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SULPHUR FERTILIZATION EXPERIMENTS ON DUTCH SANDY SOILS

door

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INTRODUCTION

In the fertilization of arable crops sulphur has received less attention than magnesium or calcium, although many crops need almost equal amounts of these elements. In the past, much sulphur was applied as a constituent or contaminant in single fertilizers (e.g. superphosphate), insecticides, fungicides and manure. During the last decade the use of compound fertilizers increased and the use of S-containing fungicides etc. decreased. Moreover natural gas replaced oil and coal as the chief source of energy; natural gas contains less sulphur. These developments made it desirable to investigate the need of arable crops for fertilization with sulphur under the present Dutch conditions.

In 1966 a study of the sulphur requirement was started by mr. A.E.R. Mes and his assistant L. van der Veen. The first experiment, a pot trial with 27 soils conducted in a glasshouse, showed that sulphur deficiency could result in a decrease in yield of 30% in turnips (Mes and Smilde, 1970). In the following years a number of experiments was conducted to test the sulphur requirement under field conditions.

Moreover, it was deemed useful to collect data on the S-content of fertilizers and of rain water and to determine their contribution to the sulphur supply. Such data could serve to predict the incidence of S-deficiency in the future.

2. MATERIALS AND METHODS

The experiments comprised twelve field experiments (see Appendix A) and one box-plot trial (designated as VP 970, see Appendix A). The latter consisted of outdoor dug-in 1 m^3 concrete containers with open bottoms. Soil from a selected site was placed into the boxes in its natural sequence of horizons. The cultivated crops were: potatoes (6 ×), sugar beets (7 ×), cereals (5 ×), turnips (4 ×) and grass (1 cut). Fertilization with S was varied; the other fertilizers were S-free.

The sulphur status of the soil was determined according to the S-water 1:10 method of Sissingh. It is a modification of the Johnson and Nishita method (1952). A quantity of 7.8 gram soil is moistened with 8 ml water and left standing during 22 hours. Then 70 ml water is added; the mixture is then shaken for half an hour at 30 rotations per minute and filtered. Of the filtrate 10 ml is pipetted into flasks and evaporated to dryness. Following addition of 2 ml water the sample is treated according to the method of Johnson and Nishita. Evaporation to dryness was necessary because of the very low concentration of the filtrate.

To get an impression of the sulphur content of rain water in the Netherlands as affected by various locations, four sites were selected: Haren, at the site of the Institute for Soil Fertility situated 3 km south of an electric power station; Ede, in a more or less industrialized area; Laren (Gld.), in a rural area; Uithuizen, near the Wadden Sea. During three years samples were taken from rain water accumulated in periods of about one month and analysed for sulphur. In addition, samples were collected during the growing season at a number of experimental fields.

3. RESULTS

3.1. Experiments

Details of the experiments, such as soil characteristics, treatments, yield, S-content crop, etc., have been tabulated in Appendix A.

3.1.1. Yield

Only in the case of experiment VP 970, conducted on a soil with an initial S-content of 2.7 mg S per litre of soil, was there an obvious response to applied sulphur in potatoes, sugar beets and spring barley. The other trials showed no response or only a small positive one. On the basis of the results of the preliminary pot trial VP 804 with wheat and turnips, a positive result could have been expected in most of these experiments. It would appear, therefore, that the sulphur contained in rain water completely or largely prevented any incipient deficiency.

3.1.2. Plant composition

Foliage. The figures show that the S-total and S-SO_4 concentrations of potato, sugar beet and turnip leaves were increased by a sulphur application. S-organic (S-total minus S-SO_4) remained rather constant. N-total, N-NO_3 and N-organic concentrations were hardly influenced by application of sulphur. N-fertilization increased S-total and even more so N-total, but N-NO_3 and S-SO_4 were hardly affected.
Straw. Only N-total was positively correlated with applied nitrogen but S-total was not. Applied sulphur hardly affected S- and N-concentrations.
Beet, tuber, grain. S-total in potato tubers and beet roots was increased by applied sulphur, but the effect on N-total was variable. Applied nitrogen increased the N-concentration of tubers and beet roots but S-concentration remained constant. Applied sulphur was found to have no effect on S- and N-concentrations of turnip roots and cereal grains. Applied nitrogen strongly raised N- and also increased S-concentration in most cases.

3.2. Sulphur in rain water

Samples of rain water were taken at a number of trial fields during the growing season, and at four other locations during the whole year. Here the results of the four locations will be described (see Appendix B and figures 1-5). Table I shows clearly the influence of location on annual amount of sulphur contained in precipitation.

TABLE I. Average amount of S in rainfall.

Location		kg S per ha per year
Haren	at the Inst. for Soil Fertility and south of electric power station	= 86
Ede	more or less industrialized area	= 27
Laren	rural area	= 20 à 25
Uithuizen	near the Wadden Sea	= 29

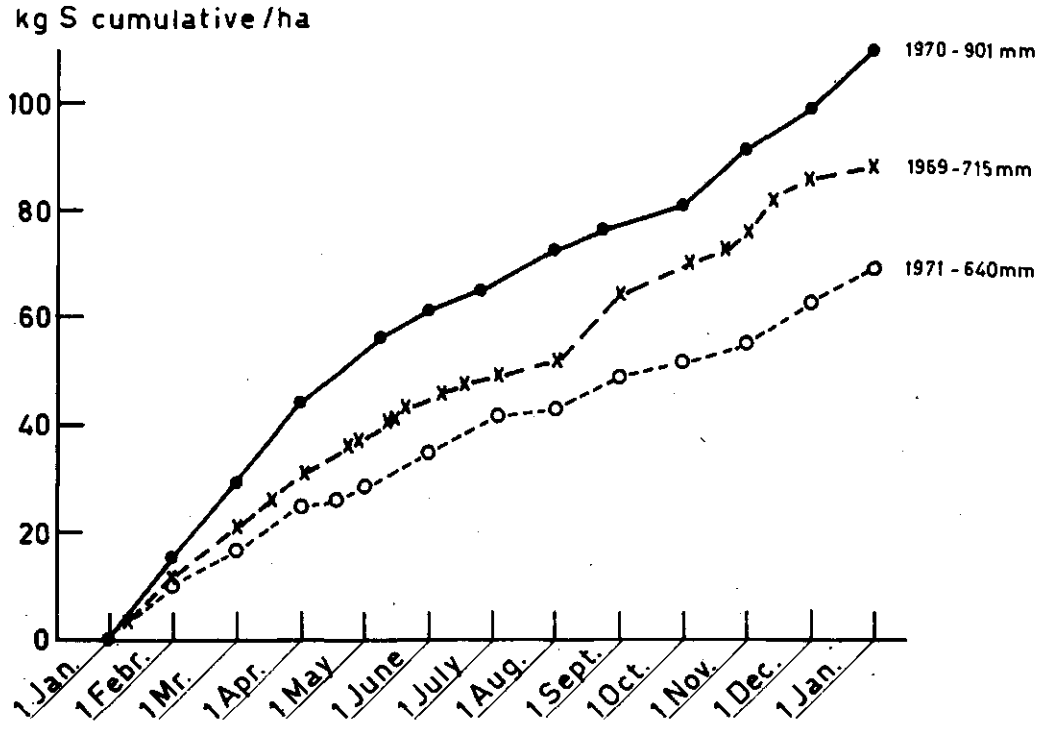

Fig. 1. The cumulative amount of S from precipitation during three different years at HAREN.

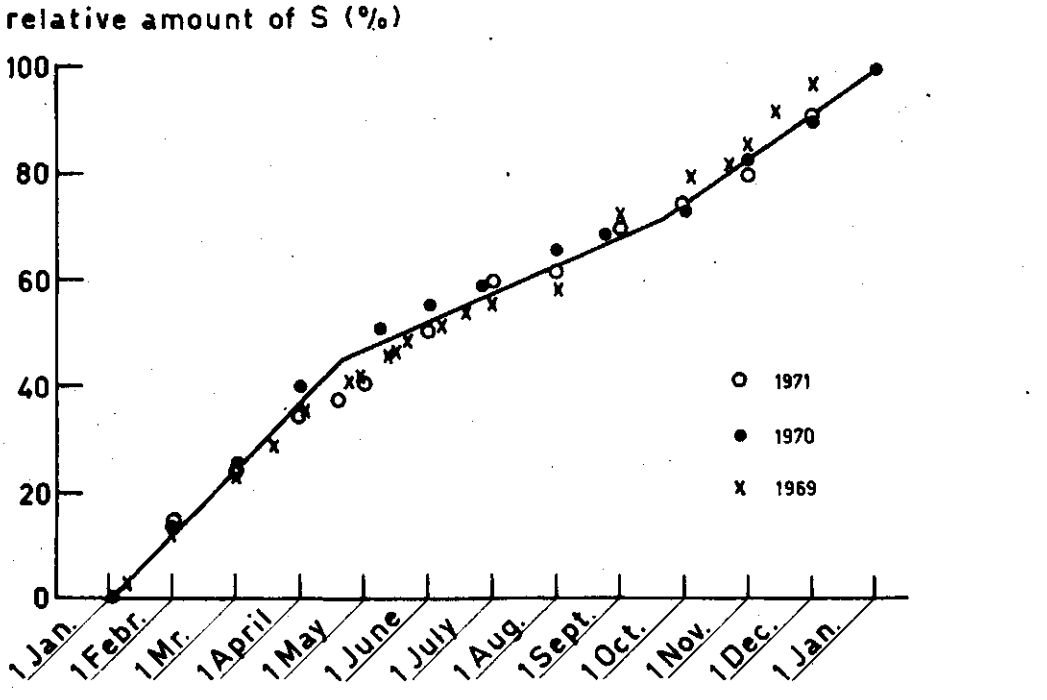

Fig. 2. The distribution of S in precipitation over the year at HAREN.

