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# PHYTOTOXICITY OF WOOD PRESERVATIVES AND POSSIBILITIES OF USING THEM IN GREENHOUSES AND BENCHES

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*SELOSTUS:*

*LAHOSUOJA-AINEIDEN MYRKYLLISYYDESTÄ KASVEILLE SEKÄ NIIDEN KÄYTTÖMAHDOLLISUUKSISTA KASVIHUONE- JA LAVARAKENTEISSA*

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## Introduction

With the growing use of wood preservatives in Finland since the 1940's it appeared that neither the builders of greenhouses nor the manufacturers and sellers of wood preservatives were aware of the fact that, because of their toxicity to growing plants, not all the compounds found effective as wood preservatives were suitable for use in greenhouse constructions. The Department of Plant Pathology of the Agricultural Research Centre received a number of samples of plants, particularly from cucumber and tomato growers, but also samples of ornamental plants, injury and often complete destruction of which was found to be caused by the treatment of the greenhouse construction materials with wood preservatives. Damage caused by certain wood preservatives had earlier been noted, e. g. in Germany, Sweden and the U.S.A. Since very little information based on plant biological tests was available concerning the toxicity of many wood preservatives in common use, particularly in Finland, it was considered necessary to carry out an investigation as to the suitability of the different types of wood preservatives on the Finnish market for the impregnation of greenhouse and bench constructions (cf. LINNASALMI 1956).

## Material and method

The following wood preservatives and solvents were used in the experiments:

W a t e r - s o l u b l e:

Boliden salt (BIS), content: arsenic acid 27.3 %, sodium arsenate 23.8 %, sodium dichromate 18.1 %, zinc sulphate 30.8 %; Algol Oy, Helsinki

Celcure, content: cupric sulphate 45 %, chromic acetate 5 %, sodium dichromate 50 %; Flinkenberg & Co Oy, Helsinki

Lahontuho K 33, content: arsenic pentoxide 35 %, chromiumtrioxide 27.42 %, cupric oxide 15.27 %; Rikkihappo- ja superfosfaattitehtaat Oy, Helsinki

Wolman salt (Tancas), content: sodium fluoride 25 %, sodium arsenate 25 %, sodium dichromate 37.5 %, dinitrophenole 12.5 %; Sulo Attila, Helsinki

Oily and oil-soluble:

copper naphthenate techn.
Aspergol KT, active compound copper naphthenate; Teknos-Tehtaat, Oy Pitäjänmäki

creosote techn.
Rusko, active compound creosote; Uittokalusto Oy, Helsinki
wood tar techn.

pentachlorophenol techn.
Valtti, active compound pentachlorophenol; Tikkurilan Väritehtaat, Tikkurila
Woodlife, active compound pentachlorophenol; Uittokalusto Oy, Helsinki

Solvents:

petroleum techn.
turpentine techn.

Splints of pine sapwood, 11 × 2 × 0,3 cm. in size, were impregnated for the experiments in the following ways: [1])

1. The impregnation with water-soluble compounds was performed by immersing the splints for 10 minutes into a 2 per cent impregnation liquid in a vacuum cylinder. The vacuum was subsequently removed when the substance had penetrated the splints. The splints were dried for 2 weeks in the laboratory at 22° C.

2. The oil-soluble wood preservatives pentachlorophenol and copper naphthenate were dissolved in the highly volatile solvent benzene, and the splints were immersed for 3 minutes in this solution. The impregnation with the commercial preparates containing these compounds, and with creosote, was carried out by keeping the splints for 3 minutes in the preparates. The wood tar was applied to the splints with a brush. After the treatments the splints were first dried for 2 weeks in the laboratory at about 22° C, and subsequently in a thermostat at 45° C for 24 hours.

3. The splints were dipped into the solvents petroleum and turpentine and then dried for 48 hours at about 22° C in the laboratory.

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[1]) The impregnation was carried out at the Wood Preservation Section of the State Institute for Technical Research, under the supervision the of Head of the Section, Dr. Osmo Suolahti, to whom I wish to express my best thanks.

The experiments were carried out as 12 experimental series in a heatable greenhouse (Table 1). The temperature of the greenhouse was measured with an automatic thermograph ('Lambrecht'). The following test plants were chosen as representing different types of vegetable and ornamental plants: cabbage, cucumber, swede, tomato, cineraria, cyclamen and tulip.

The test plants were sowed or planted in wooden boxes, 40 × 30 × 18 cm. in size, containing sandy leaf mould. The number of seedlings of cabbage, swede and tomato per box in the sowed series was about 50, that of cucumber about 30; there were 3—4 seedlings of each plant species per box in the planted series, and 12 tulip bulbs per box. The age of seedlings in the planted series at the start of the tests was: cucumber 4—5 weeks, except in series 8, 14 weeks; tomato 8—10 weeks, except in series 8, 14 weeks; swede 3 weeks; cineraria 6 weeks; cyclamen 36 weeks; tulip see Table 1, note [1]).

In the first test series (1) the boxes were kept covered with a sheet of glass for 3 weeks, leaving, however, an opening of about 1 cm. for ventilation. In the other test series each box was kept in its own glasswalled case, 45 × 45 × 80 cm. in size, which was open at the bottom. One side of each case had to be opened to facilitate watering and also for making observations. Adequate ventilation was secured from below through the splits of the greenhouse desk.

The following possible causes of damage had to be taken into account:

a. The toxic effect exerted on the plants by the compounds which pass from the preserved wood into the mould.

b. The toxic effect on the plants of the compounds which volatilize into the air from the preserved wood.

c. The toxic effect exerted on the plants by the compounds that dissolve from the preserved wood into dripping or irrigation water.

To study these different ways of causing damage the following test groups were arranged:

Soil group (a): the impregnated splints, 20 per box, except in series No. 3, where there were 50 per box, were placed vertically and at equal distances from each other in the mould at the bottom of the box in such a way that they were completely covered by mould (a mould layer of about 0.5—1 cm). Boxes with unimpregnated splints acted as controls.

Air group (b): the impregnated splints were hung in two rows on the walls of the cases, at a distance of 15 cm. and 40 cm. from the surface of the mould. In test series 2 and 4—12 there were 20 splints per case, the ratio of the total surface area of the splints to the volume of the glass cases being about 15 per cent greater than the ratio of the surface area of the standard type greenhouse wooden constructions to the cubic dimensions of the greenhouse; in test series 3 there were 50 splints per glass case, the corresponding ratio being

*Table 1. — Taulukko 1.* **Data on experimental technique** — ***Koeteknillisiä tietoja***

