

Nutritional disorders in glasshouse tomatoes, cucumbers and lettuce

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The Instituut voor Bodemvruchtbaarheid (Institute for Soil Fertility) is a governmental institution. Research work includes various aspects of soil physics, soil chemistry and soil organic matter, and of plant nutrition and fertilizer application. The Proefstation voor Tuinbouw onder Glas (Glasshouse Crops Research and Experiment Station) is also a governmental institute. The aim of the research work is to increase production and to improve quality of vegetables, fruits (grapes and strawberries) and some flower crops (e.g. chrysanthemums) grown in glasshouses. Consequently, all aspects of cultivation under glass are studied.

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This book is a revised edition of booklets on nutritional disorders in lettuce, tomatoes, cucumbers and gherkins published earlier.

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Introduction

Tomatoes (*Lycopersicon esculentum* Mill.), cucumbers (*Cucumis sativus* L.), and lettuce (*Lactuca sativa* L. cv. capitata L.) are the main vegetable crops in Dutch commercial glasshouses.

Tomatoes are grown in heated glasshouses, being planted in December/January or April. Cucumbers are planted mainly around January and gherkins, in slightly heated glasshouses, in April. Gherkins (pickling cucumbers) also of the species *Cucumis sativus* L., are generally used for canning. Unlike cucumber, gherkins require pollination for fruit setting. Malnutrition symptoms for cucumber and gherkins are very similar. Lettuce is grown in autumn, winter and spring, and experimentally in summer. Butterhead lettuce is by far the most cultivated type, but interest in iceberg lettuce is increasing. Sales of glasshouse crops in the Netherlands are presented in Table 1.

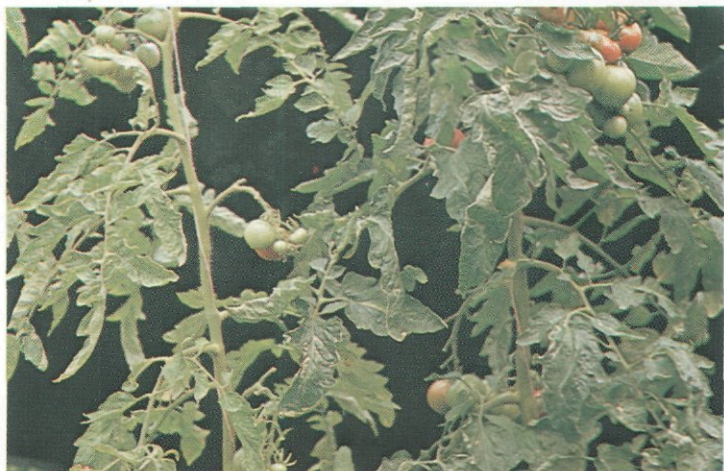
Table 1. Sales of glasshouse crops in the Netherlands (in millions of guilders).

	1978	1979	1980
Tomatoes	530	512	676
Cucumbers	233	241	332
Lettuce	155	203	155
Gherkins	42	29	34

This book is a guide to diagnosis of nutritional disorders. Deficiencies and toxicities are included, sixteen in all. Incidence of nutritional disorders has been exacerbated by the increasing use of peat and rock-wool substrates, and introduction of hydroponic culture, in particular the nutrient-film technique. Conditions pertaining to mineral disorders and methods of control are briefly described. In our trials, young just fully grown leaves were sampled for analysis. For analysis of lettuce the whole mature head was sampled, discarding yellow or decaying leaves or leaves contaminated with soil. Contents of nutrients typical of the various deficiencies and toxicities

ties, and nutrient contents in edible parts of tomato and cucumber are tabulated in the last section of this book. Data refer both to our own trials and work reported in literature.

No major differences were found between cucumber and gherkins.



1. Plants from experimental plots in a commercial glasshouse; left without, right with nitrogen.



2. Leaves from experimental plots in a commercial glasshouse; left without, right with nitrogen.

Nitrogen deficiency

Symptoms

Shoot growth is restricted and the plant is spindly in appearance. At first, the lower leaves turn yellowish green. In severe deficiency, the entire plant turns pale green. The leaflets are small and erect, and the major veins look purple, especially underneath. Fruits remain small. A nitrogen-deficient crop is susceptible to grey mould (*Botrytis cinerea* Pers. ex. Fr.) and possibly to potato blight (*Phytophthora infestans* (Mont.) de Bary).

Incidence

Nitrogen deficiency can be expected on clay soils in newly built glasshouses if insufficient nitrogen fertilizer is applied and on sandy soils after thorough leaching. It can be induced with straw or with farmyard manure containing much undecomposed straw.

Treatment

Apply 20 g N per square metre of soil as basal dressing of inorganic fertilizer, or apply nitrogen in liquid form with the irrigation water as top-dressing (200–500 mg N per litre). Spraying of a solution with 2.5 mg urea per litre is less effective.

References

4, 5, 16, 25, 28, 34, 38, 41, 50, 57, 61, 63, 72, 89, 98, 107, 109, 121, 142, 168, 176, 178, 192, 201, 202, 204, 216, 219, 235, 252.



3. Phosphate-deficient plant (cv. Sonatine) on rock-wool.

Phosphorus deficiency

Symptoms

Shoot growth is restricted and the stem remains thin, but clear symptoms are absent. In more severe deficiency (e.g. in water culture), leaves are small, stiff and curved downwards; the upper sides are bluish green and the undersides, including the veins, purple. The older leaves may turn yellow and develop scattered brownish purple dry spots; they drop prematurely.

Incidence

Phosphorus deficiency may occur on low poorly drained iron-rich (phosphate-fixing) soils. It may also be expected on barren soils landscaped by excavating or pumping in mud or sand, if no phosphate is applied. In old glasshouses, it sometimes occurs after deep digging of the soil. Symptoms of malnutrition may also appear in plants raised on peat substrates if no phosphate is applied. Factors affecting root growth, especially low temperature, promote the deficiency.

Treatment

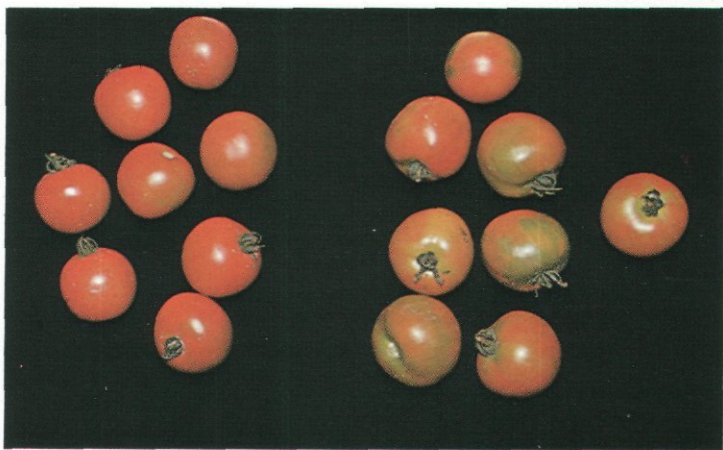
For prevention apply 50 g P_2O_5 (22 g P) per square metre of soil or 200 g P_2O_5 (87 g P) per cubic metre of peat. In acute deficiency, phosphate may be applied in liquid form, but discarding the crop and starting a new one after ample supply of phosphate will probably give better financial results.

References

4, 16, 18, 25, 28, 32, 34, 35, 36, 41, 50, 57, 61, 83, 84, 86, 89, 93, 95, 98, 107, 111, 121, 129, 133, 134, 166, 176, 178, 184, 192, 216, 219, 235, 251, 252.



4. Leaves from experimental plots in a commercial glasshouse; right and centre without, left with potassium.



5. Fruits from experimental plots in a commercial glasshouse; left with, right without potassium.

Potassium deficiency

Symptoms

The leaflets of older leaves develop scorched and curled margins and interveinal chlorosis; the smallest veins do not remain green. In some varieties small dry spots with brown margins appear in the chlorotic areas. Plant growth is restricted and the leaves remain small. At a later stage chlorosis and necrosis spread to younger leaves, after which the severely yellowed and curled older leaves drop off. Uneven ripening of the fruit can be expected. A potassium-deficient crop is susceptible to grey mould.

Incidence

As potassium has a specific influence on fruit quality, it is generally applied liberally and deficiency is rare. It can be expected on potassium-fixing clay, on coarse-textured sand, on peat substrate and in nutrient solution, if fertilizing is neglected.

Treatment

For prevention apply 100 g K_2O (83 g K) per square metre of soil or 200 g K_2O (166 g K) per cubic metre of peat. If deficiency appears during growth, apply potassium in liquid form (500 mg K per litre) in the irrigation water. The crop can also be sprayed with a solution of 20 g potassium sulphate per litre, but soil application is more effective.

References

7, 14, 16, 28, 33, 34, 37, 38, 41, 57, 59, 77, 86, 89, 98, 107, 109, 117, 121, 128, 132, 155, 176, 178, 192, 201, 202, 206, 216, 219, 233, 235, 238, 239, 243, 244, 252.



