Extract from Volume
« World Congress of Agricultural Research »
Rome 1959

THRESHOLD VALUES OF BORON CONTENTS IN DUTCH SOILS IN RELATION TO BORON DEFICIENCY SYMPTOMS IN BEET (HEARTROT) (*)

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In the Netherlands boron deficiency occurs on sandy soils, on which it is fairly widespread, on loess loam soils in the southern province of Limburg and, to a lesser extent, on river clay soils. It is only found sporadically on sea clay soils.

The aim of the present investigation was to correlate the occurrence of boron deficiency in beet (heartrot) with the boron content of the soil, so as to determine a threshold value above which plants are sufficiently provided with this minor element, but below which deficiency symptoms can occasionally be expected. The establishment of such a value would be of importance in giving advice to farmers.

The investigation was carried out in 1955 and 1956, soil samples being collected from diseased and from healthy plots and analysed for available boron. The year 1955 was rather warm and dry, especially in the months of July and August, at which time heartrot occurred very frequently on sandy soils and in many cases in a severe form. In 1956 the weather was less favourable to the disease, being much milder with a fair amount of rain and less sunshine. As a consequence, the number of samples from diseased plots preponderates in our collection of 1955, whereas in 1956 most samples originate from healthy plots.

For the estimation of boron in soils we used Truog's hot-water extraction method (12), followed by determination with curcumin. The exact method of determination will be published elsewhere (**).

(*) This investigation was carried out with the cooperation of the Advisory Services at Horst, Eindhoven, Assen, Oss and Emmen and was partly subsidized by the National Council for Agricultural Research T.N.O.

(**) All analyses were carried out under the direction of Mr. J. Ch. van Wesemael (Plant Nutrition Research Laboratory) to whom we are much obliged for his collaboration.

The 1955 results are presented graphically in Fig. 1. As the possibility had to be taken into account that the threshold value would be affected by pH, the contents of available boron in the soil were plotted against the soil pH (water). Values for diseased plots are indicated in the graph by black dots and those for healthy plots by circles.

Two categories of plots can be distinguished:

(1) those with a boron content below 0.35 p.p.m. In this category 73.4% of the plots were diseased, mainly seriously,

(2) those with a boron content above 0.35 p.p.m. In this category 38% of the plots (11 out of 29 cases investigated) were diseased.

On the basis of these results a threshold value of 0.35 p.p.m. B is very likely. Though cases of boron deficiency occur above this value, their distribution is such that even much higher contents of boron (in the neighbourhood of 1.0 p.p.m.) do not give an absolute guarantee of the absence of deficiency. Other factors may have played a role in its occurrence, for example, a less good water economy of the field in question or differences in potash supply (5).

No influence of pH was detected, but in view of the manner in which the samples were collected this need not be wondered at. We were only concerned