| Test series No. *Koesarja N:o* | Test plants *Koekasvit* — species and variety *laji ja lajike* | Test period *Koeaika* | Temperature + °C *Lämpötila + °C* — aver. minim. *keskim. min.* | aver. maxim. *keskim. maks.* | Time from treatment of soil and air group splints to start of test, months *Aika maa- ja ilmaryhmän koetikkujen käsittelystä kokeen alkuun, kk.* | Spray group *Suihkutusryhmä* — extract [7]) No. *uute [7]) no* | concentr. % *konsentr. %* | quantity of spray per time ml/case *suihkutemäärä kerrallaan ml/häkki* | spraying started *suihkutus alettu* | total number of sprayings *suihkutuskertoja yhteensä* |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | cucumber, Muromsk — *kurkku* .......<br>tomato, Dansk Eksport — *tomaatti* ...<br>cabbage, Ditmarsk Treib — *kupukaali* | 18. 7.—13. 8. 1952 | 15.0 | 25.7 | 2 | 1 | 14 | 30 | 21. 7. | 12 |
| 2 | cucumber, Muromsk — *kurkku* .......<br>tomato, Dansk Eksport — *tomaatti* ...<br>swede, Tammisto — *lanttu* ......... | 15. 9.—26. 10. 1954 | 14.1 | 24.5 | 2 | 3 | 50 | 12 | 2. 10. | 14 |
| 3 | cucumber, Perseus — *kurkku* ........<br>tomato, Selandia — *tomaatti* ......... | 20. 4.— 3. 6. 1953 | 17.8 | 30.4 | 2 | 2 | 100 | 25 | 29. 4. | 7 |
| 4 | cucumber, Perseus — *kurkku* ........<br>tomato, Selandia — *tomaatti* ......... | 10. 6.—21. 7. 1953 | 16.9 | 31.8 | 2 | 2 | 50 | 25 | 13. 6. | 17 |
| 5 | cineraria, Københavns Torve — *sineraaria* ........................<br>cyclamen, Evelens' Stam — *syklaami* | 26. 8.—14. 10. 1953 | 16.4 | 26.0 | 2 | 2 | 50 | 25 | 3. 9. | 13 |
| 6 | tulip, William Copland — *tulppaani* | 30. 3.—23. 4. 1954 ([1] | 15.3 | 27.6 | 2 | 3 | 50 | 25 | 1. 4. | 12 |
| 7 | cucumber, Perseus — *kurkku* ........<br>tomato, Selandia — *tomaatti* .........<br>swede, Tammisto — *lanttu* .......... | 20. 5.—15. 7. 1954 | 16.3 | 25.1 | 6 | — | — | — | — | — |
| 8 | cucumber, Muromsk — *kurkku* .......<br>tomato, Dansk Eksport — *tomaatti* ... | 24. 7.—26. 8. 1954 | 16.7 | 26.2 | [2]) 8 | — | — | — | — | — |
| 9 | cucumber, Perseus — *kurkku* ........<br>tomato, Selandia — *tomaatti* ......... | 14. 5.— 6. 7. 1955 | 16.6 | 22.5 | [3]) 18 | | — | — | — | — |
| 10 | cucumber, Perseus — *kurkku* ........<br>tomato, Selandia — *tomaatti* ......... | 22. 9.—20. 11. 1955 | 16.7 | 22.1 | [4]) 22 | — | — | — | — | — |
| 11 | cucumber, Perseus — *kurkku* ........<br>tomato, Selandia — *tomaatti* ......... | 19. 3.—30. 4. 1956 | 14.7 | 25.6 | [5]) 28 | — | — | — | — | — |
| 12 | cucumber, Perseus — *kurkku* ........<br>tomato, Selandia — *tomaatti* ......... | 16. 7.—31. 8. 1956 | 14.4 | 23.9 | [6]) 32 | — | — | — | — | — |

[1]) Bulbs planted in boxes, dug in and covered with soil 29. 10. 1953—30. 3. 54, shoots at start of test 7—10 cm
*Sipulit laatikoihin istutettuina aumassa 29. 10. 1953—30. 3. 54, versot kokeen alussa 7—10 cm*

[2]) Valtti and Valtti & varnish 5 months earlier
*Valtti ja Valtti & lakka 5 kk, aikaisemmin*
[3]) — » — 14 — » — — » —
[4]) — » — 18 — » — — » —
[5]) — » — 24 — » — — » —
[6]) — » — 28 — » — — » —
[7]) analyses p. 31 — *analyysit s. 31*

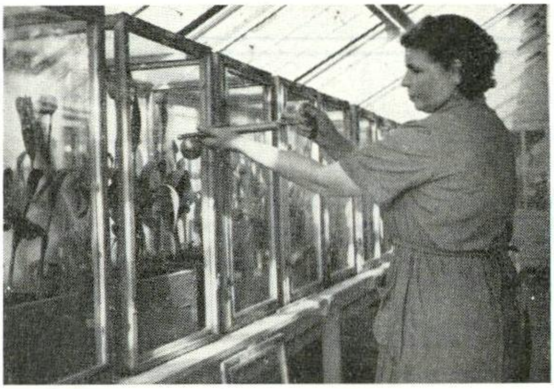


Fig. 1. Soaking water of wood, treated with salt preservatives, sprayed with small hand spray.

*Kuva 1. Suihkutus suolakyllästetyn puun liotusvedellä pientä käsiruiskua käyttäen.*

about 38 per cent. The controls consisted of cases with corresponding amounts of unimpregnated splints. In test series 1, in which the splints, 27 per box, were lightly pressed into the mould where they stood erect with 0.5 cm. of their length under the soil, the ratio of the total surface area of the splints to the air space under the covering glass was 1.5. Boxes with unimpregnated splints served as controls.

| Number of test series | 1 | | | 2 | | | 3 | | | 4 | | | 5 | | | 6 | | | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Test groups | a | b | c | a | b | c | a | b | c | a | b | c | a | b | c | a | b | c | b | b | b | b | b | b |
| Water soluble | | | | | | | | | | | | | | | | | | | | | | | | |
| Boliden salt | × | × | × | | | | × | | × | × | | × | × | | × | × | | × | | | | | | |
| Celcure | | | | × | × | × | | | | | | | | | | × | | × | | | | | | |
| Lahontuho | × | × | × | × | × | × | × | | × | × | | × | × | | × | × | | × | | | | | | |
| Wolman salt | × | × | × | × | × | × | × | | × | × | | × | × | | × | × | | × | | | | | | |
| Oily and oil-soluble | | | | | | | | | | | | | | | | | | | | | | | | |
| copper naphthenate | × | × | | × | × | | × | × | | × | × | | × | × | | × | × | | × | × | × | × | | |
| Aspergol KT | | | | | | | | | | | | | | | | | | | | | × | | | |
| creosote | | | | × | × | | × | × | | × | × | | × | × | | × | × | | × | × | × | × | × | × |
| Rusko | × | × | | | | | | | | | | | | | | | | | | | | | | |
| wood tar | × | × | | × | × | | × | × | | × | × | | × | × | | × | × | | × | × | × | × | | |
| pentachlorophenol | | | | × | × | | × | × | | × | × | | × | × | | × | × | | × | × | × | × | × | × |
| Valtti | | | | | | | | | | | | | | | | | | | | × | × | × | × | × |
| Valtti & varnish | | | | | | | | | | | | | | | | | | | | × | × | × | × | × |
| Woodlife | × | × | | | | | | | | × | × | | | | | | | | | | | | | |
| Solvents | | | | | | | | | | | | | | | | | | | | | | | | |
| petroleum | × | × | | × | × | | × | × | | × | × | | × | × | | × | × | | × | × | × | × | | |
| turpentine | | | | × | × | | × | × | | × | × | | × | × | | × | × | | × | × | × | × | | |

[1]) a = soil group, b = air group, c = spray group

Spray group (c): splints impregnated with the water-soluble substances were soaked for one week in water at about 22°C (90 splints + 2.8 l. $H_2O$) and this solution as such or diluted with water was sprayed on the test plants every second day (cf. Table 1). The controls were sprayed with a corresponding amount of pure water. The spraying was done with a small hand spray equipped with a very fine nozzle (Fig. 1).

The compounds, together with the groups tested in each series, appear in the table on page 10, x denoting the inclusion of the compound in the test.

The intensity of damage, based on daily observations, was calculated using the scale 0—10. The exact definition of the different grades in this kind of scale is very difficult, owing to the great variation in the types of damage in different cases. The principles on which the scale is based in the present study are approximately as follows:

1—2 slight damage, slight fading or darkening of the leaf tissues
3—4 slight drying, yellowing, curling or glossiness of the leaf margins or the leaf blade between the veins, slight retardation of growth
5—6 the above symptoms appearing more intensively, considerable retardation of growth
7—8 drying and death of the leaves, growth slow
9—10 the entire plant dying or completely dead

The graphic figures showing the damage to the test plants caused by the different compounds are based on evaluations with this scale.

## Results

### The effect of water-soluble wood preservatives on plants.

In the first and second (1,2) test series, containing all three test groups, the soil, air and spray groups, no kind of damage was to be found in any of the test plants in the a i r g r o u p. For this reason it was decided to exclude this group from the other test series.

During the experiments only one instance was found where damage through the s o i l could be detected. When the tulip test series (6) was being finished it was found that in the Boliden soil group the roots of all the bulbs were weaker in development than the roots of the control bulbs, and the tips of the roots were somewhat brownish, showing slight beginnings of decay, and dryish. When the damage to roots was calculated on the basis of an 0—10 scale (10 = completely healthy), Boliden was given the figure 7, while all the others were marked 10 (Fig. 2). No damage or disturbances in development were to be found in the shoots of the Boliden plants.

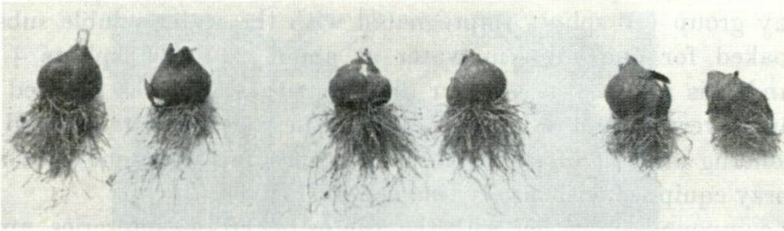


Fig. 2. Right, injuries caused by Boliden salt through soil in tulip roots; centre, Lahontuho; left, control bulbs. Photo after blooming. Test series 6 (a).