6. Leaves from magnesium-deficient plant (cv. Ailsa Craig)
(water colour)

Magnesium deficiency

Symptoms

The margins of the leaflets of older leaves show a yellowish discoloration which spreads toward the interveinal tissues. The smallest veins do not remain green. Yellowing gradually spreads from the base to the top of the plant. In the bright yellow to orange leaf tissue, many unsunken necrotic spots often develop and may coalesce into brown bands between the veins. At first, plant habit and leaf size are normal, and the petioles are not curved. As deficiency becomes more severe, the older leaves die and the whole plant turns yellow. The symptoms may vary between varieties and growing conditions. Fruit production is not seriously affected by moderate deficiency; only in severe deficiency is it markedly reduced.

Incidence

Slight magnesium deficiency occurs in almost all glasshouses and with all soil types. More severe deficiency can be expected on coarse-textured sandy soils. It is promoted by low pH and high potassium status of the soil, and by inadequate supply of nitrogen fertilizer.

Treatment

Kieserite and dolomitic lime are used for prevention. In acute deficiency, 200-300 g magnesium sulphate ($\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$) per square metre of soil is applied. High-volume or low-volume spraying with solutions of 20 or 100 g magnesium sulphate per litre, respectively, is more effective than soil application, but should be repeated several times. Apply top-dressings of nitrogen as calcium or magnesium nitrate.

References

1, 4, 14, 16, 28, 34, 57, 60, 62, 75, 86, 89, 98, 107, 114, 121, 138, 139, 153, 155, 176, 178, 183, 192, 201, 204, 206, 216, 219, 220, 227, 228, 231, 232, 233, 235, 240, 245, 252.



7. Calcium-deficient plant in water culture.



8. Blossom-end rot in fruits from a commercial glasshouse.

Calcium deficiency

Symptoms

At first the upper sides of the young leaves are dark green, except for the pale margins; the undersides turn purple. The leaflets remain tiny and are deformed and curled up. Leaf tips and margins then wither and the curled petioles die back. The growing point dies. At this stage, interveinal chlorosis and scattered necrotic spots appear in leaflets of older leaves. Those leaves soon die. Fruits show blossom-end rot. The roots develop poorly and are brownish.

Incidence

In practice, calcium deficiency occurs rarely in vegetative parts. It may arise with plants on oligotrophic peat and in nutrient solution if calcium supply is neglected. Blossom-end rot occurs on acid soils and on soils with a high salt content.

Treatment

Liming of peat (4 kg calcium carbonate per cubic metre), in acute cases spraying with a solution of $7\frac{1}{2}$ g calcium nitrate per litre.

References

4, 14, 16, 23, 28, 34, 41, 43, 57, 58, 71, 78, 98, 99, 100, 107, 108, 126, 130, 138, 139, 163, 176, 178, 189, 190, 192, 216, 219, 223, 235, 252.



9. Sulphur-deficient plant (cv. Moneymaker) in water culture (left); to the right, healthy plant.

Sulphur deficiency

Symptoms

At first plant habit and leaf size are normal. Stem, veins, petioles and petiolules turn purple and leaves turn yellow. The leaflets of older leaves show necrosis at tips and margins and small purple spots appear between the veins. Young leaves are stiff and curl downward. (Such curling does not normally occur in nitrogen-deficient plants). Eventually, large irregular necrotic spots appear on those leaves.

Incidence

Sulphur deficiency is unknown in commercial glasshouses. It may occur in crops grown on peat substrates or in nutritional solution if no sulphur fertilizers are used.

Treatment

Application of sulphate containing fertilizer.

References

25, 28, 107, 164, 176, 192, 225, 252.



10. Boron-deficient plant in water culture.



11. Detail of leaf showing boron deficiency.

Boron deficiency

Symptoms

In commercial crops the most striking symptom is a yellow to orange discoloration of the leaflets, particularly of the down-curved top leaflets. In severe deficiency shoot growth is restricted and later the growing point withers and dies. At about the same time, a slight interveinal chlorotic mottling appears in leaflets of younger leaves. These leaves remain small and curl inward and are deformed. The smallest leaflet turn brown and die. Laterals develop, but growth soon stops as growing points die. Stem, petioles and petiolules are very brittle, causing leaves and leaflets to break off suddenly, except in some 'tougher' cultivars. The veins of the leaflets, and especially the top leaflets are clogged. This symptom is specific and occurs even with moderate deficiency. Roots grow poorly and turn brown. Fruits may be malformed with brown lesions in the pericarp.

Incidence

Boron deficiency frequently occurs on sandy loam soils. It is aggravated by liming, by using much oligotrophic peat, and by undermanuring. The quality of irrigation water plays an important role.

Treatment

Apply 2 g of sodium borate per square metre of soil or spray with a solution of 1 – 2 g sodium borate per litre. Peat substrates should be dressed with 10 g of sodium borate per cubic metre as a precaution.

References

2, 10, 11, 12, 16, 25, 26, 28, 34, 45, 46, 47, 48, 51, 52, 57, 60, 66, 81, 82, 90, 91, 92, 98, 99, 106, 107, 108, 116, 121, 122, 124, 137, 138, 145, 149, 151, 155, 170, 175, 176, 177, 178, 188, 191, 192, 193, 194, 215, 216, 217, 219, 244, 250, 251, 252.



12. Copper-deficient plant in water culture.

Copper deficiency

Symptoms

Stem growth is somewhat stunted. The leaves are bluish green. The margins of leaflets of middle and of younger leaves curl into a tube towards the midribs. Chlorosis and necrosis are absent. Terminal leaves are very small, stiff and contorted. Petiolules bend typically downward, directing opposite tubular leaflets towards each other. Later, necrotic spots develop alongside and on the midribs and the larger lateral veins.

Incidence

Copper deficiency rarely occurs in commercial glasshouses. The disorder may occur in plants on oligotrophic peat or nutrient solution.

Treatment

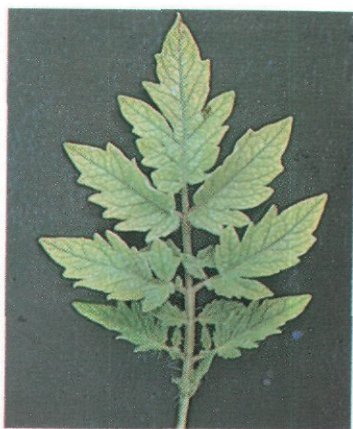
Apply 10 g copper sulphate per cubic metre of peat and 5 μmol Cu per litre in nutrient solution. Spraying is possible with a solution of 1 – 2 g copper sulphate and of 5 g hydrated lime per litre water.

References

8, 22, 28, 57, 81, 82, 104, 106, 107, 124, 136, 171, 176, 179, 180, 192, 194, 195, 201, 252.



13. Iron-deficient plant in water culture.



14. Iron deficiency induced in leaf in water culture.

Iron deficiency

Symptoms

Chlorosis develops in the terminal leaves. At first even the smallest veins remain green to produce a fine reticular pattern of green veins on yellow leaf tissues. Later, chlorosis increases in intensity and extends to the smaller veins. Eventually, affected leaves turn completely pale yellow or almost white; necrosis is not severe. Symptoms progress from the terminal to the older leaves. Growth is stunted and newly formed leaves remain small.

Incidence

Iron deficiency may be expected on fine sands or calcareous loam soils of weak structure. It occurs rather patchily, mainly in plants bearing a heavy crop. It may also occur in plants on peat substrate or in nutrient solution without iron.

Treatment

Apply iron chelates: 5 – 10 g of Fe-EDDHA (ethylene diamine di (0-hydroxy-phenylacetate) or 15–20 g of Fe-DTPA (diethylene triamine pentaacetic acid) per m² of soil or spray with a solution of 0.2 g of Fe-EDTA (ethylene diamine tetraacetic acid) per litre.

References

1, 28, 34, 49, 60, 81, 82, 85, 99, 106, 107, 118, 136, 148, 162, 176, 192, 193, 201, 208, 216, 219, 221, 222, 252.



15. Manganese-deficient plant (cv. Sonatine) in water culture.

Manganese deficiency

Symptoms

Middle and older leaves, and later the younger leaves, turn pale. This produces a characteristic chequered pattern of green veins and yellowish interveinal areas. Later, small necrotic gradually expanding spots appear in the pale areas, especially near the midribs. Chlorosis is less severe than in iron-deficient plants (where entire leaves may turn yellowish white). Another difference is that chlorosis is not confined to younger leaves.

Incidence

Manganese deficiency occurs on calcareous loam soils and on over-limed sand and peat soils. With nutrient solution, manganese deficiency may occur if manganese is not applied.

Treatment

High volume spraying with a solution of 1 g of manganese sulphate per litre of water or low volume spraying with 10 g per litre. Soil application (50 g manganese sulphate per square metre) is less effective than spraying.

References

1, 4, 16, 26, 28, 34, 57, 60, 81, 82, 89, 90, 98, 99, 106, 107, 109, 113, 126, 136, 141, 176, 178, 192, 201, 216, 217, 219, 226, 233, 252.