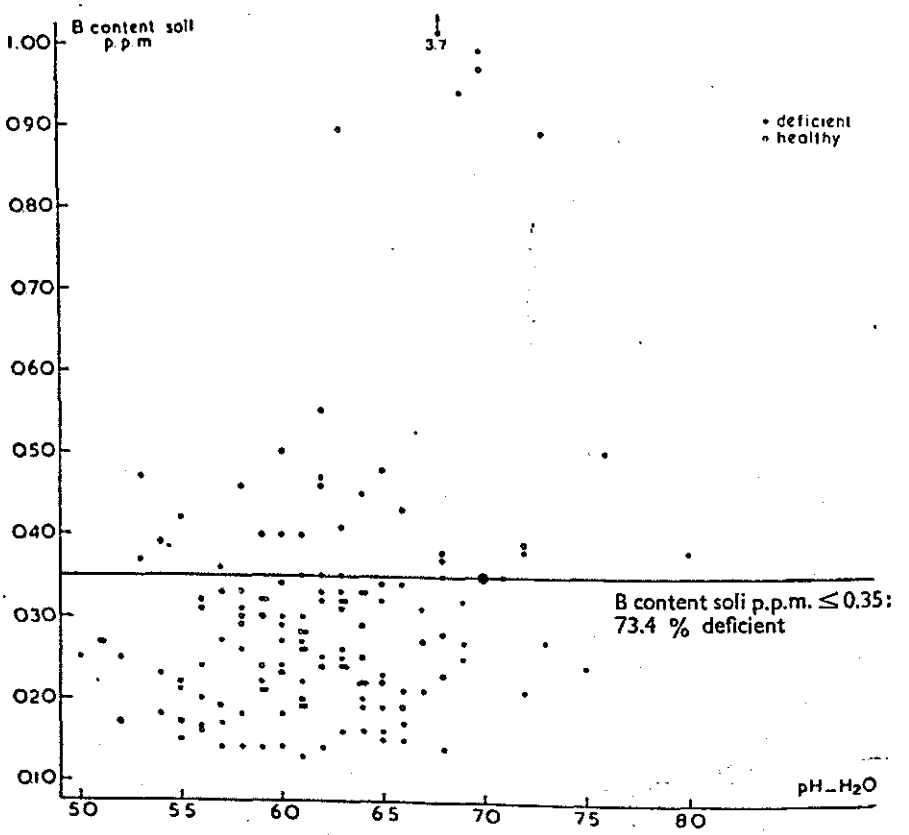

Fig. 1. - Distinction between deficient and healty sandy soils with regard to heartrot in beet in 1955.

with the presence or absence of heartrot and did not take pH as an experimental variable. Treated in this way pH could only appear as a factor if its effect were considerable. Therefore, the fact that no negative influence of pH was found in our material need not mean that the boron economy of the plant could not be influenced by liming.

The 1956 results are shown in Fig. 2. More of the plots are healthy, even at lower boron values, than in 1955, owing to the more favourable weather conditions in 1956. The threshold value for boron deficiency is clearly 0.3 p.p.m.

The two years have thus yielded results which are in close agreement, though they suggest that the threshold value is subject to a certain movement from year to year under the influence of the prevailing weather conditions. In warm, dry years it will be higher and in cool, humid years it can be expected to be lower. As a safe value, which takes unfavourable weather into account, 0.35 p.p.m. B has been adopted provisionally by the State Advisory Service as a desirable minimum for sandy and loamy soils. It may be remarked here that this threshold value is based on the occurrence of visible deficiency symptoms and disregards latent deficiencies and resultant decreases in yield.

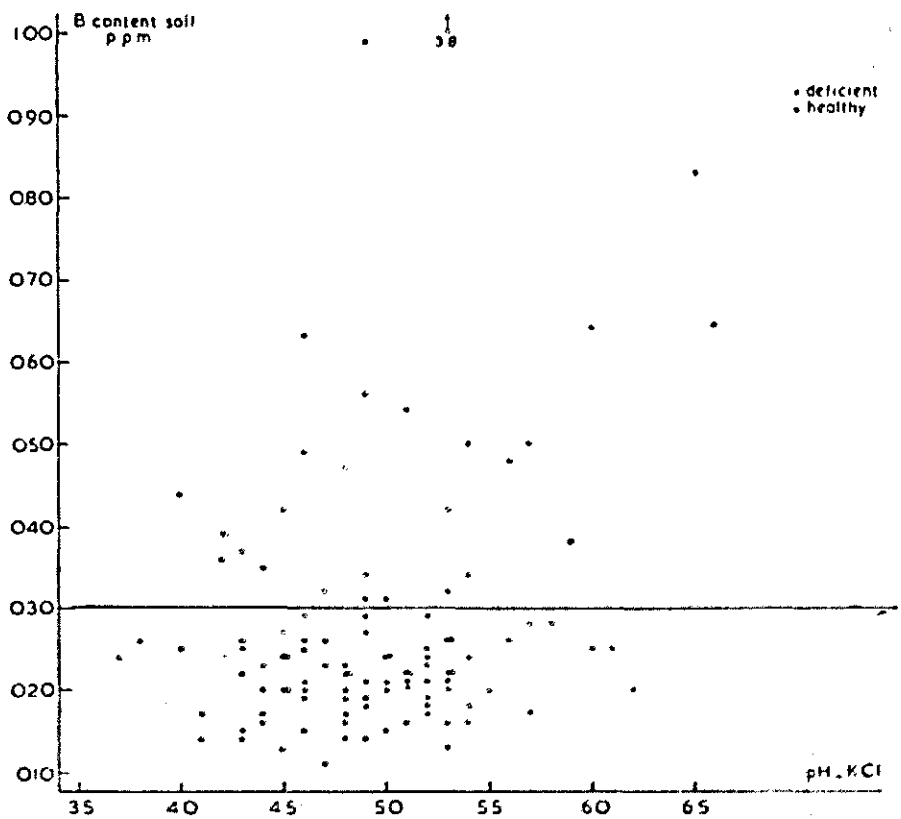

Fig. 2. - Distinction between boron deficient and healthy sandy soils with regard to heartrot in beet in 1956.