*Kuva 2. Oik. Boliden-suolavioitusta tulppaanin juuristossa maan kautta; keskellä Lahontuho-, vas. kontrollisipulit. Valok. kukinnan jälkeen. Koesarja 6 (a).*

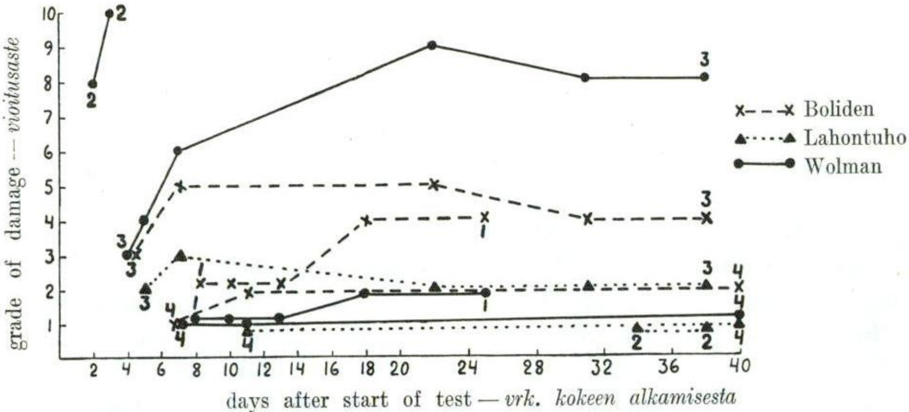
S p r a y t r e a t m e n t s with water extracts of salt compounds showed that some of their constituents can cause damage in plants when in direct contact with the shoots of the plants.

*Boliden and Wolman salts*

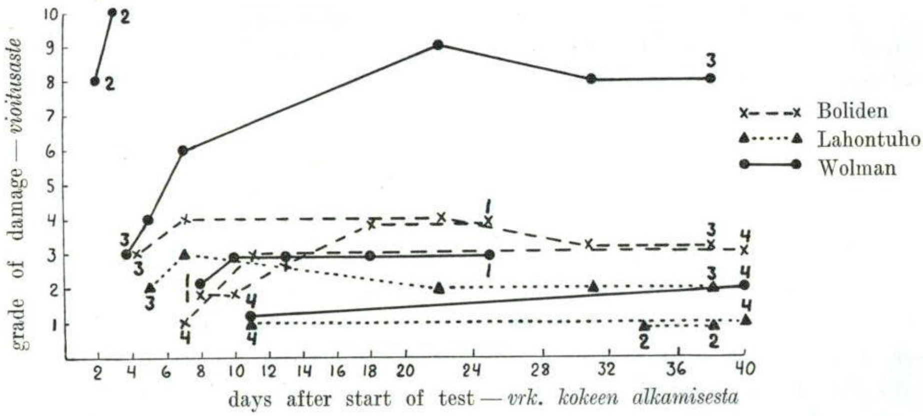
Sprayings with Wolman and Boliden were very injurious to most of the test plants. From the results it does not appear which compound is more phytotoxic, since their relative positions vary in the different series.

In the s o w e d series 1, a 14 per cent Boliden extract damaged c u c u m b e r and t o m a t o (Fig. 3 a, b) more severely than the corresponding Wolman extract. After the fourth treatment each compound caused a fading of the leaf veins in cucumber and a darkening of leaf tissues in tomato. The leaves of c a b b a g e (Fig. 3 c) were discoloured and mottled by Boliden, while Wolman turned them brown in the same way as it affected the leaves of tomato. After a period of three weeks the leaves of all the plants sprayed with Boliden exhibited burnt spots, browning, and there was even dying of the leaves. Plants sprayed with the Wolman solution were only slightly yellowed or brownish. Boliden salt was not included in the second sowed series (2), but a 50 per cent extract of Wolman salt killed the seedlings of cucumber, tomato and s w e d e (Fig. 3 c) directly after the second spraying.

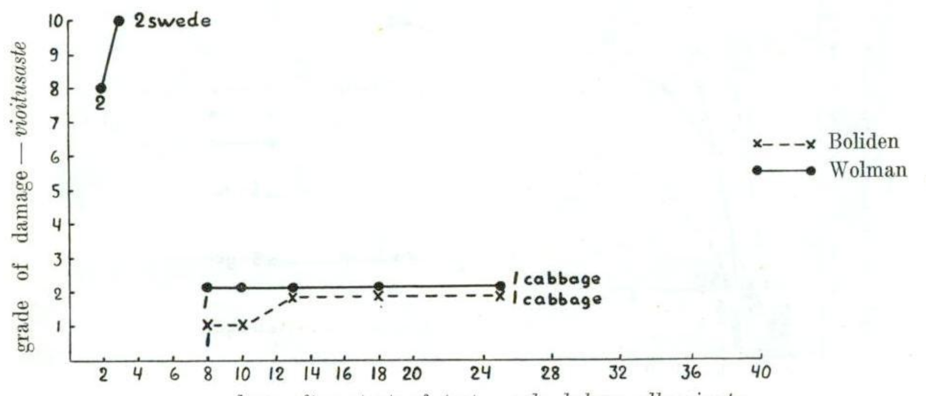
In the s e e d l i n g series 3, where the solutions were applied in a strength of 100 per cent, a Wolman spraying caused severe damage to both c u c u m b e r and t o m a t o. The leaf margins of the plants already began to grow black and dry after two treatments. Large, faded necrotic areas appeared gradually on the leaves of cucumber, and the growing points dried in parts. The leaflets of tomato darkened and dried gradually and extensively, beginning with the younger leaves. As from the fourth week, the injured seedlings managed, nevertheless, to produce new, even if very weak, growth. The Boliden injuries were similar in type, although considerably less severe. Fading spots were formed on the leaves of cucumber, the




a. Cucumber — *kurkku*




b. Tomato — *tomaatti*




c. Cabbage — *kupukaali*, swede — *lanttu*

Fig. 3. Water-soluble salt wood preservatives; test series 1—4, spray groups (c).
*Kuva 3. Vesiliukoiset kyllästyssuolat; koesarjat 1—4, suihkutusryhmät (c).*

younger leaves in particular being dark and light mottled green, gradually turning brown all over. The leaves of tomato grew dark and dried, beginning with the margins. As from the fourth test week the new growth was healthy, producing larger leaves than plants treated with Wolman salt extract, yet smaller and weaker than in the control seedlings. In the experiment (4) carried out immediately after this test series, in which the amount of extract was halved and further diluted to 50 per cent with water, the damage caused by both the Boliden and Wolman treatments was much less. However, the order was reversed: the Boliden injuries were somewhat more severe than the Wolman ones. The injuries appeared as necrotic spots on the blades and a browning of the margins.

Cineraria (Fig. 4) was equally severely affected by either of the compounds. The margins of the leaves began to grow darker by the day after the first treatment, and within 10 days practically all the seedlings had darkened and died. Cyclamen (Fig. 4) did not suffer much from the sprayings. A Boliden treatment did not markedly damage the plants and a Wolman treatment caused only slight browning at the leaf margins. Tulip (Fig. 4) was very badly injured, beginning already with the second treatment. A Wolman spraying caused a yellowing of the leaves and withering, which started at the margins, as well as a distinct retardation and stunting in the growth (Fig. 5 a). After two weeks nearly all the leaves were quite yellow, dry and paper-like. The buds had not opened properly, while the outer periantheous leaves remained greenish and somewhat shorter than the inner ones. Before dying, which took place some three weeks after the beginning of the forcing, the plants had grown only about 25—40 cm. high, i.e. about half of the height of the control plants. Boliden damage was