16. Plant with molybdenum deficiency on sphagnum peat
(water colour)

Molybdenum deficiency

Symptoms

The leaflets show a pale to yellowish interveinal mottling. The margins curl upwards to form a spout. The smallest veins turn yellow. Necrosis starts in the yellow areas, at the margins of the top leaflets and finally includes entire composite leaves, which shrivel.

Symptoms progress from the older to the younger leaves, but the cotyledons stay green for a long time.

Incidence

Molybdenum deficiency may occur on acid soils low in phosphate and rich in iron. It is common in plants grown in oligotrophic peat without supplementary molybdenum.

Treatment

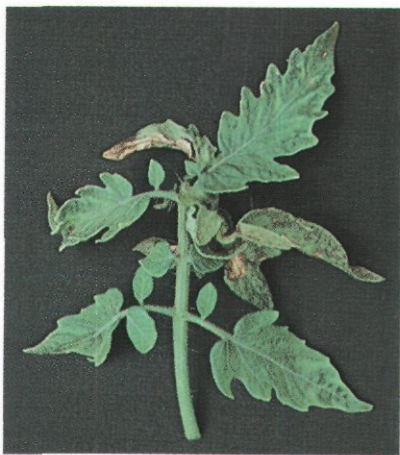
For prevention, lime the soil. Oligotrophic peat should receive 5 g ammonium or sodium molybdate per cubic metre. Spraying with a solution of 0.5 g of these salts per litre of water is also possible.

References

4, 17, 26, 28, 42, 54, 57, 76, 81, 82, 102, 103, 104, 105, 106, 107, 115, 135, 150, 157, 158, 176, 182, 192, 194, 195, 201, 205, 214, 216, 217, 252.



17. Zinc-deficient plant in water culture.



18. Zinc deficiency in leaf, induced in water culture.

Zinc deficiency

Symptoms

Terminal leaves remain small and the leaflets show slight discoloration between the veins. Growth is stunted. Older leaves are also smaller than normal. There is little chlorosis in those leaves but irregular shrivelled brown spots develop, especially on the petioles, but also on and between the veins of the leaflets. Petioles curl downward, complete leaves coil up. Necrosis progresses rapidly, within a few days the entire foliage may wither.

Incidence

Zinc deficiency does not occur in glasshouse crops, unless grown in nutrient solution without zinc.

Treatment

Apply 1 g of zinc sulphate per square metre of soil preferably in a soluble form. Peat substrates should be given 10 g of zinc sulphate per cubic metre. Nutrient solutions should contain 4.5 μmol Zn per litre.

References

26, 28, 44, 56, 57, 79, 81, 82, 104, 106, 107, 131, 136, 176, 192, 193, 201, 209, 217, 252, 253.



19. Leaf showing nitrogen toxicity.

Excess nitrogen

Symptoms

Growth is restricted. Leaves are shorter than normal, look stiff and are deep green. In acute toxicity, leaves lose turgor, margins desiccate and sunken watery spots appear, the affected leaf tissue dying back and turning whitish grey.

Incidence

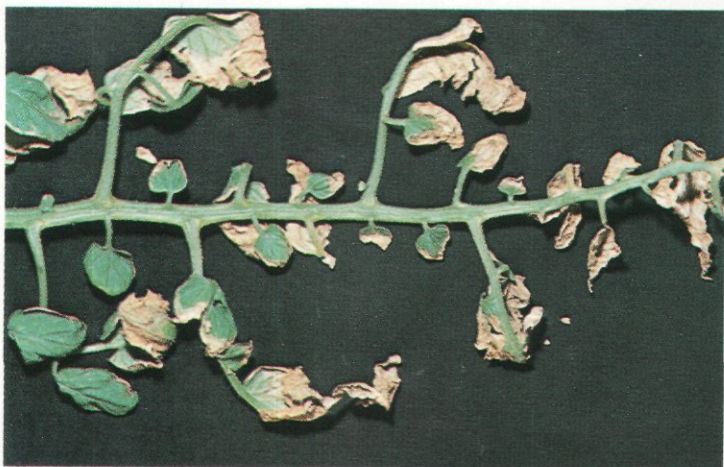
Excess nitrogen is induced by heavy dressings of nitrogen or of organic materials like dried blood. Acute toxicity is caused by excessive top dressing with inorganic nitrogen or by uneven distribution.

Treatment

Ample watering.

References

74, 89, 121, 176, 178, 219.



20. Leaf with boron toxicity, in a commercial glasshouse.



21. Curling and withering sepals caused by boron toxicity in a commercial glasshouse.

Excess boron

Symptoms

Tips and margins of the leaflets of older leaves and of cotyledons become scorched and curl. Later, sunken desiccating spots may develop, sometimes surrounded by brown concentric rings. The down-curved leaflets feel dry and papery, and finally drop. Symptoms progress from older to younger leaves. At first, the plant top looks almost normal but later, terminal leaves curl too.

Incidence

Boron toxicity is easily caused by excess boron fertilizer. Special care should be taken in applying such materials.

Treatment

Leach the soil, preferably with calcareous water. Other measures to raise soil pH are also recommended.

References

11, 19, 27, 28, 34, 52, 68, 69, 81, 82, 98, 170, 176, 218, 219.



22. Plant in water culture with manganese toxicity. (water colour)

Excess manganese

Symptoms

The plant is somewhat spindly and restricted in growth. Terminal leaves remain tiny and the leaflets show interveinal chlorosis. Many necrotic interveinal spots develop in the leaflets of older leaves, making them look dirty. Later the midrib and the larger lateral veins die. The leaves are then shed, the older ones first.

Incidence

Desinfection of soils by steaming releases much plant-available manganese which may induce manganese toxicity. Low pH promotes the disorder.

Treatment

For prevention apply lime.

References

7, 28, 54, 60, 65, 81, 82, 85, 101, 112, 113, 119, 123, 161, 186, 203, 208, 216, 219, 226, 244.



23. Plant in water culture with zinc toxicity. (water colour)

Excess zinc

Symptoms

The plant is spindly and growth is severely stunted. Symptoms differ from those produced by iron deficiency in that the younger leaves are extremely small and the leaflets show interveinal chlorosis and the undersides turn purple. Older leaves are strongly downcurved. Purplish tints develop on the undersides, spreading from the margins inwards. Leaves may later turn yellow (reddish brown veins excepted) before dropping.

Incidence

Zinc toxicity may occur in glasshouses if condensation drips from the galvanized frame onto the plants. Care should be taken with galvanized materials. The watering systems should not contain any such material.

Treatment

Application of lime and phosphate decreases the availability in soil of zinc to the plant. When cultivating plants in nutrient solution, galvanized parts in the watering system should be replaced.

References

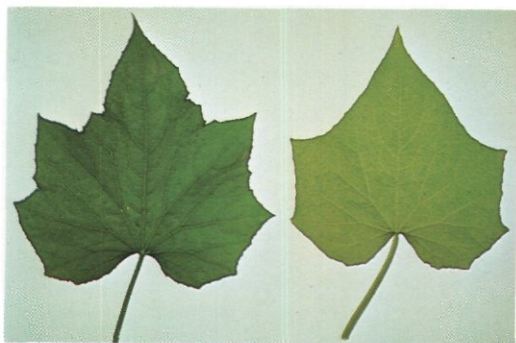
28, 79, 81, 82, 161.



24. Nitrogen deficiency in a gherkin plant (cv. Levo) grown on sphagnum peat.



25. Cucumbers (cv. Sporu) cultivated on sphagnum peat; right healthy, left nitrogen-deficient.



26. Leaves of cucumber plants from a commercial glasshouse; left healthy, right nitrogen-deficient.

Nitrogen deficiency

Symptoms

Growth is stunted and the foliage fades to yellowish green. The discoloration is most pronounced in older leaves. Occasionally the mesophyll around the main vein remains green for some time contrasting with the yellow veins. Flowers look large in relation to other plant parts. In severe deficiency, the whole plant turns yellow to almost white; cotyledons and lower leaves die, and younger leaves stop growing. Cucumber fruits of cultivar *Sporu* are short, thick, light or grayish green and spiny, whereas normal fruits are dark green and smooth. Abnormally shaped, pale yellow fruits pointed at their top end are mentioned in literature.

Incidence

Deficiency can be expected if much straw or strawy manure is used. Older plants rarely show deficiency except occasionally on coarse-textured sandy soils. Deficiency is likely on peat or in nutrient solution if nitrogen supply is neglected.

Treatment

Apply nitrogen, preferably in liquid form (200–500 mg of N per litre) with the irrigation water. Spraying with a solution of 5 g urea per litre is possible but less effective. Young plants in pots require 50–100 mg of N per plant in liquid form (e.g. 20 g of calcium nitrate per litre). To avoid scorching, residues should be removed from foliage with water.

References

3, 15, 28, 57, 64, 67, 109, 192, 201, 234.



27. Phosphorus deficiency in a gherkin plant (cv. Levo) grown on sphagnum peat.



28. Phosphorus deficiency in young cucumber plants (cv. Sporu) grown on sphagnum peat.

Phosphorus deficiency

Symptoms

Plants are stunted but do not show definite symptoms. Severe deficiency prevents growth; the younger leaves are small, stiff and dark green. Large watery spots on and between veins appear in cotyledons and older leaves, and spread to younger leaves. Affected leaves fade, the spots turning brown and desiccating. The whole leaf shrivels, except for the petiole, which remains turgid for some time. Successive stages last only a few days.