The above-mentioned value corresponds well with those determined in other countries, as is apparent from the following data from literature on the subject:

Year	Authors	Crop	Type of soil	Threshold value water-soluble boron (in p.p.m.)
1938	Sokolov (10)	beet, etc.	podzols	0.3
1946	Dawson and Gustafson (2)	alfalfa	light and heavy	0.35
1950	Powers and Jordan (6)	various crops	medium to heavy	(0.5)
1952	Walsh and Golden (13)	beets, swedes, etc.	acid	0.4
			alkaline	0.75
1953	Stinson (11)	alfalfa	heavy	0.5
			sandy	0.3
1954	Schulze Grobleben (8)	sugar beets	— — —	0.25 to 0.3
1954/55	Schachtschabel (7)	beets	light	0.3
			heavy	0.6
1955	Smith and Anderson (9)	swede roots	sandy and loamy	0.7
1957	Bucher (1)	beet, etc.	sandy	0.4
			heavy	0.5

The boron content of samples of healthy and boron-deficient beet plants was also determined, the analysis being by the carmine method. As it was already known that no correlation exists between the boron content of beet roots and their state of health (3) the investigation was limited to the foliage.

The following example shows that the blades of leaves react more sharply to the boron supply in the soil than do the petioles:

BORON CONTENT IN DRY MATTER OF FOLIAGE OF FODDER BEET (in p.p.m.)

Boron applied in nitrogenous fertilization	Variety Barres		Variety Groeningia	
	Leaf blade	Petiole	Leaf blade	Petiole
No boron	22.9	19.9	24.1	19.0
2 kg borax	32.5	25.9	32.8	26.4
4 kg borax	36.5	28.3	41.0	29.3
7 kg borax	38.3	27.5	41.5	29.3
20 kg borax	48.4	30.0	48.0	28.8

In 1957 we carried out six field trials with fodder beet on soils with various boron contents. One was a loess loam containing 0.74 p.p.m. B and the others were sandy soils. Each trial included treatments with ascending doses of boron up to a maximum of 800 g (7.2 kg borax) per ha. The basal dressing was the same for all fields and contained nitrogen in the form of $NaNO_3$.

Samples of leaf blades were collected from intermediate leaf rings of plants of all treatments in the middle of August. Fig. 3 shows the boron content of the leaf for two varieties plotted against the boron content of the soil.