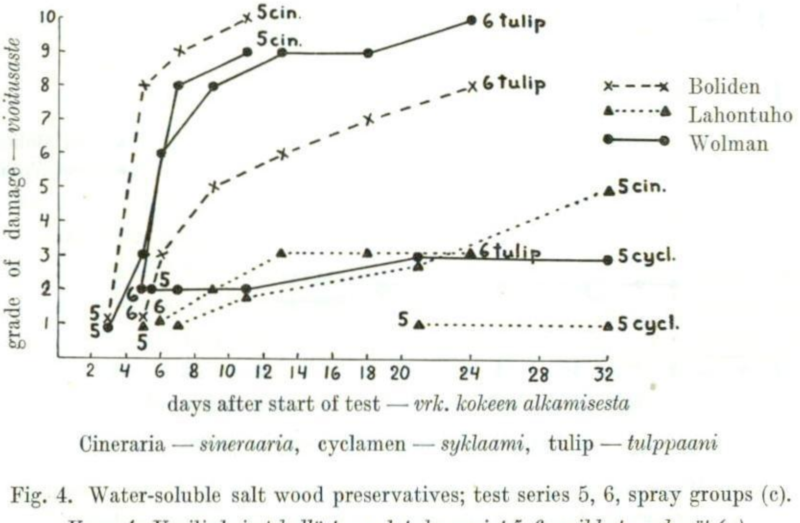
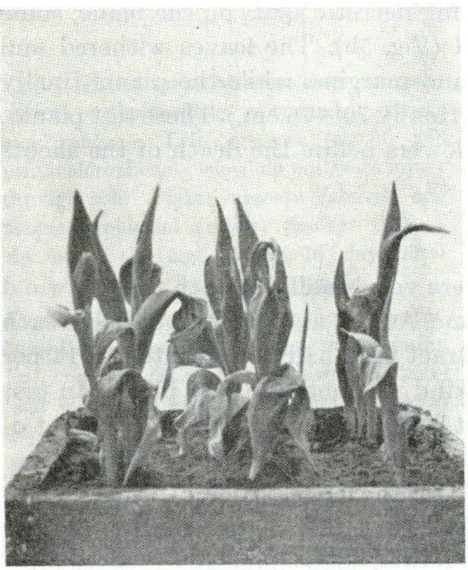
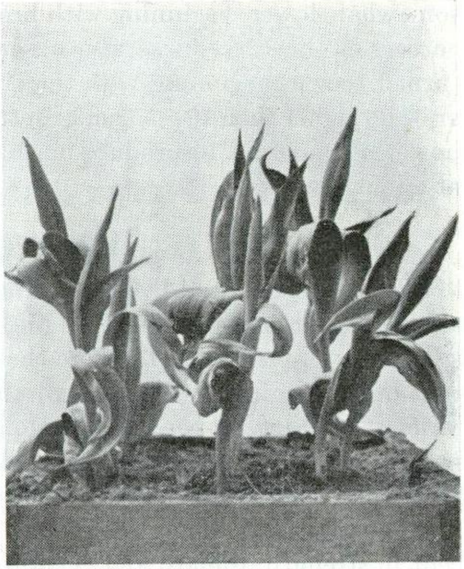



Fig. 4. Water-soluble salt wood preservatives; test series 5, 6, spray groups (c).
*Kuva 4. Vesiliukoiset kyllästyssuolat; koesarjat 5, 6, suihkutusryhmät (c)*



a. Wolman salt

*a. Wolman-suola*



b. Boliden salt

*b. Boliden-suola*

c. Lahontuho

*c. Lahontuho*

d. Control

*d. Kontrolli*

Fig. 5. Spray damage in tulip one week after start of sprayings. Test series 6 (c).

*Kuva 5. Suihkutusvioitusta tulppaanissa viikon kuluttua suihkutuksen alkamisesta. Koesarja 6 (c).*

somewhat slower, beginning with browning necrotic spots on the blade; some curling of the leaves was also observed (Fig. 5b). The leaves withered and turned brown, beginning with the tips and margins, while the plants finally grew no higher than 45—55 cm. (controls finally 70—75 cm.). These test plants, however, managed to produce normal flowers before the death of the shoots at about 3 weeks.

*Lahontuho*

The injuries caused by Lahontuho were very small. In both the s o w e d series (1, 2) the plants received the same As, Cr and Cu amounts in each spraying. In test series 1, where the extract used had been diluted to 14 per cent of the original, no damage of any kind was noted in any plant. In test series 2, extract 50 per cent, the oldest leaves of c u c u m b e r and t o-m a t o (Fig. 3 a, b) exhibited slight drying in the 8th week after sowing. These leaves had been subjected to the spraying for the longest time. In the s e e d-l i n g series (3,4), where the extract used was either 50 per cent or 100 per cent in strength, tomato and cucumber showed slight damage to leaves after one or two sprayings. The leaves developed small drying spots and the margins dried somewhat. As from the fourth week the new leaves remained uninjured in spite of continued treatments.

C i n e r a r i a (Fig. 4) was somewhat more sensitive to Lahontuho spraying than cucumber or tomato. The leaf margins turned very brown and growth was retarded to such an extent that after one month the height of the seedlings was only a fifth of that of the control plants. In c y c l a m e n (Fig. 4) retarded growth as from the third test week was the only symptom caused by Lahontuho spraying. T u l i p (Fig. 4) with its waxy surfaced leaves could be expected to stand up well to the sprayings. Nevertheless, small necrotic spots caused already by the first spraying were to be seen in the leaves, and drying of leaf margins and tips was observed later, this being rather severe in the oldest leaves (Fig. 5 c).

*Celcure*

Celcure, which was tested only on the sowed series of cucumber, tomato and swede (2) and in the tulip series (6), did not cause any damage to the plants in these experiments.

**The effect of oily and oil-soluble substances on plants.**

An essential feature of the oily and oil-soluble preservatives was the fact that they did not cause any kind of damage to plants through the s o i l (Fig. 6). Neither did the tested solvents, petroleum and turpentine, damage the plants in the soil group.

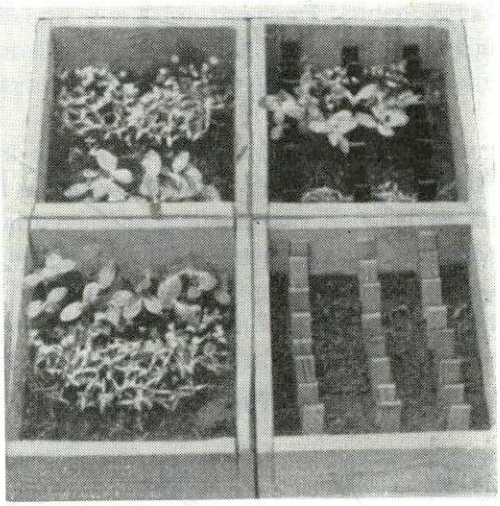


Fig. 6. The effect of oil-soluble wood preservatives on the seedlings of cucumber, tomato and cabbage. Left: creosote (above) and pentachlorophenol (below) do not cause injury through soil. Right: creosote (above) and pentachlorophenol (below) damage through air in all the test plants; 16 days after sowing. Test series 1 (a, b).

*Kuva 6. Öljyliukoisten lahosuoja-aineiden vaikutus kurkun, tomaatin ja kupukaalin taimiin. Vas. kreosootti (yllä) ja pentaklorfenoli (alla) eivät vioita maan kautta. Oik. kreosootti (yllä) ja pentaklorfenoli (alla) vioittavat ilman kautta kaikkia koekasveja; 16 vrk. kylvöstä. Koesarja 1 (a, b).*

In the air group of both the sowed and planted seedling series, *copper naphthenate*, as well as the compound Aspergol KT, which contains copper naphthenate, and the solvent *turpentine*, proved harmless to all the test plants. In this group the phytotoxic effect of the other tested oily and oil-soluble compounds became apparent.