The total amount of S from rainfall at Haren was about three to four times greater than at the other locations. Figures 1 and 2 illustrate the uneven distribution of S in rain at Haren, whereas the other locations show an even distribution over the year (figures 3-5). The uneven distribution at Haren is most probably caused by an increased fuel and gas consumption in winter of the electric power station and the central heating of the Institute. In figure 2 the slope of the line is less steep during the months May-October than during the period October-April. During the summer the S-content in rain water averaged 6 mg S per litre. During October-December the content was about 11 and in January-April 20 mg S per litre. So with the normal yearly rainfall at Haren of 360+210+205 mm in the three periods mentioned, an annual amount of 22+23+41= 86 kg S per ha can be expected. Ede and Uithuizen showed an even distribution over the year and a concentration of 3.6 and 3.9 mg S per litre, respectively. This amounts to a quantity of 27 and 29 kg S per ha per year at a normal level of precipitation of 740 mm. The results of Laren require some comment. During most of the observation time an average content of 2.7 mg S per litre was found, but in autumn 1969 and spring 1971 there was an increase to 8 to 9 mg S per litre. The samples of autumn 1969 were analysed as a separate series but those of spring 1971 were run together with others which had given normal results. Based on the content of 2.7 mg S per litre an annual amount of 20 kg S per ha can be expected at Laren in a rural area. If all analyses are taken into account, a figure of 25 kg S would be obtained.

3.3. Sulphur in fertilizers

It is rather difficult to get information on the sulphur content of compound fertilizers available on the Dutch market. The S-contents of single fertilizers mentioned in Appendix C are from Mehring and Lundstrom (1938) and Mehring and Bennet (1950) or based on own investigations. Sulphur contents of compound fertilizers vary continually due to the fact that manufacturersadapt their method of processing to prices on the raw material market. Roughly the compound fertilizers can be divided into two groups: the chlorine-containing and low-chlorine (=sulphate rich) fertilizers. The low-chlorine fertilizers contain about 5-10% sulphur. The S-content of chlorine-containing fertilizers is very variable, mostly less than 2%, but when sulphate of ammonia or sulphate of magnesium have been added it may be as high as 10%.

The main component of compound fertilizers is mono- or diammonium phosphate (0% S). To raise the N-content, ammonium nitrate or potassium nitrate (both 0% S) or ammonium suphate (23% S) are added. The K-component is obtained by adding potassium nitrate (0% S), potassium chloride (0% S) or potassium sulphate (18% S). Sometimes also magnesium is added as magnesium sulphate (22% S).

In an average crop rotation, a crop on a sandy soil usually receives per ha: 150 kg N as nitro-chalk, 75 kg P_2O_5 as superphosphate or basic slag and 150 kg K_2O as muriate of potash 40-60%, which means 10-50 kg S per ha. If a compound fertilizer is used, in some cases supplemented with nitro chalk, a crop receives 0-60 kg S per ha.

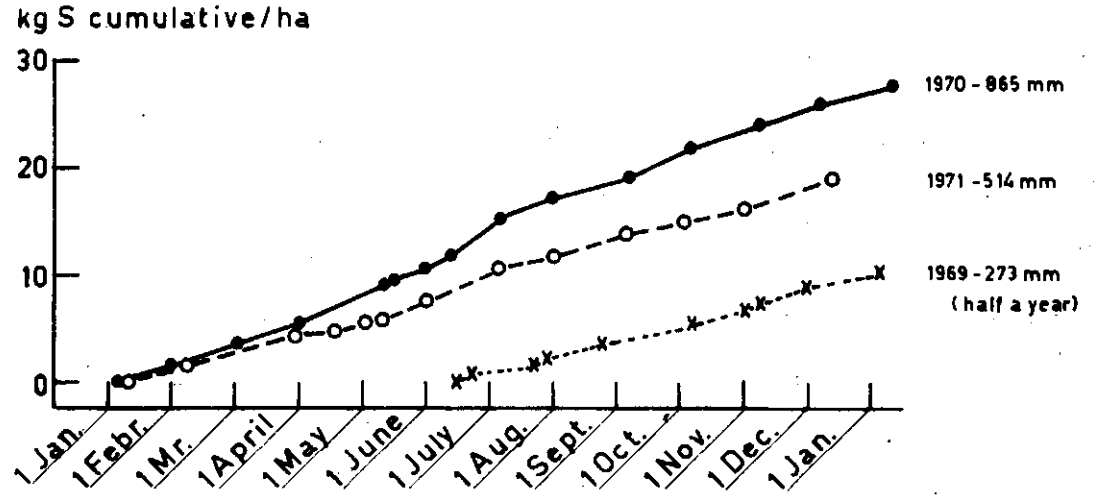

Fig. 3. The cumulative amount of S in precipitation during three different years at EDE.

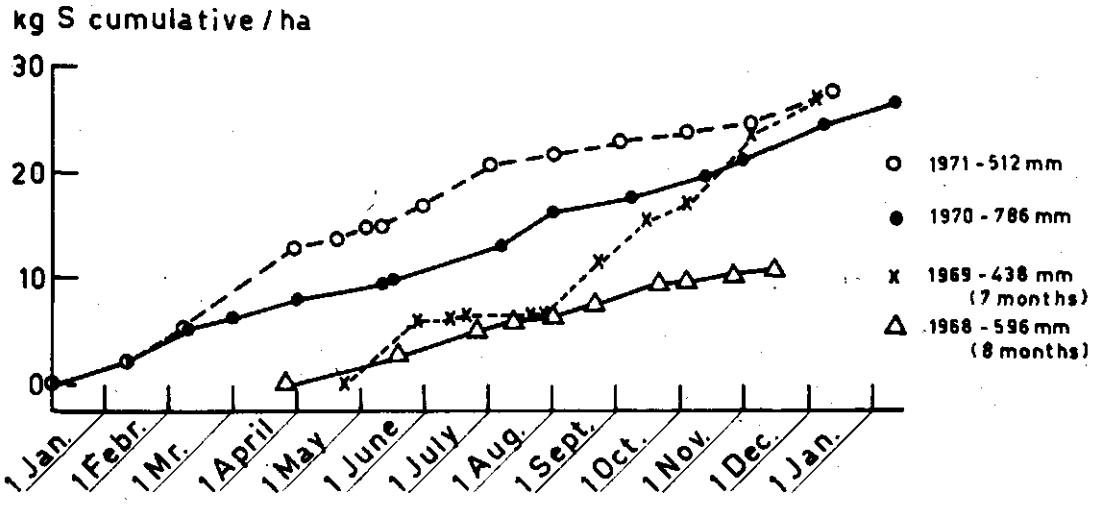

Fig. 4. The cumulative amount of S in precipitation during four different years at LAREN.

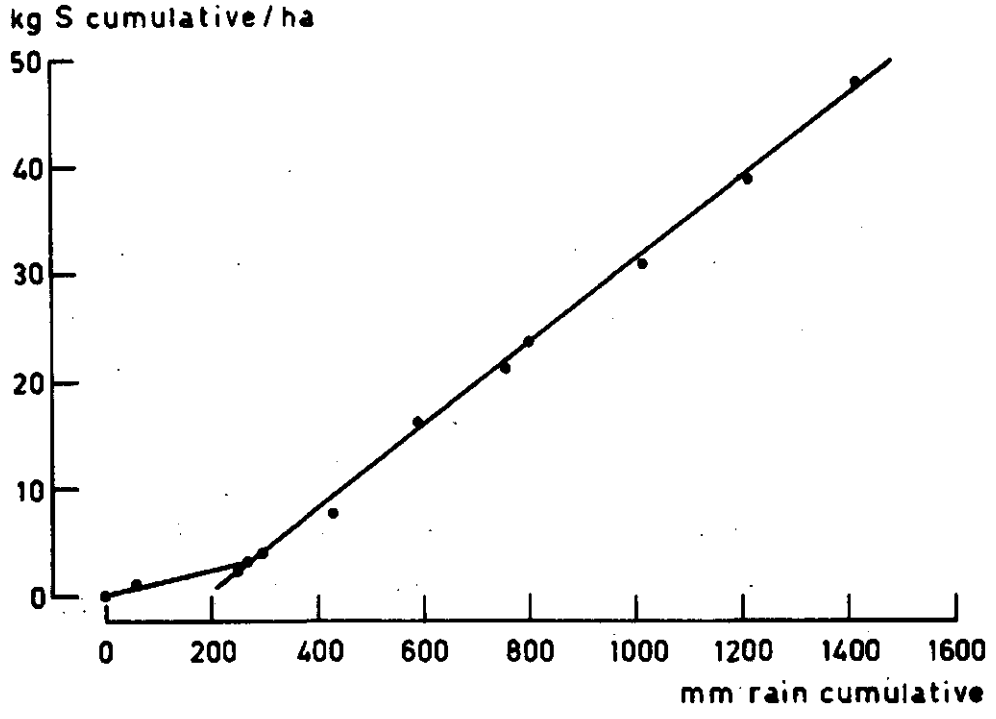

Fig. 5. Relation between amount of S from rain water and rainfall at UITHUIZEN from July '69-Jan '71.