Incidence

Symptoms occur in plants raised on oligotrophic peat. Growth may be reduced in new glasshouses on poor soils or in glasshouses levelled with unfertile subsoil, but only without either phosphate or farmyard manure.

Treatment

Apply in two portions 50 g of P_2O_5 (22 g P) per square metre of soil as triple superphosphate or polyphosphate, preferably in ample water. For young plants, use a solution with 20 g per litre, supplying 100-200 mg of P_2O_5 (44-87 mg P) per plant. Unless wetting of the plants can be avoided, they should be watered afterwards.

References

15, 28, 57, 67, 110, 234.



29. Potassium deficiency in a gherkin plant (cv. Levo) grown on sphagnum peat.



30. Leaf of a potassium-deficient gherkin plant (cv. Levo) grown on sphagnum peat.

Potassium deficiency

Symptoms

Growth is stunted, internodes remain short and leaves small. Leaves are bronzed and turn yellowish green at the margins; the main veins are sunken. At a later stage, interveinal chlorosis becomes more pronounced and spreads towards the centre of the leaf; it is followed by necrosis. Leaf margins desiccate but the veins remain green for some time. Symptoms progress from the base towards the top of the plant, the oldest leaves being worst affected.

Incidence

Potassium deficiency is rare in commercial glasshouses. It might occur on potassium-fixing soils, light sandy soils or on peat soil without potash or farmyard manure. It can also be expected in plants growing in rock-wool, peat substrate or nutrient solution without potassium supply.

Treatment

For prevention, apply 50 g K_2O (42 g K) per square metre on light sandy soils and 100 g (84 g K) on loamy soils, as a basal dressing. During growth apply potassium, preferably in liquid form with the water supply, in concentrations up to 500 mg of K per litre. The crop may also be sprayed with a solution of 20 g of potassium sulphate per litre but soil dressing is more effective.

References

3, 15, 28, 57, 67, 109, 192, 201, 234.



31. Leaf of magnesium-deficient cucumber plant (cv. Sporu).

Magnesium deficiency

Symptoms

Older leaves show interveinal chlorosis proceeding from the leaf edges inward. In moderate deficiency, stem and leaves grow normally. With more acute deficiency, chlorosis spreads further, also including the smaller veins, and becomes severe; only the main veins remain green. Sometimes chlorosis appears as large interveinal sunken blotches. Eventually the patches become necrotic and leaves shrivel. Symptoms progress from older to younger leaves and finally the entire plant turns yellow. A type of chlorosis resembling magnesium deficiency sometimes appears in cucumber grafted on *Cucurbita ficifolia*.

Incidence

Magnesium deficiency may be observed on various soils without organic manuring. Factors promoting the disorder are low pH and probably heavy potash or inadequate nitrogen dressings. It also appears in plants grown in rock-wool or in nutrient solution with insufficient added magnesium.

Treatment

Apply kieserite, dolomitic limestone or ample farmyard manure for prevention. In acute deficiency apply 150-200 g of magnesium sulphate ($\text{MgSO}_4 \cdot 7 \text{H}_2\text{O}$) per square metre, preferably with the water supply. High-volume or low-volume spraying, with a solution of 20 g or 100 g of $\text{MgSO}_4 \cdot 7 \text{H}_2\text{O}$ per litre respectively, is more effective than soil dressing.

References

3, 15, 28, 55, 57, 67, 160, 234.



32. Calcium deficiency in the top of a cucumber plant (cv. Sporu) grown in water culture.



33. More severe calcium deficiency (water culture).

Calcium deficiency

Symptoms

The youngest leaves show transparent white dots near the edges and between the veins. Interveinal chlorosis appears in most leaves, gradually increasing in severity; the main veins stay green. Plants are stunted and internodes are short, especially near the apex. The youngest leaves remain small, their edges are deeply incised and curled upwards. Later they shrivel from the edges inwards. Older leaves curve downwards. In severe deficiency, petioles are brittle and leaves drop easily. Buds abort and finally the plant dies back from the apex. The dead tissues are greyish brown. Flowers are smaller than normal and pale yellow; fruits remain small and are furrowed and tasteless.

Incidence

Calcium deficiency may occur on soils where calcium reserves are depleted by leaching, and also on sphagnum peat, used for raising young plants, unless lime is added. It also occurs in crops grown in rock-wool or nutrient solution without sufficient calcium.

Treatment

Lime oligotrophic peat with 4 kg of calcium carbonate per cubic metre. In acute deficiency, spray with a solution of 10 g of calcium nitrate fertilizer per litre (7 g/l if anhydrous calcium nitrate is used).

References

21, 28, 94, 144, 224, 234.



34. Sulphur deficiency in a cucumber plant (cv. Sporu) grown in water culture.

Sulphur deficiency

Symptoms

Growth is restricted. Leaves remain small, particularly younger ones; they bend downwards and are pale green to yellow. In contrast to nitrogen deficiency, yellowing is least pronounced in older leaves. Margins of younger leaves are markedly serrate.

Incidence

To our knowledge, sulphur deficiency has not been reported in commercial glasshouses. It may be induced in crops grown in rock-wool, peat or nutrient solution without sulphur-containing fertilizers.

Treatment

Apply sulphate-containing fertilizers.

References

225.



35. Dead bud of boron-deficient cucumber plant (cv. Sporu) grown on sphagnum peat.



36. Leaves of boron-deficient cucumber plant (cv. Sporu) grown in water culture.



37. Fruits of a boron-deficient plant (cv. Fabiola).

Boron deficiency

Symptoms

In commercial glasshouses, symptoms appear around the first harvest. Growth is not much affected but plants are brittle. Middle and lower leaves are slightly chlorotic and watery spots may appear. The crop easily loses turgor. Leaves in shoot tops are malformed and do not fully expand. Young fruits sometimes die. Developing fruits are malformed with longitudinal white stripes, as though exposed to cold. In acute deficiency the growing point and apexes of axillary shoots die. Younger leaves curl upwards and die, the dead tissues turning gray. Growth stops altogether, giving the plant a stunted appearance.

Incidence

Boron deficiency may occur in glasshouses on sandy soils. It is stimulated by liming, and using oligotrophic peat and little or no manure. Quality of irrigation water is a major factor.

Treatment

Apply evenly 2 g of sodium borate per square metre of soil. Oligotrophic peat for raising young plants should be dressed with 10 g per cubic metre. Spraying with a solution of 1-2 g per litre is also possible.

References

6, 28, 67, 81, 82, 140, 175, 185, 234.



38. Copper deficiency in a cucumber plant (cv. Sporu) grown in water culture.

Copper deficiency

Symptoms

Growth is restricted. Internodes are short, giving the plant a bushy appearance. Especially the younger leaves remain small. Interveneal chlorotic blotches may appear in older leaves, but there is not the fine chlorotic pattern typical of iron or manganese deficiency. Later the leaves turn dull green to bronze, necrosis develops and the leaf withers. Chlorosis progresses from the older to the younger leaves.

Incidence

Copper deficiency is unknown in commercial glasshouses. It might occur in crops growing in oligotrophic peat or in nutrient solution without copper.

Treatment

Add 10 g of copper sulphate ($\text{CuSO}_4 \cdot 5 \text{H}_2\text{O}$) per cubic metre to peat substrate as a precaution. Nutrient solution should contain $0.5 \mu\text{mol}$ of Cu per litre. Plants may be sprayed with up to 1 g of $\text{CuSO}_4 \cdot 5 \text{H}_2\text{O}$ per litre.

References

6, 8, 28, 106.



39. Fruit and leaf of iron-deficient cucumber plant (cv. Sporu), grown in water culture.

Iron deficiency

Symptoms

The youngest leaves exhibit a fine pattern of green veins on yellow leaf tissue. At first, plants grow normally. In more advanced stages chlorosis spreads to veins, first the smaller ones; affected leaves turn lemon-yellow to white. Shoots stop growing and necrosis appears at the edges of leaves that have lost chlorophyll completely. In contrast to manganese deficiency, the youngest leaves are affected most and symptoms progress from top to base. Axillary shoots and fruits also turn lemon-yellow.

Incidence

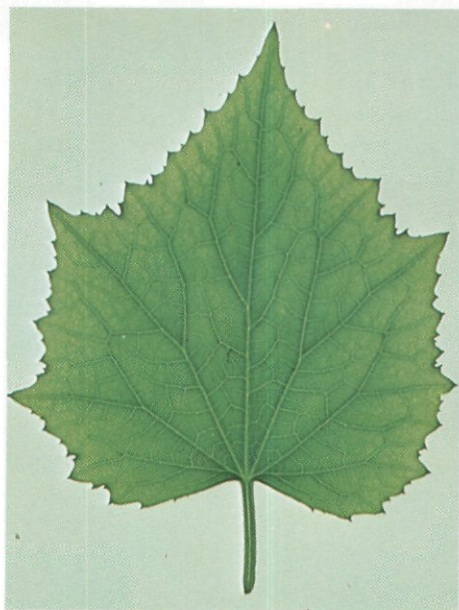
Iron deficiency may be expected on calcareous loam soils of unstable structure. It may also occur in crops grown on peat or in nutrient solution without the nutrient.