*Creosote*

Creosote as a pure compound, as well as the preparation Rusko, which contains creosote, severely injured all plant species through the air. In the sowed series (1, 2) the cotyledons of both cucumber and tomato seedlings became first concave and abnormally glossy. In tomato they curled down characteristically (Fig. 7), being paler green in colour than the leaves

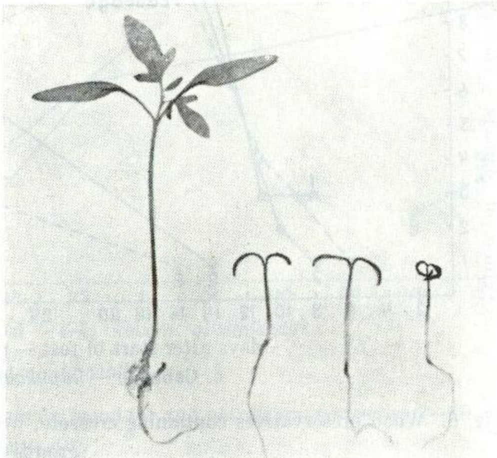
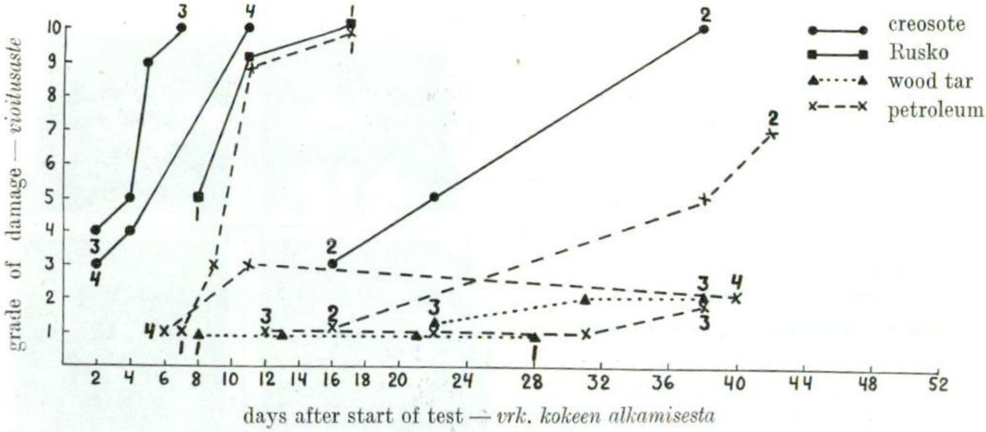
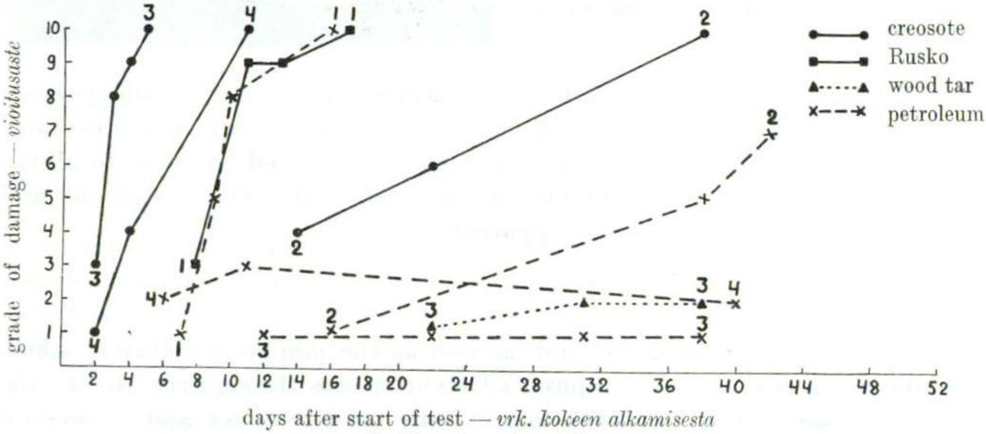


Fig. 7. Damage caused by creosote through air in tomato 4 weeks after sowing; left control. Test series 2 (b).

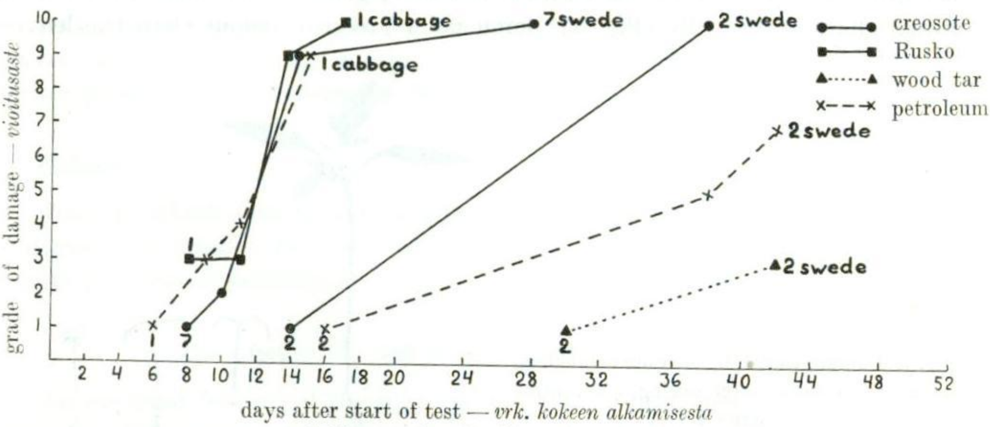
*Kuva 7. Kreosoottivioitusta tomaatissa ilman kautta 4 viikkoa kylvöstä. Vas. kontrolli. Koesarja 2 (b).*




a. Cucumber — *kurkku*




b. Tomato — *tomaatti*




c. Cabbage — *kupukaali*, swede — *lanttu*

Fig. 8. Wood preservatives containing creosote, wood tar, solvent petroleum; test series 1—4, air groups (b).

*Kuva 8. Kreosoottipitoiset lahosuoja-aineet, puuterva, liuotin petroli; koesarjat 1—4, ilmaryhmät (b).*

of the control plants. In cabbage and swede the same tendency was to be seen, though the symptoms were less marked. The growth of all the test plants was slow from the very start and the seedlings died in 2—5 weeks (Fig. 8 a, b, c).

In the seedling test series 3 and 4 the first symptoms of injury were to be observed in cucumber and tomato two days after the start of the experiment (Fig. 8 a, b). In cucumber the leaf-margins began first to lose colour and to dry rapidly, which brought about a curling of the leaves as the tissues of the central part of the blade continued to grow in the normal way. The chlorophyll began to vanish in parts from the tissues of the leaf blades, and the margins and growing points turned brown. In both cases the leaves withered completely and the plants died rapidly.