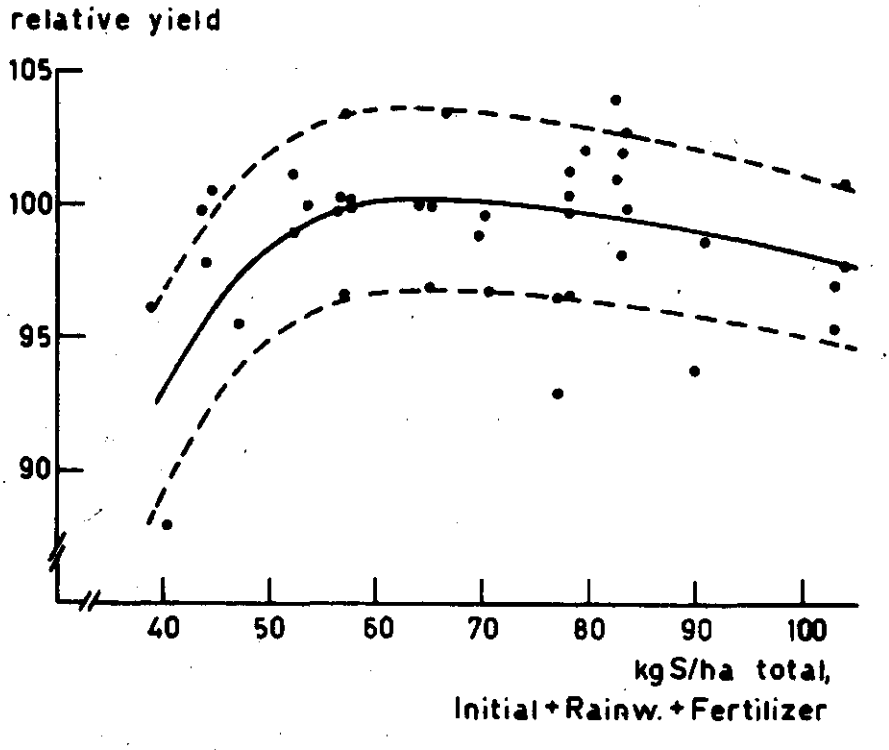

Fig. 6. Relation between yield and S-supply of sugar beets.

4. DISCUSSION

The report by Mes and Smilde (1970) showed that on soils with a very low S-content considerable yield depressions (in turnips up to 30%) may occur when supply of S by rain water is prevented and S-free fertilizers are used. A subsequent pot trial with spring wheat was partly conducted in a glasshouse and partly in an open cage. The minimum soil sulphur levels at which no decrease in yield occurred, was found to be 22 mg S per litre soil (= 20 ppm S) for the pots in the glasshouse and 14 mg S per litre soil (=12 ppm S) for the pots in the cage (exposed to rainfall). The pots in the open cage received the equivalent of 11 or 19 kg S per ha * from rain water during the growing period, which is 6½ or 12 ppm S or the entire difference (8)ppm) between the two minimum sulphur levels. This shows that sulphur from rain water is completely plant-available. According to Carpentier (1974) the sulphur supply by rain water in most cases is lost for the crop and at most contributes to their sulphur nutrition by 5-7 kg S. But it is known, however, that most trials described in literature have been performed in areas with a low sulphur fall-out or with a very high rainfall leading to sulphur leaching. Dutch conditions are different. During the growing period evaporation exeeds precipitation. Therefore the moisture content of the toplayer is at such a level that a shower of 20 mm is completely absorbed. Only rain showers of an intensity of 20 mm per day or more will cause leaching in the growing season. In the period 1964-1974 such showers occurred with a frequency of less than once a month. Thus it may be assumed that the sulphur from rain during the growing season is completely available to the crop.

As an example of the effect of the sulphur supply from rain, the results of the experiments with sugar beets are given in table II. In view of the results of the pot trial, a positive result of sulphur application could be expected in all experiments.

TABLE II. Influence of S in rain water on the calculated optimum S-levels

Trial	S-initial	+	Optimum S application†	= total S at opt. yield	S from rainfall	total S supply at opt. yield initial+applied+rainfall
VP 970	8	+	14	= 22	33	55 kg S per ha
IB 1492	48	+	0	= 48	15.5	63
1493	29	+	13	= 42	15.5††	57
1494	23	+	13	= 36	15.5††	51
1495	27	+	0	= 27	16	43
1496	29	+	0	= 29	16††	45
1497	49	+	0	= 49	16††	65

† Estimated optimum S application after graphic adjustment.
†† Estimated amount of S from rainfall on the basis of region.
S-initial converted from ppm to kg S per ha.

* It is impossible to calculate an exact amount. One method gives 11 kg S, an other 19 kg S per ha.

Table II indicates that the total supply of sulphur at optimum yields shows less variance if the sulphur contained in rainfall is included. Figure 6 presents relative yields of sugar beets i.e. yields relative to that of treatment with total 50-60 kg S per ha.

Table II and figure 6 indicate that if the initial S content of the soil with S in precipitation and optimum S-application added amounts to about 60 kg S per ha optimum yields of sugar beets are obtained. Similar values for other crops are: potatoes 40, turnips 40, cereals 30-40 kg S per ha.

The amount of sulphur in rain water available to crops amounts to 8-15 kg S per ha depending on the length of the growing period, at locations essentially unaffected by industrial emissions. At Haren this quantity amounts to 15-35 kg S per ha per year. It is clear that this amount, added to the normal amount initially present in a soil with an average content of organic matter, is sufficient under most conditions. Only if soils already low in organic matter (=low in initial S-status) are fertilized with fertilizers low in sulphur, does the possibility exist that the sulphur supply will be below optimum. If allowance is made for the average supply of sulphur from fertilizers, about 15 mg S per litre soil, it is obvious that on Dutch sandy soils the sulphur supply of arable crops is sufficient.

5. SUMMARY

In the fertilization of arable crops sulphur has received less attention than other major elements. During the last decades the use of S-containing single fertilizers and other S-sources decreased, and natural gas (low S-content) replaced oil and coal (higher S-content) as the main source of energy. These developments required an investigation into the need for application of sulphur on arable crops under the present Dutch conditions. Twelve field trials, one box-plot trial, and two pot experiments were conducted. In addition, data were collected on the S-content of fertilizers and rain water. The main conclusions are:

(1) An arable crop receives 10-50 kg S per ha through application of single fertilizers or 0-60 kg S per ha through compound fertilizers.

(2) The quantity of sulphur in rainfall during the growing season amounts to 8-15 kg S per ha at locations unaffected by industrial emissions and to 15-35 kg S per ha at locations near industrial emissions.

(3) The sulphur in rain fallen during the growing period is completely available to the crop.

(4) Optimum values for native sulphur in soil, with sulphur in precipitation and optimum sulphur fertilizer application added, are 40 kg S per ha for potatoes and turnips, 30-40 kg S for cereals and 60 kg S for sugar beets.

(5) On soils with an average content of organic matter (= average initial S-content soil) fertilized with common fertilizers, sulphur supply of crops will be sufficient normally.

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APPENDIX A

SURVEY OF THE EXPERIMENTS

The list below indicates test crops and field experiment numbers;
VP 970 is the box-plot experiment at Haren

potato - VP 970, IB 1498, 1499, 1500, IB 1436 (2 ×)
sugar beet - VP 970, IB 1492-1497
cereals - VP 970, IB 1436 (2 ×), IB 1302, IB 1437
turnips - VP 970, IB 1436, IB 1302, IB 1437
grass - IB 1436

All field experiments were located at sites with a yearly supply of 8-15 kg S per ha via the rain water during the growing period. At Haren this sulphur supply amounts to 15-30 kg S per ha.

Some symbols and abbreviations used throughout the text are explained below.

Soil characteristics

pH-KCl extraction in 1 N KCl
organic matter - loss on ignition
P-AL extraction in ammonia-lactate-acetic acid, g P_2O_5 per 100 g soil
K-HCl ,, ,, 0.1 N HCl , mg K_2O per 100 g soil
MgO ,, ,, 0.5 N NaCl, mg MgO per kg soil
S ,, ,, water 1:10, mg S per kg soil

For processing potatoes the so-called under-water-weight (U.W.Wt.) is a quick and cheap method for estimating the content of dry matter and starch. The interrelation is:

U.W.Wt.	350	400	450	500 (unit= g)
starch content	13.4	15.8	18.2	20.6 %
dry matter	18.5	21.0	23.4	25.9 %

"Industrial" weight in kg= kg tubers × $\frac{\text{U.W.Wt.}-100}{300}$. The farmer is paid according to the "industrial" weight.