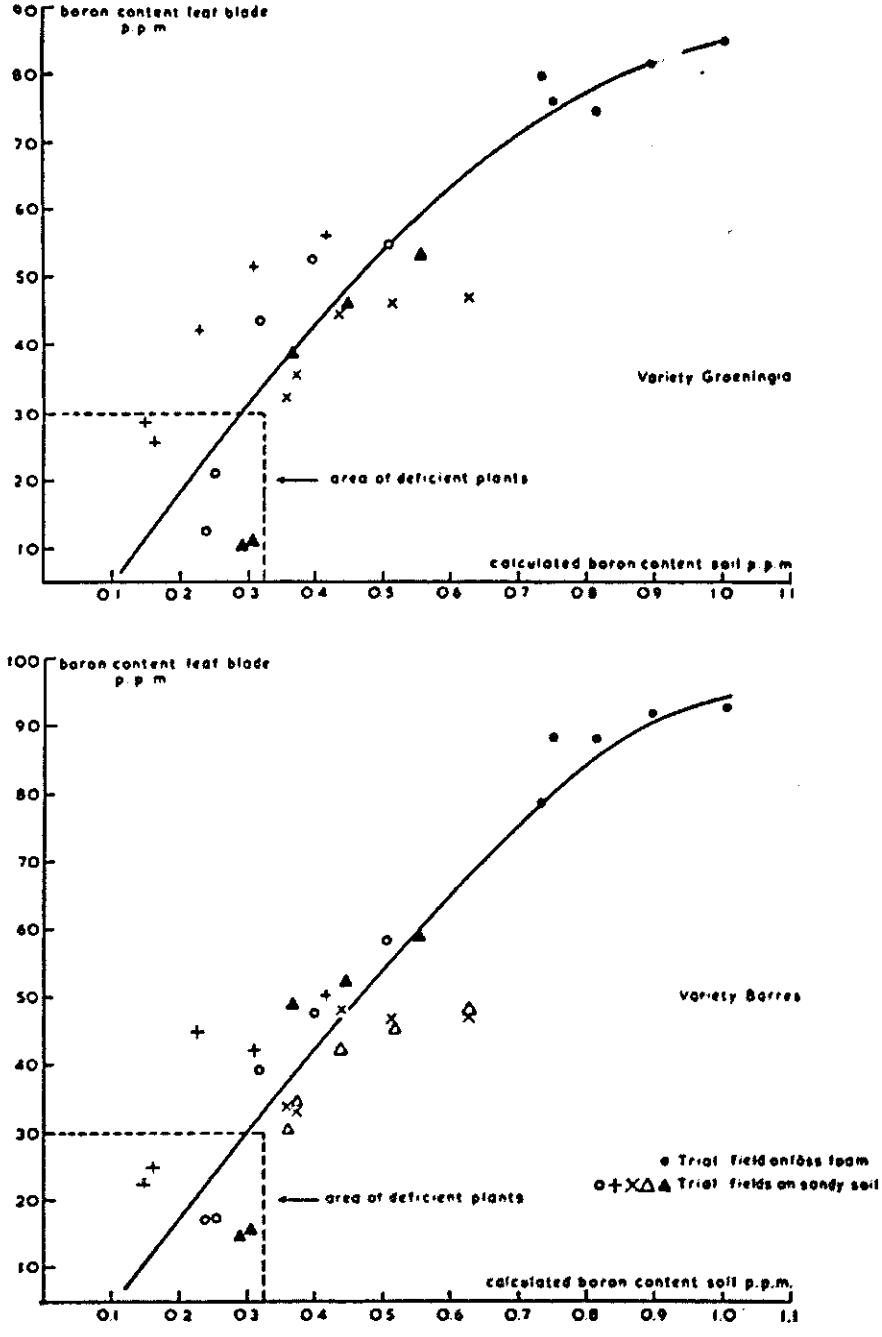

Fig. 3. - Relation between the boron content of leaf blades and the calculated boron content of the soil in field trials with fodder-beet (1957).

To determine the latter we converted the amount of boron applied in fertilization to soil boron by taking the weight of the arable layer of 1 hectare as 3,000,000 kg, thus assuming, for a first approximation, that fertilizer boron is equal in value to soil boron.

The relation between leaf content and soil content is approximately linear in the variety Barres (of which the root has a 10% dry-matter content), but deviates somewhat from this in the variety Groeningia (16% dry matter). It was confirmed in 1957 that deficiency occurs with soil contents below 0.35 p.p.m. B, as the three fields with less than this content all showed heartrot. The corresponding boron contents of the foliage were all under 30 p.p.m. of the dry matter of the leaf blade, and this could be considered to be a threshold value. This seems to agree well with the results of an earlier investigation by the first author (3), namely, that contents of about 20 p.p.m. or less generally point to serious heartrot, while contents up to 30 p.p.m. as a rule correspond to moderate or light symptoms. It must be remarked, however, that the sampling in the former investigation also included the petioles. Though beet varieties differ in their resistance to symptoms of boron deficiency, our earlier investigation and the present one both show that varieties do not differ in threshold value of leaf contents.

Foliar analysis was also carried out in plant samples from the fields included in our investigation of 1956. To this end the full-grown leaf nearest to the heart was taken from a number of beet plants on the spots where soil samples had been collected. With this more statistical material the results were less regular than in our investigation of 1957, though the general tendency was the same (fig. 4).