Treatment

Add iron chelate to peat substrate and nutrient solution. As a cure apply chelates: 5-10 g of Fe-EDDHA or 12-20 g of Fe-DTPA per square metre of soil or spray with a solution of 0.2 g of Fe-EDTA per litre every three or four days.

References

67, 81, 82, 234.



40. Leaf of a manganese-deficient gherkin plant from a commercial glasshouse.



41. Manganese-deficient cucumber plant (cv. Sporu) grown in water culture.

Manganese deficiency

Symptoms

Yellowish interveinal mottling develops either in terminal or young leaves. At first even the smallest veins remain green, producing a fine green network on a yellow background. Later, all the mesophyll except the main veins turns yellow to yellowish white, and sunken necrotic spots develop between the veins. Older leaves turn palest and die first. Shoots are severely stunted and new leaves remain small.

Incidence

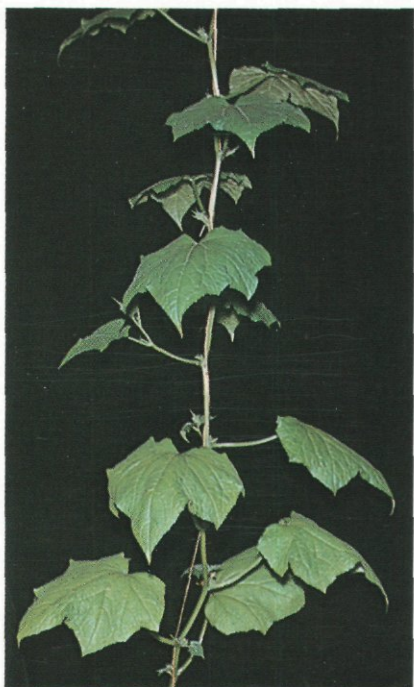
Manganese deficiency occurs on some calcareous loam soils and on excessively limed sand and peat soils. When the crop is grown in nutrient solution the disorder may be induced by omitting manganese.

Treatment

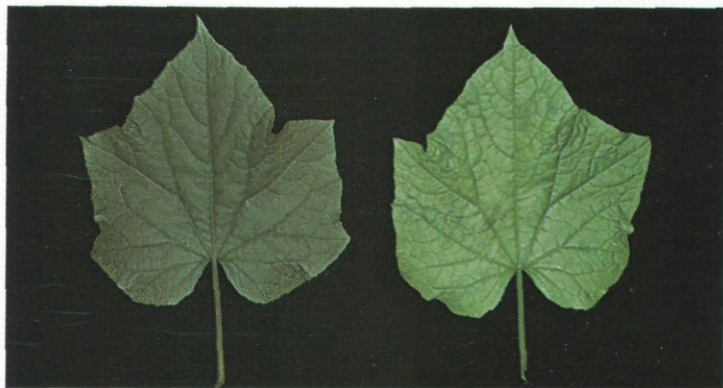
High-volume or low-volume spraying with a solution of 1.5 or 10 g, respectively, of manganese sulphate per litre. Nutrient solutions should contain 0.9 μmol of Mn per litre. Application of 50 g manganese sulphate per square metre of soil, together with ammonium sulphate or peat moss, is also possible, though less effective in curing deficiency.

References

28, 57, 67, 81, 82, 106, 109, 160, 234.



42. Molybdenum deficiency in cucumber (cv. Sporu) grown on sphagnum peat. Note the pale lower leaves.



43. Leaves of cucumber plant (cv. Sporu) grown on sphagnum peat; left healthy, right molybdenum-deficient.

Molybdenum deficiency

Symptoms

The green colour of older leaves fades, particularly between the veins. Later, leaves turn pale green, except for some green patches 0.25-2 cm across, which include both veins and interveinal areas. Eventually, leaves turn yellow and die. These symptoms start in lower leaves and spread upwards, the youngest ones remaining green. Growth is almost normal but flowers are small.

Incidence

Molybdenum deficiency in cucumber is unknown in Dutch commercial glasshouses. On oligotrophic peat the disorder may be induced by insufficient liming and by applying nitrogen as nitrate.

Treatment

Apply 5 g of ammonium or sodium molybdate per cubic metre of peat as preventive. To cure deficiency, apply 150 mg of sodium molybdate per square metre of soil in ample water or spray a solution of 1 g of sodium molybdate per litre of water.

References

28, 40, 106.



44. Zinc deficiency in the top of a cucumber plant (cv. Sporu) grown in water culture.



45. Leaf of a zinc-deficient cucumber plant (cv. Sporu) grown in water culture.

Zinc deficiency

Symptoms

Slight interveinal mottling appears in older leaves, the pattern being coarser than in iron and manganese deficiency. Symptoms spread from older to younger leaves but are not severe; necrosis is not obvious. Youngest leaves grow irregularly and internodes remain small, giving shoot tops a peculiar bushy appearance. At that stage, growth is considerably restricted.

Incidence

Zinc deficiency is not to be expected in glasshouse crops, unless grown in nutrient solution without zinc.

Treatment

Spraying the crop with a solution of up to 5 g of zinc sulphate per litre.

References

28, 106.



46. Cucumber (cv. Sporu) leaf burn caused by too heavy an application of ammonium nitrate limestone.



47. Detail of leaf burn in cucumber.

Excess nitrogen

Symptoms

Plants are dark green and growth is reduced. Middle and older leaves are curved and petioles droop slightly. Transparent spots between veins or at the edges coalesce and turn yellow to brownish grey. Affected leaves and petioles wilt, the older leaves first. Fruits are smaller than usual. In acute toxicity the entire plant collapses within a few days.

Incidence

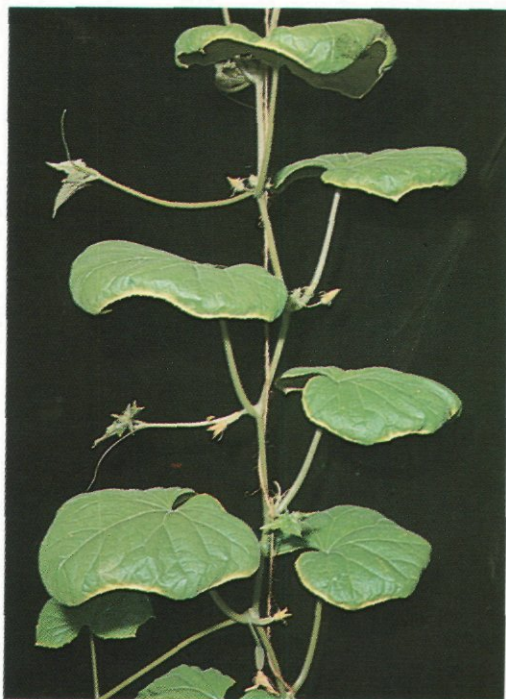
Chronic symptoms occur on soils rich in readily soluble nitrogen, especially if insufficiently watered. Acute toxicity may be caused by too heavy dressings and uneven distribution of nitrogen fertilizers; coarse- textured soils require special care.

Treatment

Water plants amply and restrict transpiration as much as possible. Plants may recover if they do not wilt.

References

3, 27, 28, 64, 67.



48. Gherkin plant (cv. Levo) grown on sphagnum peat and showing boron toxicity.



49. Boron toxicity in cucumber leaf from a plant (cv. Sporu) in water culture.

Excess boron

Symptoms

Edges of older leaves turn yellowish green, droop and wither. Leaves tend to cup downward and are more circular than usual. Symptoms progress from the base of the plant upwards, oldest leaves being affected first. In more advanced stages necrotic spots develop between veins. These spots coalesce into large brownish transparent patches, which feel papery; finally the leaf withers. Growth is stunted, upper leaves remain small and few female flowers, if any, are produced.

Incidence

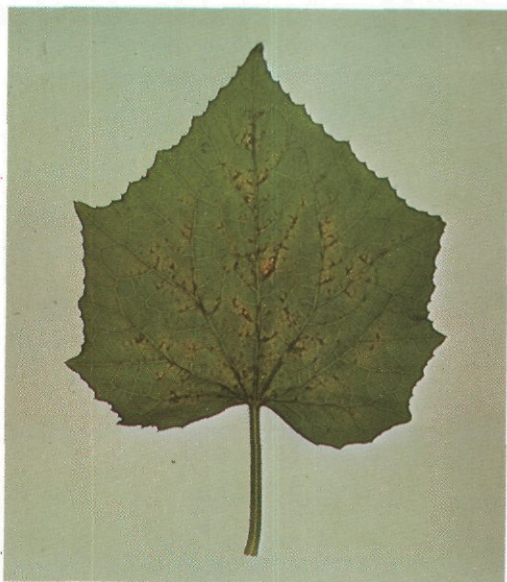
Toxicity is easily caused by careless use of boron fertilizers.