Potato

(1) VP 970 (1969): box-plot trial, Haren, Institute for Soil Fertility

Soil characteristics : pH-KCl 5.7, organic matter 1.4, P-AL 16, K-HCl 9, MgO 49, S 2.7
Treatments : 0, 6.5, 13, 26, 39 kg S/ha
Observations : Irregular patches in crop, hardly any differences between treatments.
Harvest : 3 September, rather early for processing potatoes.
Sulphur supply by rainfall : May-Sept. 27 kg S per ha (Appendix B)

TABLE 1. Yields (kg/are), under-water-weight (g), industrial weights (kg/are) and N, S contents (% of dry matter) of tubers.

Treatment	yield	u.w.wt.	industr. wt.	N_{total}†	S_{total}†
0	347	453	409	1.76	0.16
6.5	367	461	443	1.57	0.16
13	353	459	423	1.49	0.16
26	377	472	464	1.47	0.19
39	390	467	477	1.55	0.21

† In following tables the abbreviations Nt and St will be used instead of N_{total} and S_{total}.

(2) IB 1498 (1969): field trial at Diffelen

Soil characteristics : pH 5.0, organic matter 2.3, P-AL 50, K-HCl 8, MgO 24, S 4.7
Treatments : 0+0, 0+13, 13+0, 26+0. 26+13, 39+0 kg S/ha first figure: spring application (18 April); second figure: top dressing (29 May)
Observations : Well developed and regular crop, no differences between treatments.
Harvest : 28 August, very early for processing potatoes.
Sulphur supply by rainfall : not determined

TABLE 2. Yields (kg/are), under-water-weights (g) and industrial weights (kg/are).

Treatment	Tubers yield	u.w.wt.	Industr. wt.
0	335	478	420
0+13	371	468	455
13+0	336	466	410
26+0	349	471	432
26+13	331	463	412
39+0	365	468	446

TABLE 3. N, S contents of leaves and tubers (% of dry matter).

Treatm.	19 June, leaves				9 July, leaves				30 July, leaves				28 August, tubers	
	St	$S-SO_4$	Nt	$N-NO_3$	St	$S-SO_4$	Nt	$N-NO_3$	St	$S-SO_4$	Nt	$N-NO_3$	St	Nt
0	0.35	0.09	5.14	0.52	0.38	0.13	4.12	0.39	0.39	0.17	2.70	0.13	0.11	1.18
0+13													0.15	1.26
13+0	0.47	0.22	4.65	0.29	0.47	0.24	3.70	0.13	0.48	0.29	2.63	0.03	0.15	1.22
26+0	0.51	0.23	4.92	0.41	0.51	0.25	4.00	0.30	0.51	0.34	2.89	0.21	0.19	1.21
26+13													0.20	1.23
39+0	0.62	0.34	4.98	0.51	0.52	0.29	3.92	0.20	0.53	0.33	2.90	0.13	0.22	1.40

(3) IB 1499 (1969): field trial at Diffelen

Soil characteristics : pH 5.2, organic matter 3.6, P-AL 39, K-HCl 5, MgO 42, S 4.2

Treatments : 0+0, 0+13, 13+0, 26+0, 26+13, 39 +0 kg S/ha
first figure: spring application (18 April);
second figure: top dressing(30 May).

Observations : A good and rather regular crop. In the first half of August lack of water. No differences between treatments.

Harvest : 18 September

Sulphur supply by rainfall : 10.5 kg S

23 April - 29 May	:	116 mm,	2.0 mg S/l	=	2.3 kg S per ha
29/5 - 18/6	:	58	5.5	=	3.2
18/6 - 30/7	:	58	4.5	=	2.6
30/7 - 27/8	:	79	2.0	=	1.6
27/8 - 15/9	:	41	2.0	=	0.8
			Total		10.5 kg S

TABLE 4. Yields (kg/are), under-water-weights (g), industrial weights (kg/are) and N, S contents (% of dry matter) of tubers.

Treatment	Tubers				
	yield	u.w.wt.	industr. wt.	Nt	St
0	258	474	321	1.59	0.13
0+13	274	475	342	1.52	0.14
13+0	274	471	338	1.54	0.14
26+0	276	474	345	1.52	0.17
26+13	269	472	333	1.53	0.16
39+0	261	465	318	1.66	0.17

(4) IB 1500 (1969): field trial at Bergentheim

Soil characteristics : pH 4.7, organic matter 32, P-AL 72, K-HCl 8, MgO 41, S 4.0

Treatments : 0+0, 0+13, 13+0, 26+0, 26+13, 39+0 kg S/ha
first figure: spring application(22 April);
second figure: top dressing (29 May)

Observations : A good and regular crop. In August lack of water. No differences between treatments.

Harvest : 24 September

Sulphur supply by rainfall : not determined

TABLE 5. Yields (kg/are), under water weights (g), industrial weights (kg/are) and N, S contents (% of dry matter) of tubers.

Treatment	Tubers				
	yield	u.w.wt.	industr.wt.	Nt	St
0	307	485	394	1.45	0.14
0+13	354	488	456	1.42	0.15
13+0	292	491	380	1.44	0.15
26+0	308	488	399	1.41	0.18
26+13	295	491	384	1.48	0.17
39+0	300	485	384	1.49	0.18

(5) IB 1436 (1969): field trial at Laren

Soil characteristics : pH 4.9, organic matter 5.0, P-AL 23, K-HCl 9, MgO 45, S 7
Treatments : 120-160-200-240 kg N and 0-13-26-39 kg S/ha
Observations : The crop (var. Mentor) suffered a little from drought and was somewhat pale in colour. Growth index figures showed a clearly positive effect of N-application but no effect of S-application.
Harvest : 25 August, very early for processing potatoes.
Sulphur supply by rainfall : May-21Aug. = 12 kg S/ha (Appendix B)

TABLE 6. Yields (kg/are), under_water-weights (g) and industrial weights (kg/are) of processing potatoes.

Tubers (kg/are)

N	S				
	0	13	26	39	
120	299	280	294	299	293
160	300	309	291	285	296
200	306	298	296	290	298
240	301	317	302	293	303
	301	301	296	292	

U.W.Wt. (g)

N	S				
	0	13	26	39	
120	422	439	417	433	428
160	413	429	410	417	417
200	421	404	415	419	415
240	415	403	419	410	412
	418	419	415	420	

Industr. weight (kg/are)

N	S				
	0	13	26	39	
120	321	316	310	331	320
160	313	339	301	300	313
200	327	302	311	308	312
240	316	320	320	302	314
	319	319	311	310	

TABLE 7. N, S contents of leaves and tubers (% of dry matter)

Treatm.	19 June, leaves				9 July, leaves				30 July, leaves				25 August, tubers	
	St	$S-SO_4$	Nt	$N-NO_3$	St	$S-SO_4$	Nt	$N-NO_3$	St	$S-SO_4$	Nt	$N-NO_3$	St	$S-SO_4$
N 120	0.39	0.12	5.20	0.73	0.44	0.17	4.07	0.48	0.52	0.32	2.37	0.45	0.16	1.63
160	0.37	0.11	5.45	0.91	0.42	0.13	4.52	0.74	0.44	0.22	2.87	0.74	0.16	1.84
200	0.36	0.06	5.54	0.92	0.39	0.10	4.74	0.87	0.38	0.14	3.26	1.05	0.15	1.96
240	0.36	0.10	5.46	0.98	0.37	0.11	4.87	1.00	0.34	0.13	3.53	1.30	0.17	1.95
S 0	0.35	0.11	5.42	0.88	0.38	0.12	4.52	0.79	0.36	0.14	3.08	0.95	0.16	1.89
13	0.38	0.08	5.41	0.82	0.39	0.13	4.50	0.77	0.41	0.20	2.96	0.86	0.16	1.80
26	0.38	0.10	5.45	0.96	0.42	0.13	4.58	0.77	0.45	0.23	2.98	0.87	0.16	1.85
39	0.37	0.10	5.38	0.89	0.41	0.13	4.59	0.75	0.47	0.22	3.04	0.87	0.16	1.84

(6) IB 1436 (1971): field trial at Laren

Soil characteristics : pH 4.9, organic matter 5.0, P-AL 23, K-HCl 9, MgO 45, S 7

Treatments : 80-120-160-200 kg N and 0-26-52-78 kg S/ha

Observations : A rather irregular crop. Growth index figures showed a clearly positive effect of N-application. The effect of S-application is very small. Index figures for colour and dying off of the tops showed a similar trend.

Harvest : 7 September, rather early processing potatoes

Suphur supply by rainfall : May-Sept. = 10 kg S/ha (Appendix B)

TABLE 8. Yields, under-water-weights and industrial weights of processing potatoes.