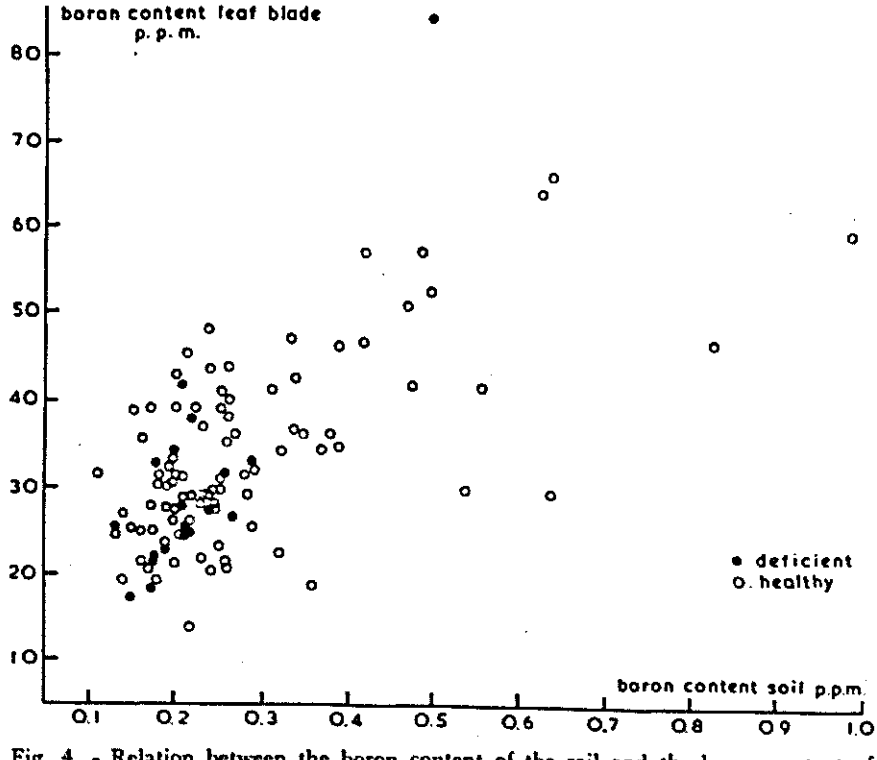

Fig. 4. - Relation between the boron content of the soil and the boron content of leaf blades (beet) in 1956.

If all leaf analysis values corresponding to soils with a boron content of ≤ 0.3 p.p.m. (compare Fig. 4) are plotted against pH (Fig. 5), it appears that no influence of pH on the leaf contents of boron is detectable. Between the pH and the boron content of the soils in Fig. 5 is no correlation (see also Fig. 2).

In principle, leaf analysis is not a very suitable practical basis for advisory work on agricultural crops, since the leaves must be sampled at a moment when it is already late for curative measures.

Soil analysis is definitely preferable for this purpose.

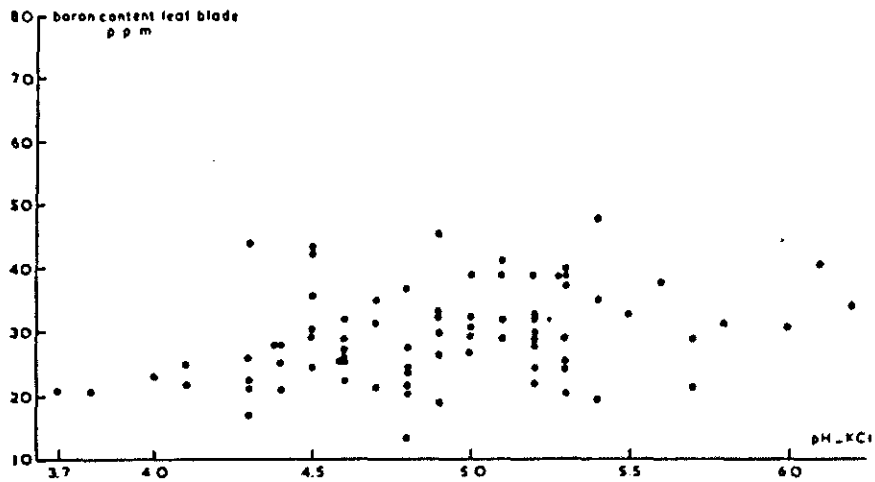

Fig. 5. - Relation between soil pH (pH — KCl) and the boron content of leaf blades (beet) on fields with a soil boron content ≤ 0.30 p.p.m.