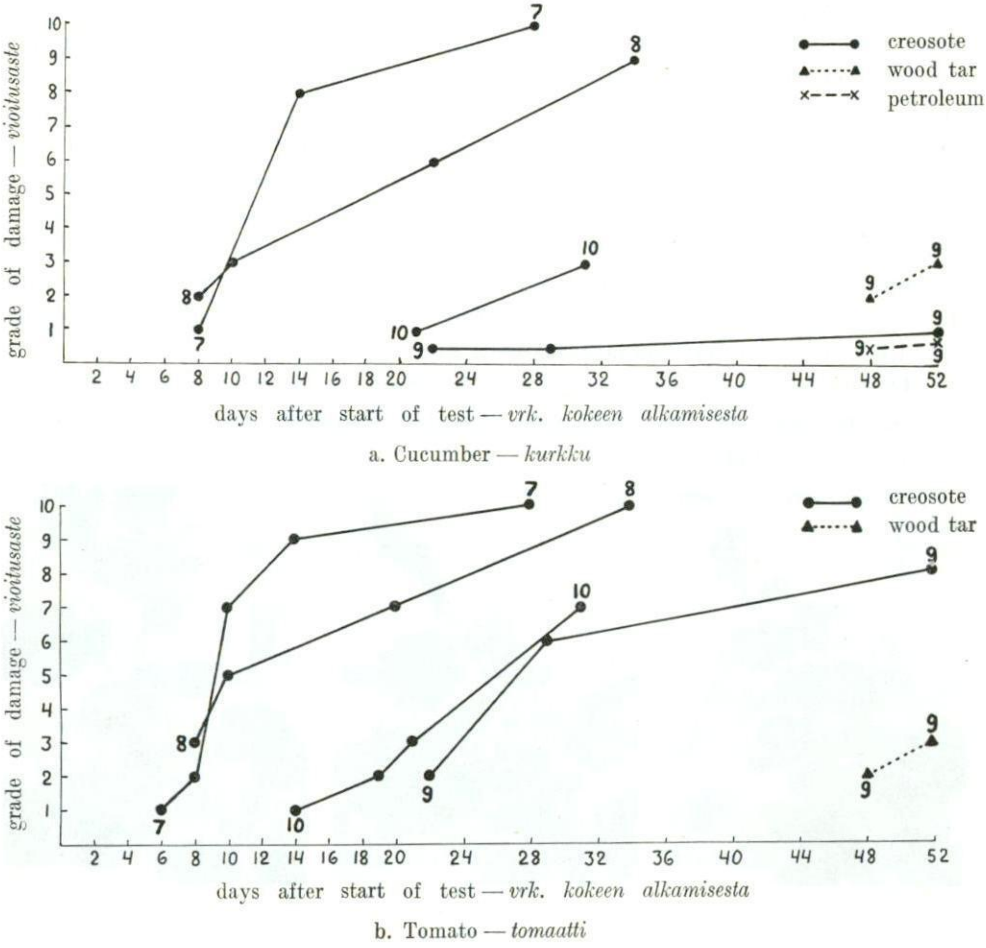


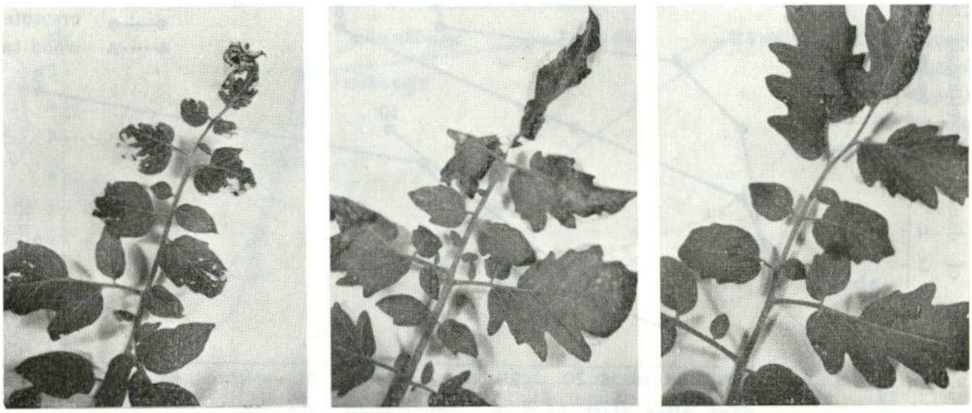

Fig. 9. The duration of the phytotoxicity of creosote, wood tar and petroleum; test series 7—10, air groups (b).

*Kuva 9. Kreosootin, puutervan sekä petrolin myrkyllisyyden kestoaika; koesarjat 7—10, ilmaryhmät (b).*

In t o m a t o creosote caused a general fading of the leaves, in the less severe cases, and in more severe cases there were brownish tints to begin with, sometimes also wrinkling. The older leaves turned yellowish-greeny-brown. Before long all the leaves withered and the plants died.

The poisonous effects of creosote treatment were observed for nearly 3 years, using cucumber and tomato as test plants (series 7—12). When more than six months had passed since the treatment of the splints (7,8) there was clearly less danger of poisoning. The symptoms of injury became apparent in both plant species only about a week after the planting (Fig. 9,a,b). At first the leaves turned yellow, later they withered and dried, generally beginning from the margins. Growth was retarded, but the plants managed, nevertheless, to survive for somewhat more than a month. After a period of over 1 ½ years had passed since the treatment (9,10) slight damage to the leaves and retardation of growth was to be observed only 2—3 weeks after the beginning of the experiment (Fig. 10a). The new leaves existed for several days without any injury, and the plants consequently did not die during the test period. In the test series 11 and 12, where over 2 ½ years had passed since the time of the impregnation, only a slight fading of the colour was to be noted in the leaves, while growth was normal in cucumber as well as in tomato. At the end of the test period there was thus no marked difference to be seen in the growth as compared with the control plants. It should be pointed out that KAUFERT and LOERCH (1955) discovered in their experiments that creosote was injurious to tomato as late as in the fourth test year.

The leaves of c i n e r a r i a began to turn dark from the margins already during the first test days; they subsequently withered and the plants died in about 10 days (Fig. 11).



a. Creosote *kreosootti* b. Pentachlorophenol *pentaklorfenoli* c. Control *kontrolli*

Fig. 10. Damage caused in tomato by oil-soluble wood preservatives through air. Test series 10 (b).
*Kuva 10. Öljyliukoisten lahosuoja-aineiden vioitusta tomaatissa ilman kautta. Koesarja 10 (b).*

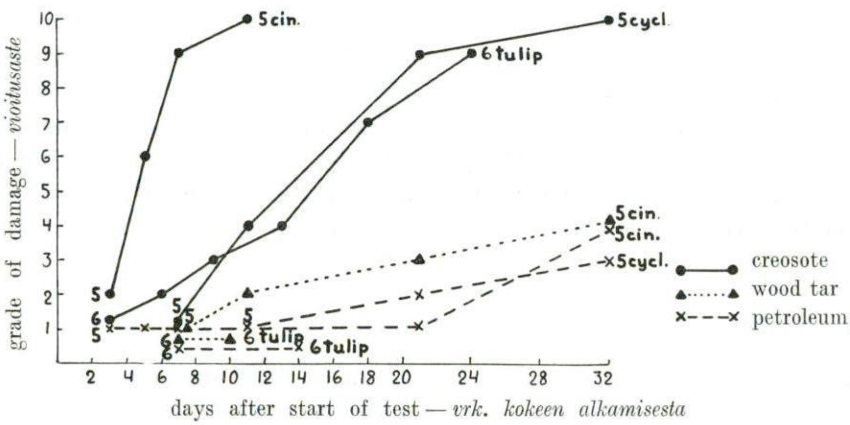
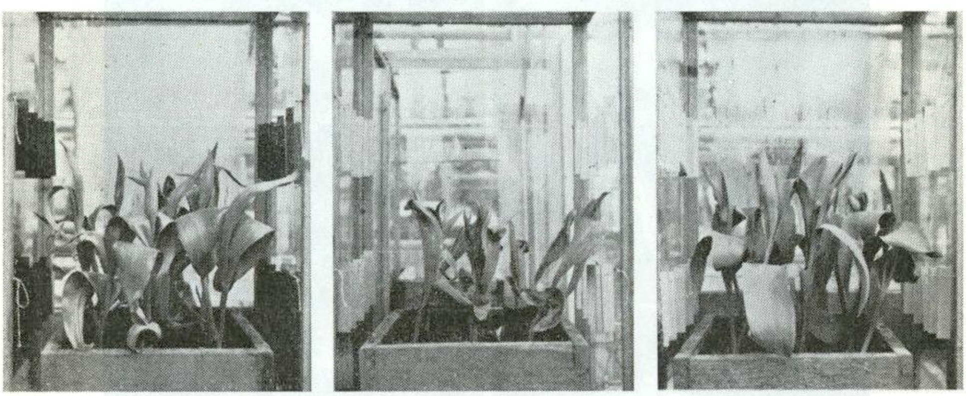



Fig. 11. Wood preservatives containing creosote, wood tar, solvent petroleum; test series 5, 6, air groups (b).

*Kuva 11. Kreosoottipitoiset lahosuoja-aineet, puuterva, liuotin petroli, koesarjat 5, 6, ilmaryhmät (b).*

In c y c l a m e n the youngest leaves in the rosette began to curl after the first test week (Fig. 11). Brown necrotic spots appeared in the intervenial region of the blade; by the time the plants were some 3 weeks old their foliage was yellow or dry and brown, and the plants died.

T u l i p exhibited injury as from the end of the first test week (Fig. 11). The first symptoms appeared as a bending of the leaves and a paler colour in the leaves as compared to that of the control (Fig. 12 a). This paleness of the



a. Creosote *kreosootti* b. Pentachlorophenol *pentaklorfenoli* c. Control *kontrolli*

Fig. 12. Damage caused by oil-soluble wood preservatives through air in tulip 9 days after start of driving. Test series 6 (b).

*Kuva 12. Öljyliukoisten lahosuoja-aineiden vioitusta ilman kautta tulppaanissa 9 vrk. hyödön alkamisesta. Koesarja (6) b.*

leaves, as well as a slight degree of glossiness, continued to be evident in the test plants. The general development was retarded; the flowers were only in bud 2 weeks after the start of the forcing, while the control plants were by then in full bloom. In the third week the tips and margins of the leaves were in the process of drying to a leathery brown, the flowers had opened, but were entirely white in colour. Their outer periantheous leaves were some 1 cm. shorter than the inner ones, the plants being about 40 per cent shorter than the controls.

*Wood tar*

In some of the experimental series tar caused slight damage (Fig. 8 a,b,c). Cucumber exhibited in the sowed series (1) slight concave bending of the leaf-blade and glossiness soon after the emergence of the seedlings, later narrow borders dried in the margins. In the seedlings of swede (2) it was also possible to note a slight curling of leaves and an upward curling of the margins a month after the sowing. (Fig. 13). In the seedling test series 3 a slight fading tendency of the colour of the margins and blade was to be noted both in cucumber and tomato in about 3 weeks' time. The tar was retained in the test until the 10th series, but the lower leaves of cucumber and tomato exhibited fading and dying by turning yellow only at the final stage of series No. 9 (Fig. 9 a,b).

