status is partly offset by sulphur addition via the rain water. It is not known to which extent sub-optimum soil sulphur levels lead to yield depressions under field conditions. Considering the results obtained in the open cage, sulphur deficiency under field conditions in remote areas cannot be excluded although they may remain unnoticed because of lack of visual deficiency symptoms.

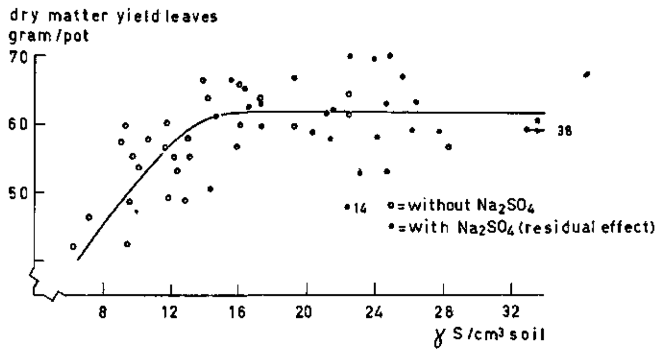

Fig. 4 Effect of water-soluble soil sulphur on leaf dry-matter yields of spring wheat grown in open cage.

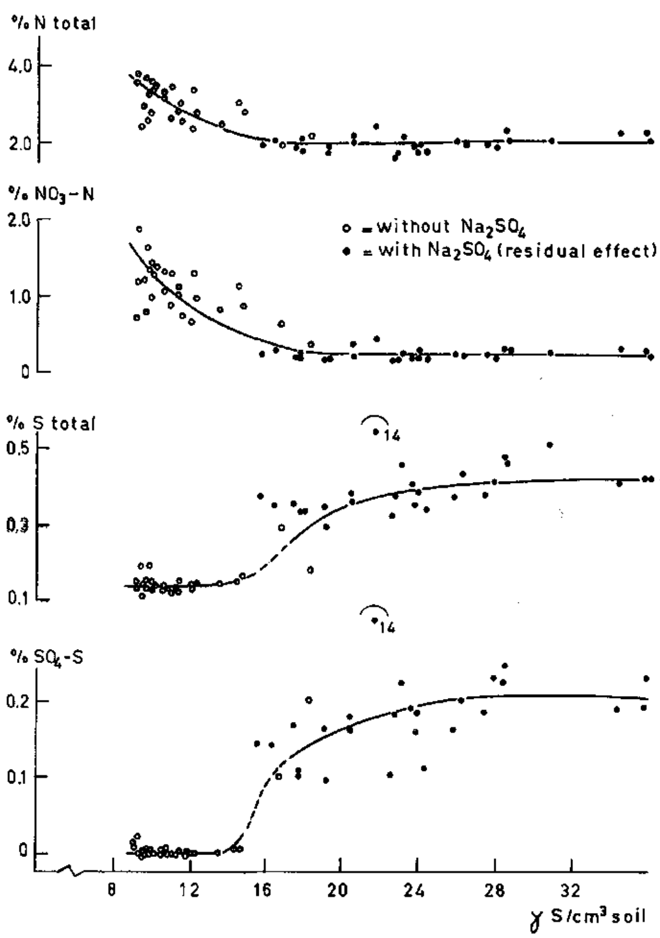

Fig. 5 Relationship between water-soluble soil sulphur and total N, NO_3-N, total S and SO_4-S in turnip leaves.

Leaf total N, NO_3-N, total S and SO_4-S for the second crop of turnips is shown in Figure 5. The data for the other crops were very similar. Leaf total and nitrate-nitrogen decreased with an increase in water-soluble soil sulphur, but at levels higher than about 16 γ S/cm³ there was no further effect. The trends in leaf total and nitrate-nitrogen are opposite to those in dry matter production (Figure 2) and, therefore, can largely be ascribed to dilution. In soils with less than 12 γ S/cm³ leaf total and sulphate-sulphur did not attain values higher than 0.15 and 0.02% respectively. This was followed by a steep rise, especially for sulphate, in the range 12 to 16 γ S/cm³ whereby concentrations of about 0.3 and 0.10% were reached for leaf total and sulphate-sulphur respectively. The latter may represent sufficiency levels. According to Walker and Bentley (7), quoted by Dijkshoorn and Van Wijk (2), various plant crops responding to sulphur contained less than 0.006 g atoms of sulphate-sulphur (0.02% SO_4-S) in leaf dry matter. These data are in accordance with the results found in the present study.

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