Tubers (kg/are)

N	S				
	0	26	52	78	
80	212	230	222	219	220
120	254	267	256	246	256
160	276	267	262	271	269
200	282	255	270	275	270
	256	254	252	253	

U.W.Wt. (g)

N	S				
	0	26	52	78	
80	440	437	442	449	442
160	434	442	438	450	441
200	430	429	438	430	432
240	410	422	427	436	424
	428	432	436	441	

Industrial weights (kg/are)

N	S				
	0	26	52	78	
80	240	258	252	254	251
120	286	303	288	288	291
160	304	292	295	297	297
200	293	273	294	308	292
	280	281	282	287	

TABLE 9 . N, S contents (% of dry matter) of tubers.

S-total

N	S				
	0	26	52	78	
80	0.08	0.09	0.09	0.09	0.09
120	0.08	0.08	0.08	0.08	0.08
160	0.08	0.10	0.08	0.08	0.09
200	0.09	0.09	0.08	0.09	0.09
	0.08	0.09	0.08	0.08	

N-total

N	S				
	0	26	52	78	
80	1.12	1.05	1.04	1.13	1.08
120	1.19	1.14	1.15	1.17	1.16
160	1.38	1.26	1.24	1.19	1.27
200	1.39	1.30	1.34	1.32	1.34
	1.27	1.19	1.20	1.20	

Sugar Beet

(1) VP 970 (1969): box-plot trial, Haren, Institute for Soil Fertility

Soil characteristics : pH 5.7, organic matter 1.4, P-AL 16, K-HCl 9, MgO 49, S 2.7
Treatments : 0-6.5-13-26-39 kg S/ha
Observations : Very irregular crop; without S there was a somewhat poorer development.
Harvest : 16 October
Sulphur supply by rainfall : May-October = 33 kg S/ha (Appendix B)

TABLE 10. Yields (kg/are) of roots, leaves and sugar

Treatment	Roots	Leaves	% sugar	Sugar
0	360	463	14.4	52
6.5	387	499	14.9	58
13	409	498	14.8	61
26	414	459	15.0	62
39	410	472	15.0	62

TABLE 11. N, S contents (% of dry matter) of leaves and roots at harvest time.

Treatment	Leaves				Roots	
	St	$S-SO_4$	Nt	$N-NO_3$	St	Nt
0	0.38	0.24	2.03	0.06	0.08	0.69
6.5	0.33	0.23	1.86	0.06	0.07	0.70
13	0.34	0.23	1.73	0.04	0.08	0.66
26	0.44	0.31	1.90	0.06	0.07	0.67
39	0.40	0.30	1.87	0.03	0.02	0.69

(2) IB 1492 (1969): field trial at Wilbertsoord

Soil characteristics : pH 5.4, organic matter 5.8, S 19.1
Treatments : 0+0, 0+13, 13+0, 26+0, 26+13, 39+0 kg S/ha
first figure: spring application (16 April);
second figure: top dressing (29 May)
Observations : A well developed crop, but irregular spacing. No differences between treatments
Harvest : 24 October
Sulphur supply by rainfall :

3 July - 24 July	: 38 mm,	2.8 mg S/l	=	1.1 kg S/ha
24/7 - 12/8	: 17	7.7	=	1.3
12/8 - 28/8	: 114	8.7	=	9.9
28/8 - 27/10	: 29	11.0	=	3.2
		Total 3 July-27 Oct.		15.5 kg

TABLE 12. Yields (kg/are) of roots, leaves and sugar.

Treatment	Roots	Leaves	% sugar	Sugar
0	563	454	16.2	91
0+13	523	435	16.8	88
13+0	543	453	16.5	89
26+0	528	482	16.6	88
26+13	513	451	16.4	84
39+0	537	483	16.4	88

TABLE 13. N, S contents (% of dry matter) of leaves and roots at harvest time.

Treatment	Leaves				Roots	
	St	$S-SO_4$	Nt	$N-NO_3$	St	Nt
0	0.35	0.18	2.30	0.03	0.04	0.84
0+13	0.37		2.18		0.04	0.88
13+0	0.32	0.16	2.22	0.03	0.04	0.76
26+0	0.36	0.19	2.38	0.03	0.04	0.76
26+13	0.34		2.02		0.05	0.74
39+0	0.43	0.22	2.24	0.02	0.05	0.76

(3) IB 1493 (1969): field trial at Wilbertsoord

Soil characteristics : pH 4.7, organic matter 3.2, S 10.5
Treatments : 0+0, 0+13, 13+0, 26+0, 26+13, 39+0 kg S/ha
first figure: spring application (16 April)
second figure: top dressing (27 May)
Observations : A good crop, perhaps some lack of water first weeks of August.
Harvest : 30 October
Sulphur supply by rainfall : not determined

TABLE 14. Yields (kg/are) of roots, leaves and sugar.

Treatment	Roots	Leaves	% sugar	Sugar
0	519	419	16.9	88
0+13	554	418	17.3	96
13+0	518	411	16.9	88
26+0	534	439	16.8	90
26+13	526	443	17.1	90
39+0	547	449	17.1	94

TABLE 15. N, S contents (% of dry matter) of leaves and roots at harvest time.

Treatment	Leaves				Roots	
	St	$S\text{-}SO_4$	Nt	$N\text{-}NO_3$	St	Nt
0	0.29	0.16	2.25	0.04	0.04	0.96
0+13	0.22		2.28		0.05	0.83
13+0	0.31	0.15	2.37	0.06	0.06	0.92
26+0	0.33	0.19	2.28	0.06	0.05	0.97
26+13	0.35		2.36		0.05	0.82
39+0	0.34	0.20	2.44	0.05	0.05	0.81

(4) IB 1494 (1969): field trial at Wilbertsoord

Soil characteristics : pH 5.5, organic matter 6.1, S 9.4
Treatments : 0+0, 0+13, 13+0, 26+0, 26+13, 39+0 kg S/ha
first figure: spring application (14 April);
second figure: top dressing (27 May)
Observations : A good crop, somewhat irregular. A slight positive effect of S at the end of the growing period.
Harvest : 23 October
Sulphur supply by rainfall : not determined

TABLE 16. Yields (kg/are) of roots, leaves and sugar.

Treatment	Roots	Leaves	% sugar	Sugar
0	600	411	17.6	106
0+13	614	434	17.9	110
13+0	628	425	17.4	109
26+0	601	414	17.4	105
26+13	623	433	17.8	111
39+0	616	435	17.5	108

TABLE 17. N, S contents (% of dry matter) of leaves and roots at harvest time.

Treatment	Leaves				Roots	
	St	$S-SO_4$	Nt	$N-NO_3$	St	Nt
0	0.32	0.26	1.90	0.03	0.06	1.06
0+13	0.31		1.81		0.06	1.22
13+0	0.40	0.31	1.96	0.04	0.05	1.22
26+0	0.31	0.22	1.79	0.03	0.05	1.10
26+13	0.38		1.76		0.06	1.08
39+0	0.38	0.25	1.92	0.03	0.07	0.96

(5) IB (1969): field trial at Wanroy

Soil characteristics : pH 4.0, organic matter 4.4, S 10.5
Treatments : 0+0, 0+13, 13+0, 26+0, 26+13, 39+0 kg S/ha
first figure: spring application (15 April);
second figure: top dressing (27 May)
Observations : A good crop, but irregular spacing. No differences between treatments.
Harvest : 27 October
Sulphur supply by rainfall:

15 April - 21 May	70 mm,	2.0 mg S/l	=	1.4 kg S per ha
21/5 - 3/6	44	8.0	=	3.5
3/6 - 3/7	38	2.8	=	1.1
3/7 - 24/7	35	5.2	=	1.8
24/7 - 12/8	30	6.7	=	2.0
12/8 - 28/8	116	2.0	=	2.3
28/8 - 28/10	38	10.0	=	3.8
		Total		15.9 kg S

TABLE 18. Yields (kg/are) of roots, leaves and sugar.

Treatment	Roots	Leaves	% sugar	Sugar
0	518	343	17.4	90
0+13	534	361	17.8	95
13+0	510	341	17.7	90
26+0	508	350	17.6	90
26+13	525	347	17.3	91
39+0	522	352	17.5	91

TABLE 19. N, S contents (% of dry matter) of leaves and roots at harvest time.

Treatment	Leaves				Roots	
	St	$S-SO_4$	Nt	$N-NO_3$	St	Nt
0	0.34	0.17	2.47	0.05	0.05	0.96
0+13	0.40		2.45		0.05	0.90
13+0	0.43	0.16	2.38	0.05	0.05	0.98
26+0	0.38	0.20	2.42	0.04	0.04	0.92
26+13	0.35		2.41		0.05	0.97
39+0	0.32	0.16	2.54	0.05	0.07	0.96

(6) IB 1496 (1969): field trial at Sint Hubert

Soil characteristics : pH 4.5, organic matter 2.9, S 11.4
Treatments : 0+0, 0+13, 13+0, 26+0, 26+13, 39+0 kg S/ha
first figure: spring application (16 April)
second figure: top dressing (27 May)
Observations : A rather irregular developed crop and irrigular spacing. No differences between treatments.
Harvest : 28 October
Sulphur supply by rainfall : not determined

TABLE 20. Yields (kg/are) of roots, leaves and sugar.