The seedlings of cineraria suffered somewhat during the first three test weeks (Fig. 11). In the younger leaves slight wrinkling and bulging was to be noted, also they were smaller in size than the leaves of the control

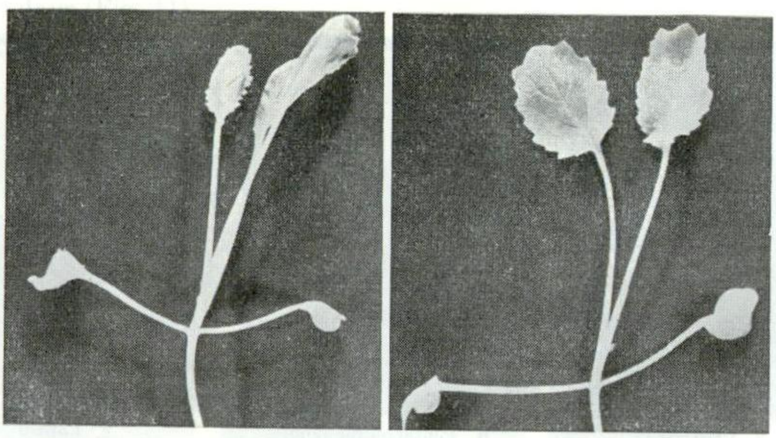


Fig. 13. Tar damage through air: left, damaged swede seedling 5 weeks after sowing; right, control. Test series 2(b).

*Kuva 13. Tervavioitusta ilman kautta: Vas. vioittunut lantun taimi 5 viikkoa kylvöstä. Oik. kontrolli. Koesarja 2 (b).*

plants. At this stage a very distinct symptom was found in the fact that the leaves drooped to the ground while the rosettes of the control plants stood erect. No damage was noted in c y c l a m e n. At the turn of the first week the leaves of t u l i p were somewhat paler green than those of the control plant (Fig. 11).

*Petroleum*

Petroleum was found to be slightly poisonous to all the test plants. The compound had a considerably more injurious effect in the s o w e d series than in the seedling test series. In series 1 the leaves of c u c u m b e r and t o m a t o curled down in about a week after sowing, the leaves of c a b b a g e began to turn dark, and the development of all the plant species

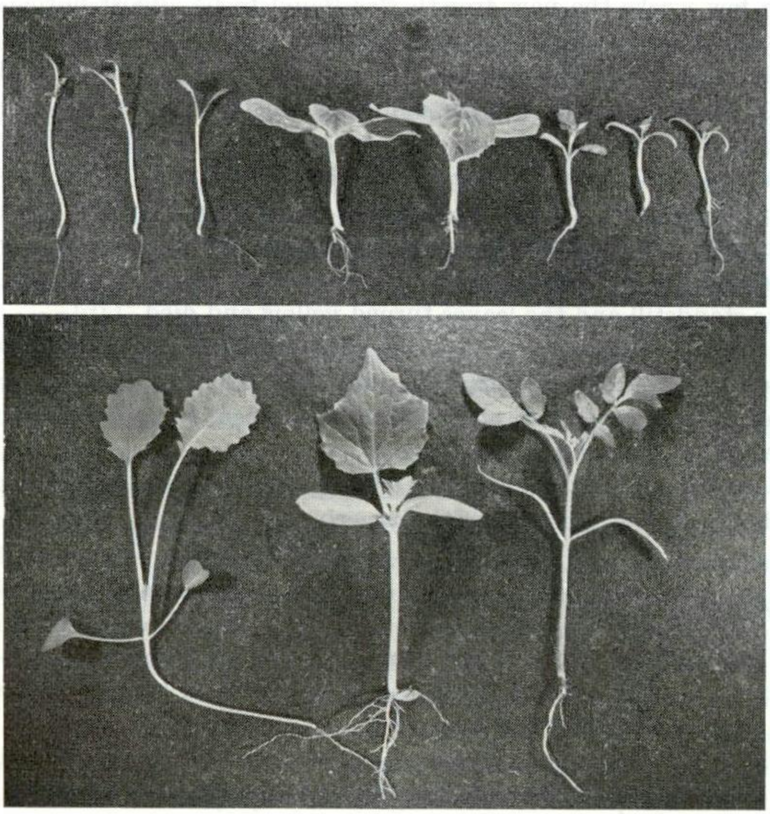


Fig. 14. Above, petroleum damage through air in swede, cucumber and tomato 5 weeks after sowing; below, control seedlings. Test series 2 (b).
*Kuva 14. Ylh. petrolivioitusta ilman kautta lantussa, kurkussa ja tomaatissa; 5 viikkca kylvöstä. Alh. kontrollitaimia. Koesarja 2 (b).*

was retarded (Fig. 8 a,b,c). During the following week first of all the cucumber plants turned yellow, brown and died. The tomatoes survived somewhat longer having curled, blackened cotyledons, and similarly the cabbage seedlings, which gradually turned dark and withered. In series 2 the effect was less severe, beginning to affect development only a couple of weeks after sowing. The growth of the plants gradually came to a standstill and at the end of the experiment, in 6 weeks, the leaves of cucumber, tomato and swede were full of necrotic spots (Fig. 14).

In the seedling series 3 and 4, the injury to cucumber and tomato was slight (Fig. 8 a, b). At first the leaves turned somewhat paler as compared to the leaves of the controls, and the leaves of tomato bent down into a drooping position. Later the margins went completely yellow and pale necrotic spots formed on the blades; the leaves of cucumber also turned mottled green and white in parts. The older leaves died prematurely, but in a few weeks the new growth was found to be almost normal, which showed that the petroleum volatilized relatively rapidly. The petroleum was retained up to the 10th series, though only at the end of one of the later series (9) the leaves of cucumber exhibited a slight tendency to turn pale (Fig. 9 a).

Cineraria suffered more than the above plant species from the effects of petroleum (Fig. 11). Growth was retarded, new leaves grew asymmetrically, darker than normal, glossy and curly, particularly at the margins, and the leaf veins thickened. In about a month growth came to a complete standstill and the leaves turned yellow and died.

The oldest leaves of cyclamen (Fig. 11) began to turn yellow at the margins in a couple of weeks from the start of the experiment, and gradually they died. The growth had almost totally stopped, but the younger leaves appeared to look healthy at this stage.

The only symptom of injury in tulip (Fig. 11) was the fading of the leaves during the second week of the experiment.

*Pentachlorophenol*

In the air group of the experiments pentachlorophenol, as well as Valtti and Woodlife, which contain this compound, proved to be the most phytotoxic substances of all those tested.

In the sowed series (1,2) the leaves of all the test plants curled up, the effect being similar to that of creosote. In cucumber the symptoms were particularly distinct. The cotyledons bent into a boat-like shape, and grew thick and glossy (Fig. 15). The growth of all the plant species stopped at the cotyledon stage, and in about a week after emergence all the seedlings were dead (Fig. 6, p. 17; Fig. 16 a,b,c).