Treatment

Leach the soil, preferably with hard water. Probably plants tolerate more boron at high pH. Liming of acid soils is recommended.

References

13, 26, 27, 28, 67, 68, 73, 81, 82, 175, 187.



50. Manganese toxicity in a gherkin leaf from a plant (cv. Levo) on sphagnum peat.



51. Detail of a cucumber leaf (cv. Sporu) showing manganese toxicity (red veins).

Excess manganese

Symptoms

Veins of the oldest leaves turn dark red or reddish brown, and light green or transparent spots appear between veins. As discoloration advances, necrosis develops and leaves die. The symptoms progress from lower leaves upwards. In severe toxicity plants are stunted and stems, petioles and leaves are covered with numerous purple dots.

Incidence

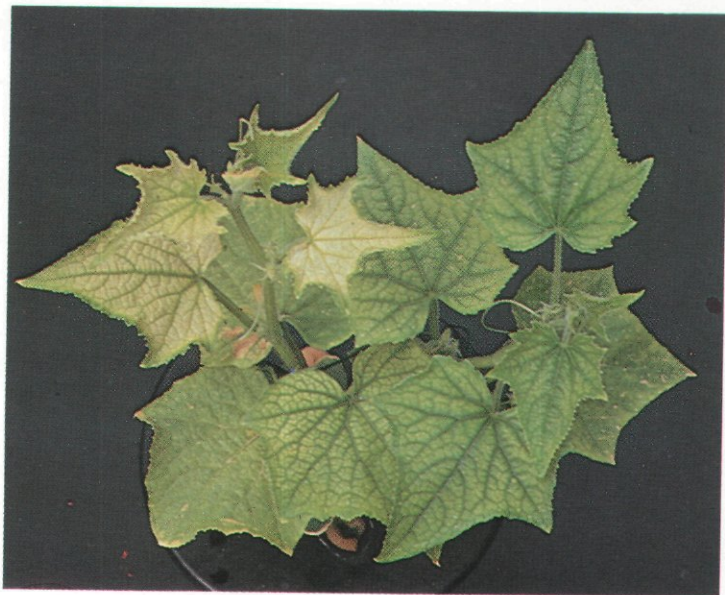
Steaming releases much plant-available manganese and may induce toxicity in later crops, especially at low pH.

Treatment

Lime the soil.

References

28, 67, 81, 82, 119, 234.



52. Zinc toxicity in the top of a cucumber plant (cv. Sporu) grown in water culture.

Excess zinc

Symptoms

Plants are severely stunted. Chlorotic symptoms resembling those of iron deficiency appear in the youngest leaves. Later, symptoms spread to older leaves.

Incidence

Soil-borne toxicity is possible near zinc and metal smelters. The disorder may also occur in cucumber or gherkin crops grown in glasshouses with galvanized frames. It can be expected with nutrient solutions if the watering system contains galvanized materials.

Treatment

Apply lime and phosphate to reduce zinc availability to plants.

References

28, 67.



53. Lettuce (cv. Noran) from a trial plot in a commercial glasshouse; left with, right without nitrogen.



54. Nitrogen deficiency in commercially grown lettuce (cv. Noran).

Nitrogen deficiency

Symptoms

Growth is restricted and foliage yellowish green. With severe deficiency older leaves turn pale and eventually decay. Leaf shape is normal. With severe stunting, no head is formed in the youngest leaves. Nitrogen-deficient plants often have a dense root system. A purple flush develops in cultivars with anthocyanin. Some authors mention smooth leaves, other describe leaves as tough.

Incidence

Deficiency occurs in various soils with insufficient nitrogen fertilizer, particularly in coarse-textured soils watered excessively, and on peat blocks if the potting compost has been leached by rain for long.

Treatment

For coarse-textured soils subject to leaching, top dress once or twice with a solution containing about 300 mg of N per litre, preferably as nitrate. Spraying is possible but less effective.

References

28, 57, 87, 96, 98, 121, 143, 159, 212, 213, 216, 247, 249.



55. Phosphorus deficiency in lettuce (cv. Valore) from a trial plot in a commercial glasshouse.

Phosphorus deficiency

Symptoms

Plants are stunted but show no clear symptoms. They head late, if at all, looking flat and rosette-like. Older leaves die with severe deficiency. Cultivars with anthocyanin have purple or red tints. Generally leaves are darker than normal.

Incidence

Deficiency occurs in newly built glasshouses on poor arable soils, on ploughed grassland unless enough fertilizer is supplied, on soils levelled by excavating or pumping mud or sand, and on peat blocks unless dunged or dressed with inorganic phosphate.

Treatment

Apply phosphate fertilizer, on levelled soils at least 100 g of P_2O_5 (44 g P) per square metre as triple superphosphate or dicalcium phosphate. After planting out, the soil may be watered with phosphate, but a basal dressing is more effective. When raising young plants on peat blocks, apply 200 to 500 mg of P_2O_5 (87 – 219 mg P) per cubic metre peat.

References

28, 29, 57, 83, 87, 96, 98, 121, 143, 159, 212, 213, 216, 246, 249.



56. Potassium-deficient lettuce plant (cv. Deci-Minor).



57. Potassium deficiency in cos lettuce (cv. Romaine Grise Maraichère) grown on sphagnum peat.

Potassium deficiency

Symptoms

Changes are not obvious, though moderate lack of potassium reduces growth. Leaves are less crinkled and darker green than normal. With severe deficiency they become more petiolate, more rounded or heart-shaped (older leaves) and mottled dark green. Chlorotic spots develop at the tips of older leaves, coalesce later and may become necrotic. Cultivars with anthocyanin have purple margins.

Incidence

Deficiency occurs in young plants on oligotrophic peat without inorganic fertilizer or dung, in newly built glasshouses on poor soils, and in older glasshouses if fertilization is neglected. In commercial glasshouses deficiency is rare, as the nutrient is generally applied in liberal amounts in a rotation with crops more responsive than lettuce.

Treatment

Apply dung or 30 g of K_2O (25 g K) per square metre and twice the rate on potassium-fixing clays. To cure deficiency, apply 30 g of K_2O (25 g K) per square metre by sprinkling with a solution of 2 g of potassium nitrate fertilizer per litre or, for seedlings in peat blocks, a more concentrated solution as long as plants are washed afterwards. Spraying with potassium sulphate (20 g/litre) is less effective.

References

28, 31, 57, 87, 96, 98, 120, 121, 143, 159, 212, 213, 216, 248.



58. Magnesium deficiency in lettuce (cv. Rapide) grown in water culture.

Magnesium deficiency

Symptoms

Older leaves show a yellow discoloration, which spreads from the edges inwards between veins, also including smaller veins. Later they become mottled. Growth is only slightly stunted. In cultivars with anthocyanin, chlorotic areas have a purple flush, especially in older leaves. In acute deficiency symptoms first develop in younger leaves; growth becomes severely stunted and the chlorotic areas die.

Incidence

In practice, magnesium deficiency is mainly ascribed to poor root development in cold and wet soils.

Treatment

Cropping methods should be designed to promote root growth. For prevention, apply dolomite when liming, or kieserite. In acute deficiency, apply 100 g of $\text{MgSO}_4 \cdot 7 \text{H}_2\text{O}$ per square metre, preferably sprinkled as a solution of 10 g per litre. As with other crops, a good supply of nitrate is essential. High-volume or low-volume spraying with a solution of 20 or 100 g of $\text{MgSO}_4 \cdot 7 \text{H}_2\text{O}$ per litre, is also possible. It should be repeated a few times.

References

20, 57, 96, 98, 121, 143, 159, 216.



59. Calcium deficiency in lettuce (cv. Rapide) grown in water culture.

Calcium deficiency

Symptoms

Growth is severely stunted, the plant looks flat and the leaves have an open rosette growth. Growth is most restricted in the youngest leaves that are somewhat darker and more crinkled than normal.

Irregularly shaped brown to grey lesions develop in the margins of the youngest leaves and spread to older ones. They coalesce, causing leaves to die from the tips and margins inwards. The dead leaf tissue is greyish green. A light purple discoloration was sometimes observed in the middle leaves of cultivars with anthocyanin. Tipburn is sometimes looked upon as local calcium deficiency. According to the literature calcium-deficient lettuce is highly susceptible to *Botrytis cinerea*.

Incidence

Calcium deficiency is unknown in practice, but may occur in young plants raised on oligotrophic peat if no lime is added. Bad patches occurring in crops growing on lime-deficient soils may be caused by manganese and aluminium toxicity, or molybdenum deficiency.

Treatment

For prevention, apply 4 kg of lime per cubic metre oligotrophic peat. In glasshouse soils a minimum reserve of 2 g of calcium carbonate per kilogram of dry soil is favourable. Curing the deficiency is not feasible. If large acid patches occur, it is better to discard the crop and replant after liming the soil.

References

28, 57, 96, 98, 100, 143, 169, 207, 216.