Treatment	Roots	Leaves	% sugar	Sugar
0	557	403	17.1	96
0+13	553	398	17.6	97
13+0	554	405	17.6	98
26+0	535	409	17.3	92
26+13	553	412	17.2	95
39+0	569	433	17.2	98

TABLE 21. N, S contents (% of dry matter) of leaves and roots at harvest time

Treatment	Leaves				Roots	
	St	$S-SO_4$	Nt	$N-NO_3$	St	Nt
0	0.30	0.18	2.18	0.06	0.05	0.98
0+13	0.36		2.42		0.05	0.99
13+0	0.36	0.21	2.35	0.06	0.05	0.96
26+0	0.35	0.21	2.35	0.10	0.05	0.96
26+13	0.38		2.45		0.04	0.96
39+0	0.40	0.25	2.40	0.09	0.05	0.91

(7) IB 1497 (1969): field trial at Mill

Soil characteristics : pH 4.6, organic matter 2.5, S 17.7
Treatments : 0+0, 0+13, 13+0, 26+0, 26+13, 39+0
first figure: spring application (14 April)
second figure: top dressing (27 May)
Observations : A very good and regular crop. No differences between treatments.
Harvest : 29 October
Sulphur supply by rainfall : not determined

TABLE 22. Yields (kg/are) of roots, leaves and sugar.

Treatment	Roots	Leaves	% sugar	Sugar
0	645	382	17.4	112
0+13	623	359	17.3	107
13+0	653	393	17.3	113
26+0	636	387	17.0	108
26+13	651	362	17.5	114
39+0	631	393	17.4	110

TABLE 23. N, S contents (% of dry matter) of leaves and roots at harvest time.

Treatment	Leaves				Roots	
	St	$S-SO_4$	Nt	$N-NO_3$	St	Nt
0	0.42	0.29	2.36	0.04	0.08	0.94
0+13	0.37		2.20		0.05	0.79
13+0	0.41	0.25	2.49	0.05	0.05	0.82
26+0	0.46	0.35	2.48	0.04	0.06	0.89
26+13	0.40		2.50		0.05	0.78
39+0	0.50	0.31	2.43	0.05	0.05	0.80

Cereals

(1) VF 970 (1969): Spring barley; box-plot trial, Haren, Inst. for Soil Fertility

Soil characteristics : pH 5.7, organic matter 1.4, P-AL 16, K-HCl 9, MgO 49, S 2.7
Treatments : 0, 6.5, 13, 26, 39 kg S/ha
Observations : A good and regular crop. No differences
Harvest : 4 August
Sulphur supply by rainfall : May-August = 15 kg S (Appendix B)

TABLE 24. Yields (kg/are) and N, S contents (% of dry matter) at harvest time.

Treatment	Grain	Straw	Grain		Straw	
			St	Nt	St	Nt
0	38.7	49.2	0.18	1.76	0.15	0.58
6.5	40.2	49.9	0.14	1.82	0.16	0.53
13	39.5	48.2	0.15	1.76	0.22	0.40
26	41.5	49.2	0.15	1.78	0.16	0.56
39	38.4	50.5	0.14	1.81	0.18	0.58

(2) IB 1436 (1968): rye; field trial at Laren

Soil characteristics : pH 4.9, organic matter 5.0, P-AL 23, K-HCl 9, MgO 45, S 7
Treatments : 60 and 120 kg N; 0-30-60-90 kg S per ha
Observations : A moderately developed crop. A positive reaction of N-application, no effect of S.
Harvest : 5 August
Sulphur supply by rainfall : 23 March-30 July: 6 kg S per ha (Appendix B).

TABLE 25. Yields (kg/are) of rye.

Grain				Straw			
S	60 N	120 N	Average	S	60 N	120 N	Average
0	24.8	30.8	27.8	0	54.1	55.0	54.6
30	22.9	29.6	26.8	30	45.9	54.5	50.2
60	21.6	33.6	27.6	60	46.4	55.8	51.1
90	24.1	27.9	26.0	90	47.7	54.6	51.2
Average	23.4	30.5		Average	48.5	55.0	

(3) IB 1436 (1970): rye; field trial at Laren

Soil characteristics : pH 4.9, organic matter 5.0, P-AL 23, K-HCl 9, MgO 45, S 7
Treatments : 40-80-120-160 kg N; 0-13-26-39 kg S per ha
Observations : A moderately developed crop showing a distinct and positive response to N (about 80 to 120 kg N is optimum). There is some indication that a S-rate of 13 kg is optimum.
Harvest : 12 August
Sulphur supply by rainfall : January-31 March = 8 kg S per ha
1 April-30 July = 8 kg S per ha

TABLE 26. Yields (kg/are) of rye.

Grain						Straw					
S	N				Average	S	N				Average
	40	80	120	160			40	80	120	160	
0	23.2	25.6	27.5	23.6	25.0	0	41.2	49.8	50.5	51.4	48.2
13	22.8	28.7	22.3	23.6	24.3	13	43.8	53.8	48.2	48.0	48.5
26	23.6	23.6	25.0	25.4	24.4	26	42.7	48.4	51.1	49.3	47.9
39	23.6	25.5	23.2	26.1	24.6	39	42.4	49.5	49.5	49.2	47.6
Average	23.4	25.8	24.5	24.7		Average	42.5	50.4	49.8	49.5	

TABLE 27. N, S contents (% of dry matter) at harvest time.

St in grain

S	N				Average
	40	80	120	160	
0	0.14	0.15	0.14	0.15	0.146
13	0.14	0.15	0.15	0.16	0.150
26	0.12	0.16	0.16	0.20	0.160
39	0.13	0.14	0.15	0.18	0.151
Average	0.13	0.15	0.15	0.17	

Nt in grain

S	N				Average
	40	80	120	160	
0	1.50	1.84	2.23	2.56	2.03
13	1.56	1.74	2.23	2.52	2.01
26	1.60	1.99	2.22	2.34	2.04
39	1.64	1.97	2.21	2.38	2.05
Average	1.57	1.88	2.22	2.45	

St in straw

S	N				Average
	40	80	120	160	
0	0.08	0.08	0.09	0.09	0.09
13	0.11	0.08	0.08	0.10	0.09
26	0.08	0.08	0.09	0.11	0.09
39	0.11	0.09	0.08	0.12	0.10
Average	0.09	0.08	0.08	0.10	

Nt in straw

S	N				Average
	40	80	120	160	
0	0.42	0.39	0.48	0.57	0.46
13	0.37	0.40	0.44	0.62	0.46
26	0.38	0.38	0.54	0.60	0.47
39	0.40	0.42	0.52	0.61	0.49
Average	0.39	0.40	0.50	0.60	

(4) IB 1302 (1968): spring wheat; field trial at Millheeze

Soil characteristics : pH 4.8, organic matter 5.0, P-AL 26, K-HCl 7, MgO 70, S 20
Treatments : 40-80-120-160 kg N; 0-30-60-90 kg S per ha
Observations : A well developed crop, but somewhat irregular. A clear and positive effect of N, but no response to S-application.
Harvest : 27 August
Sulphur supply by rainfall : 18 April-26 August = 5 kg S per ha.

TABLE 28. Yields (kg/are) of spring wheat.

Grain

S	N				Average
	40	80	120	160	
0	33.3	39.3	38.3	36.5	36.9
30	36.2	37.4	39.4	37.2	37.5
60	34.0	35.3	38.4	35.8	35.9
90	34.0	35.8	39.8	36.6	36.6
Average	34.4	37.0	39.0	36.5	

Straw

S	N				Average
	40	80	120	160	
0	37.1	46.2	40.3	44.4	42.0
30	39.2	44.4	44.8	42.4	42.7
60	40.3	38.9	48.2	42.4	42.4
90	38.9	36.9	46.5	42.4	41.1
Average	38.9	41.5	44.9	42.9	

TABLE 29. N, S contents (% of dry matter) of spring wheat.

Treatment		Leaves				Grain	
		17 June		2 July		27 August (harvest time)	
N	S	St	Nt	St	Nt	St	Nt
40	0	0.21	1.59	0.17	1.13	0.16	1.95
40	30	0.21	1.51	0.17	1.06	0.16	1.84
80	0	0.22	1.88	0.22	1.36	0.19	2.04
80	30	0.24	2.00	0.22	1.32	0.18	2.12
120	0	0.25	2.19	0.24	1.60	0.19	2.28
120	30	0.30	2.43	0.26	1.68	0.18	2.29
160	0	0.27	2.41	0.26	1.88	0.19	2.50
160	30	0.31	2.69	0.27	1.82	0.20	2.49

(5) 1437 (1968): small test plots; simple trial at 12 places; crop is rye except no 11 barley

TABLE 30. Soil characteristics and yields.