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THRESHOLD VALUES OF BORON CONTENTS IN DUTCH SOILS IN RELATION TO BORON DEFICIENCY SYMPTOMS IN BEET (HEARTROT)

Valeurs minima des teneurs en bore des sols néerlandais liées aux symptômes de carence en bore de la betterave (pourriture du coeur de la racine)
Grenzwerte an Borgehalt in holländischen Böden und deren Beziehung zu Bormangelerscheinungen in Runkelrüben (Rotfäule)
Valores límite del contenido de boro en los suelos holandeses en relación con los síntomas de deficiencia de boro en la remolacha (pudrición del corazón)
Valori limite del contenuto di boro nei terreni olandesi in relazione ai sintomi di deficienza di boro nella barbabietola (mal del cuore)

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Summary

Soil samples were collected from beet fields in the Netherlands, both from boron-deficient plots and from plots which showed no signs of such deficiency. The soils were analysed for boron by extraction with hot water and determination with curcumin. In 1955, when the weather was warm and dry, heartrot occurred very frequently on sandy soils with a boron content of less than 0,35 p.p.m. In 1956 the weather was much milder and the incidence of heartrot was limited. A boron content of 0.30 p.p.m. was established as the level above which plots were healthy and below which they were deficient. As a threshold value for use as a basis for advice for sandy and loamy soils 0.35 p.p.m. B has been adopted.

Leaf analyses were also made and it was found that the boron content of the leaf blades is a suitable measure to correlate with the boron content of the soil and by which to judge the state of health of beet plants (carmine method). The threshold value for the foliage (leaf blades) appeared to be a dry matter content of 30 p.p.m. boron. The correlation between boron in plants and boron in soils was better in the material from a series of trial fields with two varieties of fodder beet in 1957 than in the statistical investigation in 1956, when different varieties were used.

Soil analysis is preferable as a basis for practical advisory work, as it enables curative measures to be taken at an early stage.

Résumé

Des échantillons de sols ont été prélevés dans des champs de betteraves aux Pays-Bas, dans les parcelles présentant des signes de carence en bore et dans d'au-

tres ne présentant pas ces symptômes. Les échantillons ont fait l'objet d'analyses consistant à extraire le bore avec de l'eau chaude et à en déterminer la teneur avec de la curcumine. L'année 1955, *qui a été chaude et sèche, a favorisé la pourriture de la racine qui a été très fréquente dans les sols sableux dont la teneur en bore était inférieure à* 0,35 *milligrammes par kg. En* 1956, *le temps a été beaucoup plus doux et les ravages de la pourriture de la racine ont été limités. Il a été établi qu'une teneur en bore de* 0,30 *milligrammes per kg. de sol constituait le niveau, au-dessus duquel les terrains étaient sains et au-dessus duquel ils étaient déficients. La valeur limite adoptée comme base pour les conseils à donner sur la teneur en bore des terrains riches en sable et en argile a été de* 0,35 *milligrammes de bore par kg. de terre.*

On a également procédé à des analyses de feuilles et il a été constaté que la teneur en bore des feuilles pouvait valablement être mise en corrélation avec la teneur en bore du sol et permettait de juger de l'état de santé des betteraves (méthode du carmin). Il a été établi que la valeur minima pour les feuilles était de 30 *milligrammes par kg. de matière sèche. La corrélation entre la teneur en bore des plantes et celle du sol s'est avérée meilleure sur le matériel tiré d'une série d'essais en champ exécutés en* 1957 *avec deux variétés de betteraves fourragères, qu' au cours de l'enquête statistique menée en* 1956 *sur différentes variétés.*

L'analyse du sol est préférable pour les travaux de consultation pratique, car elle permet de prendre plus tôt les mesures curatives.

Zusammenfassung

In Holland wurden Bodenproben von Runkelrübenfeldern gesammelt und zwar sowohl von Bormangel aufweisenden Parzellen, als auch von solchen, wo keine Mangelerscheinungen zu verzeichnen waren. Der Bodenborgehalt wurde anhand eines heissen Wasserauszugs mit Kurkuma bestimmt. Während des warmen und trockenen Wetters von 1955 *traten sehr oft Erscheinungen von Rotfäule in Sand- und Lehm böden mit einem unter* 0,35 *p.p.m. liegenden Borgehalt auf. Im Jahre* 1956 *war das Wetter viel milder und das Vorkommen von Rotfäule begrenzt.*

Als Grenzwert für gesunde Parzellen wurde ein Borgehalt von über 0.30 *p.p.m. festgelegt. Parzellen mit einem über dem Grenzwert von* 0.30 *p.p.m. liegenden Borgehalt waren gesund, während solche mit einem unter diesem Grenzwert liegenden Borgehalt Mangelerscheinungen zeigten. Als für Sand- und Lehm-Böden zu empfehlender Grenzwert wurde ein Borgehalt von* 0,35 *p.p.m. angenommen.*