60. Sulphur deficiency in lettuce (cv. Vitesse) grown in water culture.

Sulphur deficiency

Symptoms

The whole plant, particularly the heart, turns greenish yellow and growth is restricted. Leaves are less crinkled, thicker and stiffer than normal, and the older leaves look dull. Leaves of cultivars containing anthocyanin sometimes show a pale purple flush at the edge and in the tissue around the smaller veins. Growth of iceberg lettuce is stunted, but, in contrast to cos lettuce, the entire plant is slightly chlorotic.

Incidence

Sulphur deficiency is unknown in commercial glasshouses.

Treatment

Apply sulphate-containing fertilizers.

References

None.



61. Boron deficiency in lettuce (cv. Vitesse) grown in water culture.



62. Boron deficiency in cos lettuce (cv. Romaine Grise Maraichère) grown in water culture (longitudinal section).

Boron deficiency

Symptoms

Plants are darker than normal and severely stunted. Butterhead lettuce is rosette like. Leaves, especially the youngest ones, are stiff and rounded with chlorotic mottling at the edges and between the veins. Cultivars with anthocyanin are discoloured purplish brown. Brown spots develop at the growing point and in the youngest folded leaves. In acute deficiency, the growing point dies. Roots develop extremely poorly. Dwarfing and a dark colour are characteristic of boron deficient iceberg and cos lettuce. Boron deficiency may be mistaken for tipburn, especially latex-tipburn.

Incidence

Boron deficiency in lettuce grown in Dutch commercial glasshouses has not been observed. It may occur after excessive liming of sandy soils dressed with much oligotrophic peat and little or no manure. Boron deficiency may occur in young plants raised on oligotrophic peat, but has not been observed.

Treatment

For prevention, apply sodium borate but only after soil analysis. To cure deficiency, distribute evenly 2 g of sodium borate per square metre and spray a solution of 1 g per litre. Oligotrophic peat should receive 10 g per cubic metre.

References

2, 28, 39, 57, 88, 91, 127, 143, 146, 147, 154, 177, 192, 201, 207.



63. Copper deficiency in lettuce (cv. Deci-Minor) grown in water culture.



64. Leaves of a copper-deficient plant (cv. Deci-Minor) grown on sphagnum peat.

Copper deficiency

Symptoms

The plant lacks firmness and growth is reduced. Leaves are narrow and cupped, and as chlorosis develops along the edges, they curl downward. Later, the leaves yellow and wilt from the edge and tip inwards towards the base, the veins turning pink. Symptoms progress from older to younger leaves.

No heads are formed.

Incidence

Copper deficiency is unknown in glasshouses. In trials, it was noticed in young plants growing on sphagnum peat without copper.

Treatment

Add 10 g of copper sulphate per cubic metre of oligotrophic peat as a precaution. Plants may be sprayed with copper sulphate at concentrations up to 1 g per litre.

References

8, 28, 57, 80, 143, 192, 194, 201.



65. Iron deficiency in lettuce (cv. Noran) grown in water culture.



66. Iron deficiency in lettuce (cv. Magiola) grown in water culture.

Iron deficiency

Symptoms

The whole plant turns pale green and growth is stunted. Older leaves are mottled as the veins, especially the larger ones, are less chlorotic than the interveinal tissue. In later stages, the youngest leaves particularly turn pale yellow and the veins become chlorotic too. Growth stops completely and the older leaves die. Usually, leaves are less crinkled than normal, also in iceberg lettuce. In cultivars with anthocyanin, a purple flush was noticed in the youngest leaves affected by acute iron deficiency.

Incidence

Iron deficiency may occur on calcareous loam soils of unstable structure. We know no quantitative data on its occurrence in practice.

Treatment

To cure deficiency, apply iron chelates: 5-10 g of Fe-EDDHA or 12-20 g of Fe-DTPA per square metre.

References

96, 143.



67. Manganese deficiency in lettuce (cv. Noran) grown in water culture.

Manganese deficiency

Symptoms

The entire plant turns greenish yellow but growth is only slightly stunted. Leaves are smoother than normal. Iceberg and cos lettuce turn yellowish green. With acute deficiency the older leaves especially become chlorotic but the veins, including the smallest ones, remain green. Cultivars with anthocyanin show no red discoloration.

Incidence

Manganese deficiency may occur on calcareous loam soils and on excessively limed sand or peat soils. The extent of the disorder in practice is unknown.

Treatment

High-volume spraying with a solution of 1 g of manganese sulphate per litre or low-volume spraying with 10 g per litre will cure the deficiency. Two treatments each of 25 g manganese sulphate per square metre, with or without ammonium sulphate, may be applied in liquid form with a sprinkler-irrigation system.

References

28, 57, 143, 159, 216.



68. Molybdenum-deficient plant (cv. Desico) grown in a peat block.



69. Leaves of a molybdenum-deficient lettuce plant showing necrotic spots.

Molybdenum deficiency

Symptoms

Young plants turn pale green, the cotyledons remaining somewhat darker. Leaves wither from the tip and margins inwards, the dying tissue turning brownish yellow. Transparent spots which later become necrotic and coalesce, may appear on leaves of older plants. Symptoms progress from older to younger leaves, which stay alive longest. Growth of both foliage and roots is severely restricted and plants may collapse.

Incidence

Molybdenum deficiency may occur in young plants raised on oligotrophic peat without added nutrient. It is promoted by a low pH and a high sulphate content of the medium; low light intensity may also play a part.

Treatment

For prevention, lime the soil and apply 5 g of ammonium or sodium molybdate per cubic metre of potting soil. In acute deficiency, apply 150 mg of ammonium or sodium molybdate per square metre in ample water. Spraying with a solution of 0.5 g of these fertilizers per litre is also possible.

References

26, 28, 53, 57, 76, 102, 103, 135, 143, 156, 157, 158, 159, 165, 172, 173, 174, 182, 194, 200, 214, 229, 230, 242.



70. Zinc deficiency in lettuce (cv. Deci-Minor) grown in water culture.



71. Lettuce leaf showing zinc deficiency (bottom and right top of the leaf were shaded by other leaves during growth).

Zinc deficiency

Symptoms

Affected plants have a rosette appearance and growth is restricted. At first no chlorosis develops. Later, large papery necrotic spots with a dark margin appear along leaf edges, especially in the interveinal tissue. As leaf areas not exposed to light remain green and fresh, the plant looks typically 'scorched'. The symptoms commence in older leaves and progress to younger ones.

Incidence

Zinc deficiency in crops grown outdoors is only known in some parts of the world. Glasshouse lettuce is unlikely to show deficiency symptoms.

Treatment

To cure deficiency, spray with a solution of 0.5 g of zinc sulphate per litre.

References

28, 30, 143, 181.



72. Excess nitrogen in lettuce (cv. Rapide) grown on sphagnum peat; right, part of a normal plant.

Excess nitrogen

Symptoms

Plants are dark or greyish green and have a rosette appearance. Growth is inhibited. Leaves are small, rounded and more crinkled than normal, and resemble spinach leaves. In cultivars with anthocyanin, the margins of younger leaves may turn red. The symptoms are like those caused by excess sodium chloride. In trials, tipburn is sometimes associated with high nitrogen dressings. However, crops with growth reduced by excess nitrogen are less susceptible to tipburn.

Incidence

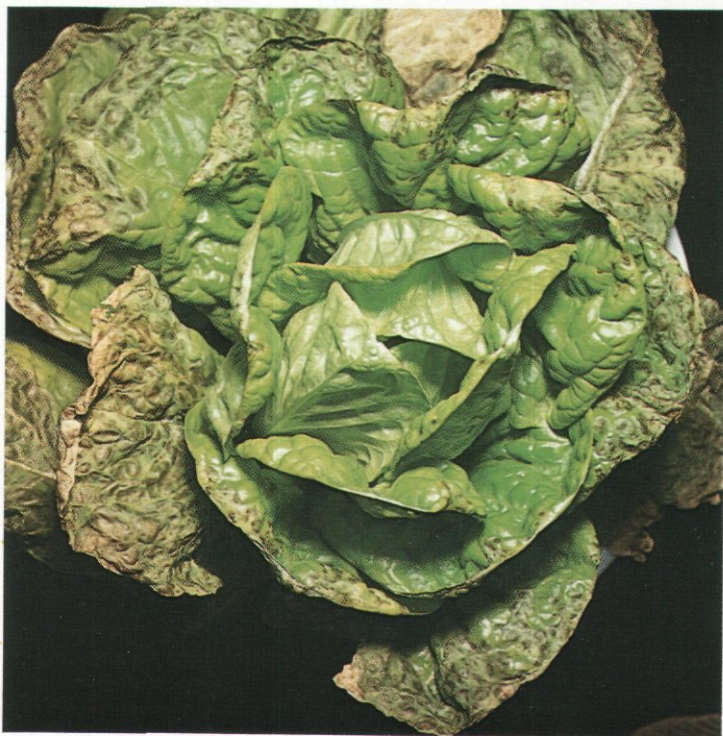
Symptoms occur on soils rich in readily soluble nitrogen, especially if insufficiently watered.

Treatment

To cure toxicity, apply ample water.

References

None.