Site	Soil characteristics				Grain		Straw	
	pH	org. mat.	S †	S ††	0	55 kg S/ha	0	55 kg S/ha
01	5.6	2.2	54	8	36.8	38.2	66.2	64.8
02	4.8	3.9	63	17	37.0	39.2	62.0	60.9
03	4.7	1.7	28	14	36.0	35.7	51.6	51.3
04	5.0	2.9	48	17	30.6	32.3	48.4	50.7
05	4.9	2.7	60	21	35.9	36.1	51.1	49.2
06	4.4	6.3	113	26	37.6	37.7	65.4	68.3
07	4.6	5.1	91	26	34.7	35.3	55.3	57.7
08	5.0	4.4	102	14	40.4	41.4	71.1	69.6
09	5.0	3.6	73	19	33.6	33.2	73.4	71.8
10	5.3	4.1	99	17	33.2	34.5	60.7	67.5
11	4.7	5.0	125	19	40.4	41.2	52.6	55.8
12	4.7	3.7	54	13	36.2	34.3	60.2	58.1
Average					36.0	36.5	59.9	60.5

S † Deviating determination: 0.5 g moistened soil directly in reduction solution of Johnson and Nishita.

S †† Normal determination, samples taken at harvest time from untreated plots.

Turnips

(1) VP 970 (1969): box-plot trial, Haren, Institute for Soil Fertility

Soil characteristics : pH 5.7, organic matter 1.4, P-AL 16, K-HCl 9, MgO 49, S 2.7
Treatments : 0, 6.5, 13, 26, 39 kg S per ha
Observations : A good and regular crop; somewhat spindly plants. No differences between treatments.
Harvest : 10 November
Sulphur supply by rainfall : 23 kg S per ha (Appendix B)

TABLE 31. Yields (kg/are) of turnips.

Treatment	Fresh weight			Dry matter		
	root	leaf	crop	root	leaf	crop
0	107	397	504	8.3	36.6	44.9
6.5	100	399	499	7.3	34.8	42.1
13	93	388	482	7.5	33.9	41.3
26	97	421	518	7.0	37.5	44.5
39	92	393	485	7.3	33.7	41.0

TABLE 32. N, S contents (% of dry matter) of leaves and roots at harvest time.

Treatment	Leaves				Roots			
	St	$S\text{-}SO_4$	Nt	$N\text{-}NO_3$	St	$S\text{-}SO_4$	Nt	$N\text{-}NO_3$
0	0.65	0.37	3.30	0.85	0.59	0.25	2.83	0.56
6.5	0.74	0.43	3.60	0.78	0.69	0.31	3.15	0.55
13	0.74	0.45	3.54	0.90	0.60	0.31	3.02	0.58
26	0.82	0.55	3.82	0.88	0.70	0.32	3.20	0.67
39	0.80	0.56	3.66	0.88	0.64	0.31	2.94	0.62

(2) IB 1436 (1968); field trial at Laren

Soil characteristics : pH 4.9, organic matter 5.0, P-AL 23, K-HCl 9, MgO 45, S 7
Treatments : 40-80-120-160 kg N; 0-30-60-90 kg S per ha
Observations : A normal crop. Particulary the lower rates of N are a bit poorer in developement; no effect of S-application.
Harvest : 14 November
Sulphur supply by rainfall : 20 Aug-14 Nov = 3 kg S per ha

TABLE 33. Yields (kg/are) of turnips.

Leaves					
S	N				Average
	40	80	120	160	
0	122	167	184	212	171
30	120	179	184	215	174
60	115	156	197	207	169
90	119	167	195	200	170
Average	119	167	189	208	

Roots					
S	N				Average
	40	80	120	160	
0	97	89	110	89	99
30	97	101	108	102	102
60	98	103	101	97	100
90	100	91	98	102	98
Average	98	96	104	98	

Total					
S	N				Average
	40	80	120	160	
0	219	257	294	301	268
30	217	279	292	317	276
60	213	259	298	304	269
90	219	258	293	302	268
Average	217	263	294	306	

TABLE 34. N, S contents (% of dry matter) of turnip roots and leaves at harvest time.

Leaves, St

S	N				Average
	40	80	120	160	
0	0.58	0.71	0.68	0.74	0.68
30	0.59	0.67	0.72	0.76	0.68
60	0.64	0.67	0.73	0.81	0.71
90	0.60	0.68	0.74	0.72	0.68
Average	0.60	0.68	0.72	0.76	

Leaves, Nt

S	N				Average
	40	80	120	160	
0	2.24	2.87	2.90	3.28	2.82
30	2.14	2.66	2.88	3.62	2.82
60	2.25	2.62	2.94	3.38	2.80
90	2.34	2.70	3.07	3.09	2.80
Average	2.24	2.71	2.95	3.34	

Roots, St

S	N				Average
	40	80	120	160	
0	0.35	0.42	0.40	0.40	0.39
30	0.33	0.38	0.40	0.46	0.39
60	0.35	0.38	0.42	0.43	0.40
90	0.34	0.40	0.44	0.40	0.40
Average	0.34	0.40	0.41	0.42	

Roots, Nt

S	N				Average
	40	80	120	160	
0	1.20	1.54	1.59	1.44	1.44
30	1.12	1.19	1.25	2.00	1.39
60	1.23	1.33	1.56	1.79	1.48
90	1.12	1.26	1.76	1.51	1.41
Average	1.17	1.33	1.54	1.68	

Leaves, $N\text{-}NO_3$

S	N				Average
	40	80	120	160	
0	0.02	0.07	0.04	0.08	0.05
30	0.01	0.02	0.06	0.32	0.10
60	0.01	0.02	0.04	0.18	0.06
90	0.01	0.06	0.19	0.09	0.09
Average	0.01	0.04	0.08	0.17	

Roots, $N\text{-}NO_3$

S	N				Average
	40	80	120	160	
0	0.01	0.09	0.07	0.10	0.07
30	0.01	0.01	0.03	0.30	0.09
60	0.01	0.02	0.04	0.17	0.06
90	0.00	0.01	0.10	0.08	0.05
Average	0.01	0.03	0.06	0.16	

(3) IB 1302 (1967): field trial at Milheeze

Soil characteristics : pH 4.8, organic matter 5, P-AL 26, K-HCl 7, MgO 70, S 20
Treatments : 0 and 60 kg S; 60-100-140-180 kg N per ha
Observations : A good and regular crop. A notable and positive effect of N; no effect of S-application.
Harvest : 30 November
Sulphur supply by rainfall : not determined

TABLE 35. Yields (kg/are) of turnips.

Leaves

N	S		Average
	0	60	
60	233	224	228
100	261	261	261
140	291	270	280
180	323	339	331
Average	277	274	

Roots

N	S		Average
	0	60	
60	144	198	171
100	212	197	209
140	191	230	210
180	188	167	177
Average	184	198	

Total

N	S		Average
	0	60	
60	376	422	399
100	473	458	466
140	482	499	490
180	512	506	509
Average	461	471	

% Root

N	S		Average
	0	60	
60	45	47	46
100	45	43	44
140	40	46	43
180	37	33	35
Average	41.6	42.3	

TABLE 36. St content (% of dry matter) of leaves and roots during the growing period and harvest time.

Treatment		Leaves					Roots
N	S	5 Oct.	17 Oct.	30 Oct.	13 Nov.	29 Nov.	29 Nov. (harvest time)
60	0	0.65	0.64	0.49	0.47	0.58	0.41
100	0	0.60	0.68	0.53	0.53	0.60	0.43
140	0	0.70	0.64	0.52	0.49	0.62	0.48
180	0	0.64	0.70	0.54	0.54	0.63	0.48
60	60	0.58	0.70	0.55	0.48	0.60	0.41
100	60	0.64	0.73	0.57	0.58	0.62	0.44
140	60	0.64	0.79	0.63	0.62	0.63	0.44
180	60	0.72	0.79	0.63	0.65	0.69	0.52

TABLE 37. N, S contents of leaf and root at harvest time (29 Nov.).

Treatment		Leaves			Roots		
N	S	St	Nt	$N\text{-}NO_3$	St	Nt	$N\text{-}NO_3$
60	0	0.58	2.93	0.11	0.41	1.97	0.23
100	0	0.60	3.09	0.08	0.43	1.95	0.19
140	0	0.62	3.46	0.18	0.48	2.61	0.33
180	0	0.63	3.76	0.40	0.48	2.93	0.53
60	60	0.60	2.78	0.03	0.41	1.58	0.08
100	60	0.62	3.09	0.08	0.44	1.97	0.24
140	60	0.63	3.31	0.20	0.44	2.32	0.34
180	60	0.69	4.16	0.45	0.52	3.23	0.53

(4) IB (1968); small test plots; simple trial at different places

Soil characteristics : see cereals table 30

Treatments : 0+0, 0+60, 55+0, 55+60 kg S per ha
first figure: 0 or 55 kg S applied to rye= after effects
second figure: 0 or 60 kg S applied to turnips, end of September

TABLE 38. Yields (kg/are) of turnips.