Aus den Untersuchungen ergab sich, dass zwischen dem Borgehalt der Blätter und dem des Bodens eine Wechselbe beziehung besteht. Diese Untersuchung vermittelt somit wertvolle Aufschlüsse über den Gesundheitszustand der Rübenpflanzen (Karmin-Methode). Der Grenzwert für die Blätter scheint bei einem Trockensubstanz Borgehalt von 30 *p.p.m. zu liegen. Wechselbeziehungen zwischen dem Pflanzenborgehalt und dem Bodenborgehalt traten deutlicher zutage bei einer Reihe von Feldversuchen, die mit zwei Futterrübenarten in* 1957 *ausgeführt wurden, als bei der statistischen verschiedene Arten in Betracht ziehenden Untersuchung von* 1956.

Die Bodenanalyse dient zur praktischen Beratung, da sie Vorbeugungsmassnahmen im Anfangsstadium ermöglicht.

Resumen

Se tomaron muestras de suelo en los campos remolacheros de los Paises Bajos, tanto de parcelas deficientes en boro como de otras que no mostraban signos de tal deficiencia. Se analizaron los suelos para su contenido de boro mediante la extracción con agua caliente y la determinación con curcumina. En 1955, *con*

tiempo cálido y seco, se presentaba la pudrición del corazón con gran frecuencia en los suelos arenosos con un contenido de boro inferior a 0,35 p.p.m. (partes por millón). En 1956 el tiempo fué mucho más benigno y se limitó la frecuencia de esa enfermedad. Se estableció un contenido de boro de 0,30 p.p.m. como nivel por encima del cual las parcelas resultaban sanas, siendo deficientes por debajo del mismo. Se ha adoptado como valor límite el de 0,35 p.p.m. para su uso como base de asesoramiento en los suelos arenosos y arcillosos.

Se efectuó también el análisis de las hojas observándose que el contenido de boro en ellas es una medida apta para correlacionarla con el contenido de boro del suelo, y mediante la cual se puede juzgar el estado sanitario de las plantas de remolacha (método del carmín). El valor límite para el follaje (láminas foliares) resultó ser un contenido en materia seca de 30 p.p.m. de boro. La correlación entre el boro en las plantas y en los suelos resultó mejor en el material de una serie de ensayos de campo con dos variedades de remolacha forrajera en 1957, que en la investigación estadística de 1956, para la que se usaron variedades diferentes.

El análisis del suelo debe utilizarse como base para el asesoramiento práctico, ya que permite adoptar medidas curativas en las fases iniciales.

Riassunto

Campioni di terreno furono prelevati dai campi di barbabietole in Olanda, sia da parcelle boro-deficienti che da parcelle che non mostravano alcun segno di tale deficienza. Fu eseguita l'analisi del boro nei terreni mediante estrazione con acqua calda e determinazione con zafferano. Nel 1955, quando il clima era caldo e asciutto, il mal del cuore si verificò frequentemente nei terreni sabbiosi e argillosi con un contenuto di boro inferiore a 0,35 p.p.m. (parti per milione). Nel 1956 il clima fu molto più temperato e l'incidenza del mal di cuore fu limitata.

Un contenuto di boro di 0,30 p.p.m. fu stabilito come il livello al di sopra del quale le parcelle erano sane ed al di sotto del quale esse erano deficienti.

Come valore limite da essere usato come base per perizie di terreni sabbiosi e di terreni argillosi, è stato adottato 0,35 p.p.m. di boro.

Furono anche eseguite analisi sulle foglie e fu scoperto che il contenuto di boro delle foglie è una misura atta a correlare col contenuto di boro del terreno e per mezzo del quale è possibile giudicare lo stato di salute delle barbabietole (metodo del carminio). Il valore limite per il fogliame (lamine fogliari) sembrò essere un contenuto in materia secca di 30 p.p.m. di boro.

La correlazione tra boro nelle piante e boro nei terreni risultò migliore nel materiale ottenuto da una serie di esperimenti su campo con due varietà di barbabietole da foraggio nel 1957, che non in occasione dell'indagine statistica del 1956, in cui furono usate varietà diverse.

L'analisi del suolo è preferibile come base per il lavoro di consulenza pratica, poichè essa consente di prendere provvedimenti curativi nella fase iniziale.