73. Boron toxicity in lettuce, grown in sand culture.

Excess boron

Symptoms

Along the edges of older leaves brownish grey sunken spots develop into a ring-shaped pattern, with dark brown veins (perceptible if the leaf is held against the light). As the toxicity becomes more severe, the spots coalesce and desiccate, making the tissue of the entire leaf tip papery to the touch. Symptoms start in older leaves and progress to younger leaves, the youngest ones continuing to grow almost normally.

Incidence

Toxicity is easily caused by applying too much boron fertilizer and so great care should be taken in using such material.

Treatment

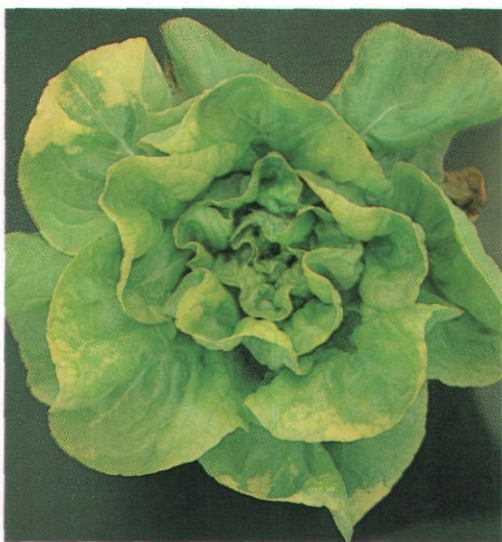
Slight symptoms may be suppressed by heavy watering. In severe toxicity discard the crop and leach the soil. Additional measures are liming or applying large amounts of limed oligotrophic peat.

References

19, 28, 69, 127, 143, 154, 241.



74. Manganese toxicity in lettuce (cv. Noran) of a (unsteamed) trial plot of low pH in a commercial glasshouse.



75. Manganese toxicity in lettuce (cv. Deci-Minor) grown in water culture.

Excess manganese

Symptoms

The veins, particularly the smaller ones, of older leaves turn brown. Leaves may show severe marginal chlorosis. Small necrotic spots develop, especially at the leaf tip and the margins of the leaf base. The spots coalesce into larger ones, causing leaves to desiccate from the margins inwards. As older leaves die and younger leaves are stunted the developing head is loose and tulip-shaped. Symptoms and susceptibility vary with cultivar.

Incidence

Steaming of clay and loam soil releases much plant-available manganese and may induce toxicity, especially at low pH. On very acid soils, the disorder may also occur without steaming. In hydroponic culture, the problem may arise with moderate Mn concentrations in the nutrient solution.

Treatment

For prevention, lime the soil. In hydroponic culture, pH should be checked regularly and silicate may be added to reduce manganese toxicity.

References

9, 24, 26, 28, 70, 97, 101, 119, 125, 143, 152, 167, 174, 196, 197, 198, 199, 210, 211, 236, 237, 241.



76. Zinc toxicity in lettuce (cv. Deci-Minor) grown in water culture.



77. Zinc toxicity in iceberg lettuce (cv. Great lakes) grown in water culture.

Excess zinc

Symptoms

The plant shows a brownish yellow flush and growth is stunted. Sometimes red-brown spots develop on the main veins and the surrounding leaf tissue, especially in middle leaves. With acute toxicity, leaves are cupped and erect and no head is formed. The oldest leaves are affected most, whole leaves yellowing, wilting and dying.

Incidence

Zinc toxicity in lettuce has not been observed so far in practice. The disorder might occur in glasshouses with galvanized frames, and in hydroponic culture if the nutrient solution is in contact with galvanized materials.

Treatment

Apply lime and phosphate to reduce availability of soil zinc. Avoid using galvanized parts in watering systems.

References

28, 143, 167.

Table 2. Content of nutrients in dry matter of leaves from healthy tomato plants and from plants with deficiency or toxicity symptoms. Content of dry matter ranges from 90 to 120 g with 116 g as an average per kg of fresh leaves.

Nutrient element	Healthy		Deficiency	Toxicity	Remarks
	range	mean			
Nitrogen (mol/kg)					
- total N	2.0-3.5	2.64	<1.7		
- nitrate N	0.20-0.70		<0.07		
Phosphorus (mol/kg)	0.13-0.21	0.15	<0.07		
Potassium (mol/kg)	0.7-1.5	0.97	<0.30		
Magnesium (mol/kg)	0.15-0.35	0.28	<0.12-0.15		
Calcium (mol/kg)	0.6-1.8	0.92	<0.17		
Sulphur (mol/kg)					
- total S	0.3-1.0	0.55	<0.15		
- sulphate S	0.2-0.8	0.45			
Boron (mmol/kg)	3-9	6.9	<2.7	> ± 15	
Copper (mmol/kg)	0.16-0.25	0.20	<0.10		
Iron (mmol/kg)	1.8-7	4.4	<1.4-1.8		Not diagnostic
Manganese (mmol/kg)	1.0-7	4.8	<0.5	> ± 10	
Molybdenum (mmol/kg)	0.01-0.10	0.06	<0.002		
Zinc (mmol/kg)	0.3-1.3	0.69	<0.3	> ± 5	

Table 3. Content of nutrients in dry matter of leaves from healthy cucumber plants and from plants with deficiency or toxicity symptoms. Content of dry matter ranges from 80 to 110 g with 98 g as an average per kg fresh leaves.

Nutrient element	Healthy		Deficiency	Toxicity	Remarks
	range	mean			
Nitrogen (mol/kg)					
- total N	1.8-3.6	2.96			
- nitrate N	0.07-1.0	0.24	<0.07	1.3	
Phosphorus (mol/kg)	0.11-0.25	0.17	<0.07		
Potassium (mol/kg)	0.5-1.5	0.97	<0.4-0.5		
Magnesium (mol/kg)	0.2-0.8	0.42	<0.10		
Calcium (mol/kg)	0.5-2.5	1.19	<0.5		
Sulphur (mol/kg)					
- total S	0.13-0.30	0.19	<0.08		
- sulphate S	0.05-0.28	0.13			
Boron (mmol/kg)	2.8-10	7.0	<2.5	>25	
Copper (mmol/kg)	0.03-0.3	0.20	<0.03		
Iron (mmol/kg)	1.7-5.4	4.2	<0.9-2.7		Not diagnostic
Manganese (mmol/kg)	0.9-11	5.8	<0.4-0.7	> ± 10	
Molybdenum (mmol/kg)	0.01-0.06	0.032	<0.008-0.010		
Zinc	0.9-3.0	2.1	<0.3	> ± 10	

Table 4. Content of nutrients in dry matter of heads from healthy lettuce plants and from plants with deficiency or toxicity symptoms. Content of dry matter ranges from 45 to 65 g with 53 g as an average per kg of fresh heads.

Nutrient element	Healthy		Deficiency	Toxicity	Remarks
	range	mean			
Nitrogen (mol/kg)					
- total N	1.5-4.0	2.8			
- nitrate N	0.4-1.5	0.58			Depends on date of harvest or light intensity
Phosphorus (mol/kg)	0.13-0.3	0.19	<0.19		More in glass-house crops than in the open
Potassium (mol/kg)	1.0-2.5	1.5	<1		
Magnesium (mol/kg)	0.15-0.37	0.21	<0.12		
Calcium (mol/kg)	0.22-0.50	0.30	<0.2		
Sulphur (mol/kg)					
- total S	0.06-0.13	0.09	<0.08 (?)		
- sulphate S	0.03-0.07	0.04	<0.03 (?)		
Boron (mmol/kg)	2.0-6.0	3.7	<2	>5-6	
Copper (mmol/kg)	0.08-0.27	0.17	<0.04		
Iron (mmol/kg)	1.0-10	4.32			Values vary widely
Manganese (mmol/kg)	0.55-3.6	2.09	<0.4	>3.6-5.5	
Molybdenum (mmol/kg)	0.002-0.04	0.18	<0.002-0.003		
Zinc (mmol/kg)	0.5-3.0	1.0	<0.4	>6	

Table 5. Content of nutrients in dry matter of fruits from healthy tomato or cucumber plants. Content of dry matter ranges from 45 to 75 g with 60 g as an average and from 25 to 55 g with 40 g as an average per kg fresh fruits, respectively.

Nutrient element	tomato	cucumber
Nitrogen (mol/kg)		
– total N	1.2-2.5	1.5-3.2
– nitrate N	0.02-0.03	0.00-0.3
Phosphorus (mol/kg)	0.09-0.26	0.16-0.35
Potassium (mol/kg)	0.7-1.5	0.8-1.9
Magnesium (mol/kg)	0.05-0.12	0.07-0.25
Calcium (mol/kg)	0.035-0.09	0.06-0.27
Sulphur (mol/kg)		
– total S	0.03-0.08	0.10-0.13
– sulphate S	0.015-0.05	0.09-0.12
Boron (mmol/kg)	0.8-2.5	2.3-6.7
Copper (mmol/kg)	0.09-0.31	0.12-0.20
Iron (mmol/kg)	0.6-2.7	0.9-3.6
Manganese (mmol/kg)	0.16-0.60	0.55-1.2
Molybdenum (mmol/kg)	0.002-0.015	0.02-0.03
Zinc (mmol/kg)	0.25-0.8	0.5-1.5

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