Site	Leaf+Root				% Leaf				
	0+0	0+60	55+0	55+60	0+0	0+60	55+0	55+60	kg S/ha
01	309	291	268	288	65	64	58	59	
04	217		201		54		57		
05	340	343	349	345	67	73	68	71	
06	271		271		60		63		
08	397	379	396	381	82	83	80	82	
09	380	401	394	394	76	80	81	77	
10	373		387		70		78		
11	390		365		67		61		
12	375		366		70		70		
13	372	347	352	345	75	72	71	75	
15	400		392		60		67		
Average (11)	348		340		(11)68		68		
Average (5)	360	352	352	351	(5) 73	74	72	73	

Grass

IB 1436 (1971): field trial at Laren

First cut used for seed production. The following cut is sampled for analyses.

Soil characteristics : pH 4.9, organic matter 5, P-AL 23, K-HCl 9, MgO 45, S 7

Treatments : 0-20-40-60 kg S; 0-40-80-120 kg N

Observations : A clear and positive effect of N-rate; no effect of S-application

TABLE 39. N, S contents (% of dry matter) of grass in silage phase.

S-total

N	S				Average
	0	20	40	60	
0	0.21	0.26	0.33	0.48	0.32
40	0.26	0.23	0.22	0.22	0.23
80	0.22	0.23	0.25	0.26	0.24
120	0.24	0.26	0.26	0.29	0.26
Average	0.23	0.24	0.26	0.31	

$S-SO_4$

N	S				Average
	0	20	40	60	
0	0.15	0.15	0.15	0.19	0.16
40	0.07	0.09	0.08	0.09	0.08
80	0.05	0.08	0.08	0.09	0.07
120	0.05	0.06	0.07	0.06	0.06
Average	0.08	0.09	0.09	0.11	

N-total

N	S				Average
	0	20	40	60	
0	1.16	1.16	1.21	1.22	1.19
40	1.62	1.82	1.52	1.70	1.66
80	2.34	2.20	2.09	2.27	2.22
120	2.52	2.94	2.73	2.93	2.78
Average	1.91	2.03	1.89	2.03	

$N-NO_3$

N	S				Average
	0	20	40	60	
0	0.01	0.01	0.01	0.01	0.01
40	0.01	0.03	0.01	0.01	0.015
80	0.06	0.03	0.02	0.03	0.035
120	0.08	0.11	0.12	0.10	0.10
Average	0.04	0.05	0.04	0.04	

APPENDIX B

RAINFALL, S-CONTENT OF RAIN WATER, AMOUNT OF S APPLIED BY RAIN

I Haren, figure 1 and 2

Month	1969			1970			1971		
	rain (mm)	mg S/1	kg S/ha	rain (mm)	mg S/1	kg S/ha	rain (mm)	kg S/1	kg S/ha
Jan	40	21-29†	11.1	24	63	15.3	57	19	10.7
Febr	41.3	23.2	9.6	79	17	13.6	41	14	5.8
March	28	18	5.2	70	22	15.4	26	30	7.8
April	81	10-21	11.1	118	10	11.8	16	25	4.0
May	57	7-16	6.0	19	25	4.9	41	16	6.7
June	99	5-10	5.9	20	22	4.1	115	6	6.5
July	36	7.6	2.7	133	6	7.5	53	3	1.4
Aug	144	8.7	12.5	70	5	3.5	93	6	5.9
Sept	34	17.7	6.1	105	4	4.2	36	7	2.6
Oct	22	16+127††	5.2	114	9	10.6	53	7	3.7
Nov	125	6-10	10.2	101	8	8.1	69	11	7.3
Dec	8	33	2.5	48	23	11.0	40	16	6.6
	715		88	901		110	640		69

† A range indicates that during the month more samples were taken.
†† A light shower of 1.6 mm after a dry period of three weeks.

N.B. in most cases a round value for mm rain and mg S/1 is given.

II Ede, figure 3

1969			
Period	Rain (mm)	mg S/1	kg S/ha
15-22 June	19	3.6	0.7
22/6-21/7	43	2.0	0.9
21/7-27/7	5	8.8	0.5
27/7-24/8	59	2.7	1.6
24/8-6/10	29	6.0	1.8
6/10-2/11	14	7.3	1.0
2/11-9/11	24	3.3	0.8
9/11-30/11	35	3.3	1.2
30/11-5/1	44	4.0	1.8

1970			
Month	Rain (mm)	mg S/1	kg S/ha
Jan	35	4	1.4
Febr	105	2	2.1
March	58	3.3	1.9
April } May	120	3.7-7	5.0
June	98	3-6.3	4.8
July	86	2	1.7
Aug	50	4	2.0
Sept	116	2.3	2.7
Oct	106	2.0	2.1
Nov	75	2.7	2.0
Dec	16	10	1.6
	865		27

Ede, continued

1971

Month	Rain (mm)	mg S/l	kg S/ha
Jan	54	3	1.6
Febr March	71	3.7	2.6
April	22	4.7-7.3	1.2
May	59	3.5	2.0
June	114	2.7	3.0
July	29	4.3	1.2
Aug	48	4.3	2.1
Sept	18	5.7	1.0
Oct	28	3.7	1.0
Nov Dec	71	4.3	3.1
	515		19

III Laren, figure 4

1968

Period	Rain (mm)	mg S/l	kg S/ha
26/3-24/4	13	5.2	0.7
24/4-17/5	56	3.8	2.1
17/5-26/6	99	2.2	2.2
26/6-11/7	45	2.6	1.1
11/7-30/7	43	1.0	0.4
30/7-20/8	65	1.7	1.1
20/8-20/9	108	1.8	2.0
20/9-4/10	91	0?	0.0?
4/10-25/10	41	1.8	0.7
25/10-14/11	35	1.2	0.4

1969

Period	Rain (mm)	mg S/l	kg S/ha
24/4-28/5	72	8.4	6.1
28/5-13/6	50	0	0
13/6-19/6	6	5.2	0.3
19/6-20/7	41	0.4	0.2
20/7-28/7	3	5.6†	0.2
28/7-21/8	73	6.7†	4.9
21/8-15/9	71	6.2†	4.4
15/9-4/10	18	8.7†	1.6
4/10-4/11	56	11.2†	6.3
4/11-4/12	48	7.0†	3.3

† doubtful: see page 9

III Laren, continued

1970			
Period	Rain (mm)	mg S/l	kg S/ha
Jan-10/2	79	6.7	5.3
10-28/2	62	1.7	1.0
March	78	2.0	1.6
April-11/5	98	1.7	1.6
11/5-6/7	66	1.7-8	3.6
6/7-30/7	116	2.7	3.1
Aug	50	2.5	1.2
Sept-12/10	87	2.3	2.0
12/10-31/10	60	3.0	1.8
Nov-7/12	88	3.7	3.2
7/12-11/1	15	15.0	2.2

1971			
Period	Rain (mm)	mg S/l	mg S/ha
7 Dec-11 Jan	15	15.0	2.2
11/1-8/2	59	5.7	3.3
8/2-29/3	62	12.0	7.4
29/3-19/4	4	19.0	0.7
19/4-3/5	21	5.3	1.1
3/5-10/5	2	14.7	0.2
10/5-1/6	45	4.7	2.1
June	119	3.0	3.6
July	31	3.7	1.1
August	61	2.0	1.2
Sept	14	4.7	0.7
Oct	13	6.3	0.8
Nov-13/12	66	4.3	2.9

IV Uithuizen, figure 5

Period	Rain (mm)	mg S/l	kg S/ha
July '69	60	1.6	1.0
Aug	188	0.7	1.3
Sept	20	4.7	1.0
Oct	29	3.3	0.6
Nov	134	2.7	3.6
Dec '69-Febr '70	159	5.3	8.5
March+April	166	3.0	5.0
May+June	41	6.3	2.5
July+August	219	3.3	7.3
Sept+Oct	200	4.0	8.0
Nov '70-Jan '71	206	4.7	9.0

Figure 5 shows that 100 mm of rain contributes 3.9 kg S/ha.
The normal yearly rainfall is about 740 mm, thus a total of 29 kg S per ha per year.

APPENDIX C

SULPHUR CONTENT OF FERTILIZERS (Dutch and American figures)

	Dutch	American
Nitrogen		
nitro-chalk	0	-
nitro-chalk (containing Mg)	4	-
nitrate of lime	0	0.6
chilean nitrate	0.1	0.1
sulphate of ammonia	23	23
Phosphorus		
superphosphate	9-13	11
double super	1.5	1.5
basic slag	1.5	12
rock phosphate	0.6	± 0.5
Potassium		
kainit	ca 4	3-7
muriate of potash		
(20%)	ca 1	3-5
(40%)	ca 2	1.4
(60%)	ca 0.2	0.3
sulphate of potash and magn.	18	-
sulphate of potash	18	17

	Dutch	American
Magnesia		
kieserite	22	26
Epsom salt	12	12
sulphate of potash and magn.	18	-
Lime		
gypsum	19	17
Components of compound fertilizers		
sulphate of ammonia	23	23
phosphate of ammonia	< 1	2.4
nitrate of ammonia	0	0
muriate of potash	< 0.2	0.1
sulphate of potash	18	17
sulphate of magnesia	22	26