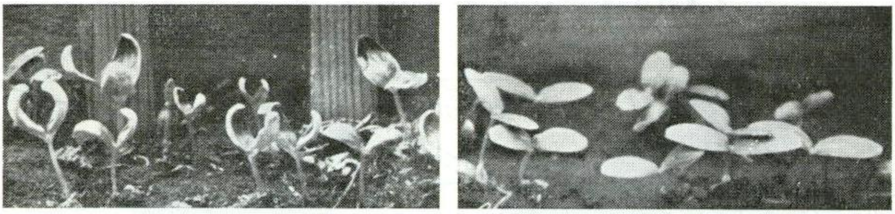
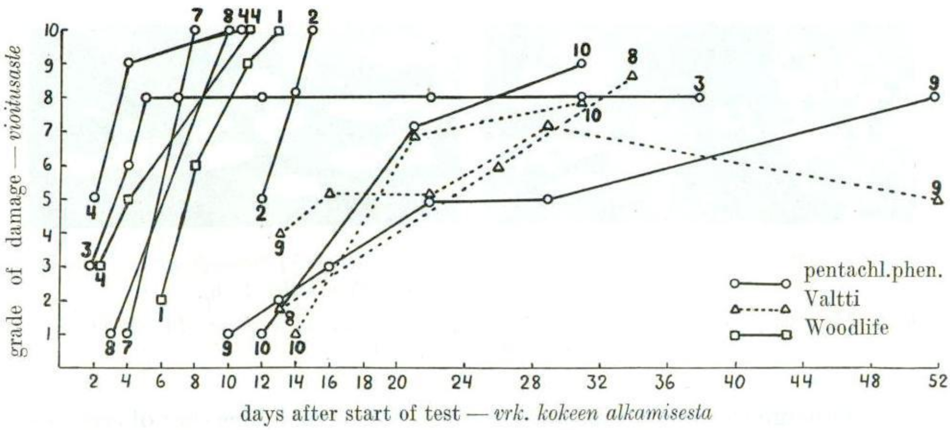


Fig. 15. Left, damage caused by pentachlorophenol (Woodlife) through air in cucumber 10 days after sowing; right, control. Test series 1 (b).
*Kuva 15. Vas. pentaklorfenolivioitusta (Woodlife) ilman kautta kurkussa 10 vrk. kylvöstä. Oik. kontrolli. Koesarja 1 (b).*

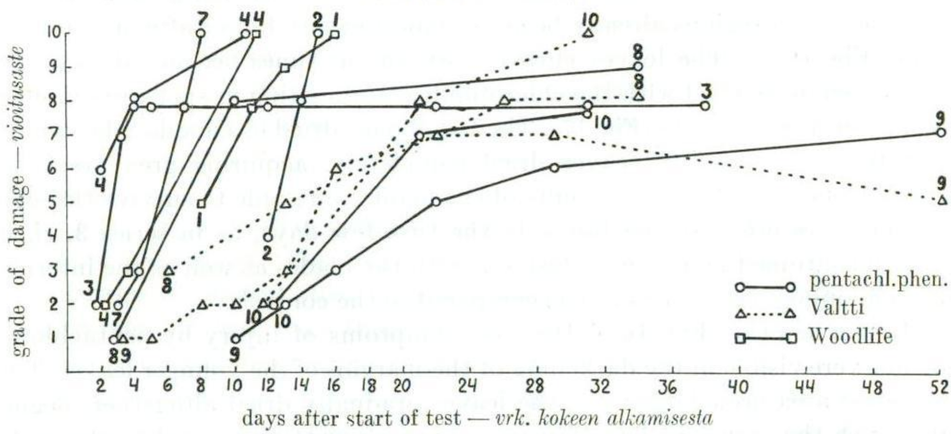
The damage caused by pentachlorophenol also resembles that of creosote in the s e e d l i n g test series (3,4). In c u c u m b e r the marginal as well as the intervenial regions already began to fade and turn brown after a couple of days (Fig. 16 a). The leaves curled down and at times became abnormally dark green or mottled with the chlorophyll accumulating in spots, resembling cucumber mosaic virosis (Fig. 17). The faded spots dried in a few days becoming necrotic spots, and the leaves dried completely, acquiring grey greenish-brown tints. If the growing points of the plants were able to survive through the intensive effect of the fumes in the first few days, as in series 3, their growth continued in a stunted fashion, with the blades as well as the internodes remaining very undersized as compared to the control.

In t o m a t o (Fig. 16 b) the first symptoms of injury by pentachlorophenol were visible in the darkening of the margins of the younger leaves. The darkened area grew larger and the leaves gradually dried altogether, beginning with the margins. The damage was sometimes also noted in the early stages as a shrinking of the youngest leaves, which could be pale or mottled greenish- white, as in cucumber. Older leaves exposed to the fumes became first yellowish-green, turning subsequently brownish-green and finally drying completely after a week or two. In series 3 the growing points of tomato were able to survive over the first few days. The seedlings continued to grow, although this was slow as the new leaves were continuously being damaged.

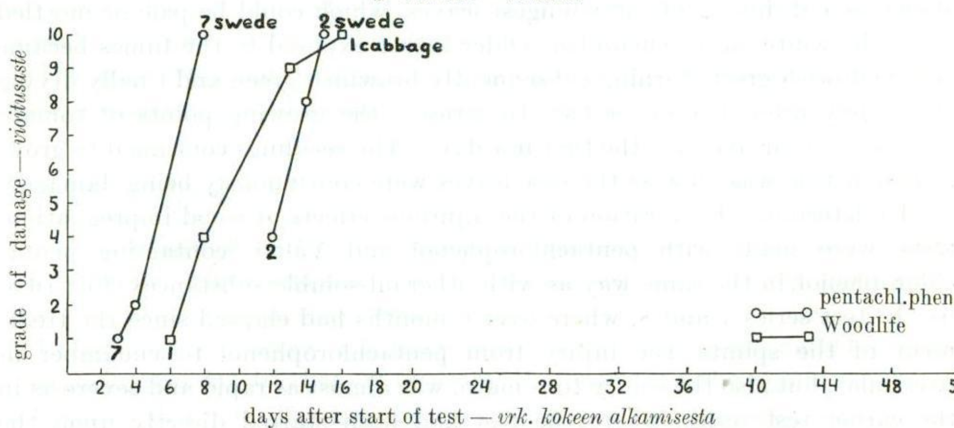
To determine the duration of the injurious effects of wood impregnation, tests were made with pentachlorophenol and Valtti, containing pentachlorophenol, in the same way as with other oil-soluble substances (Fig. 16 a, b). In test series 7 and 8, where over 6 months had elapsed since the treatment of the splints, the injury from pentachlorophenol to cucumber in particular, but also the injury to tomato, was almost as rapid and severe as in the earlier test series, where the test had been started directly upon the treatment and drying of the splints. After another year (9,10) damage generally began to show only after 10 to 14 days. The symptoms, especially in cucumber, were, nevertheless, very severe. Leaf-margins began to curl up and




a. Cucumber — *kurkku*




b. Tomato — *tomaatti*




c. Cabbage — *kupukaali*, swede — *lanttu*

Fig. 16. Wood preservatives containing pentachlorophenol; test series 1—4, 7—10, air groups (b).
*Kuva 16. Pentaklorfenolipitoiset lahosuoja-aineet; koesarjat 1—4, 7—10, ilmaryhmät (b).*

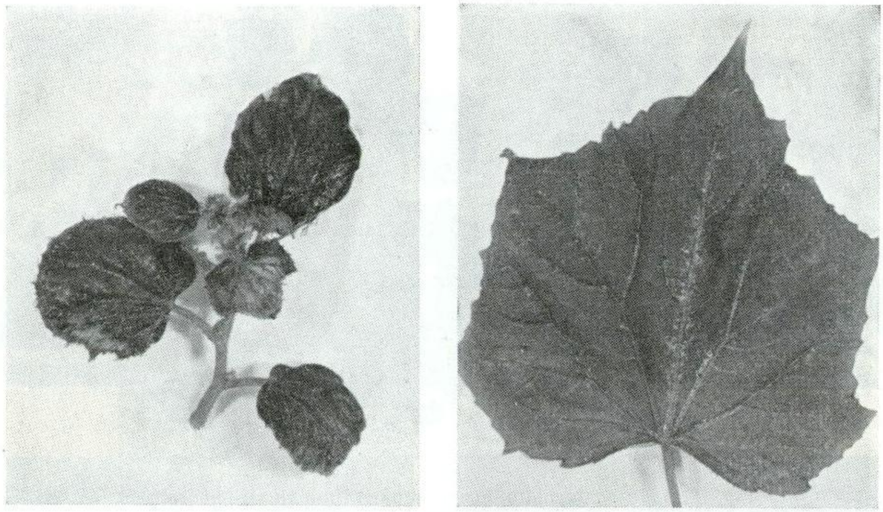


Fig. 17. Left, pentachlorophenol damage through air in cucumber 2 years after impregnation; right, leaf from control plant. Both about ½ of their natural size. Test series 10 (b).
*Kuva 17. Vas. pentaklorfenolivioitusta ilman kautta kurkussa 2 v. kuluttua kyllästämisestä. Oik. kontrollikasvin lehti. Molemmat n. ½ luonnollisesta koosta. Koesarja 10 (b).*

dry immediately the leaves appeared. The blade wrinkled and bulged, exhibiting lighter spots and glossiness. Growth was retarded, the internodes remained abnormally short, the leaves were undersized (Fig. 17) and died one after another in a short space of time, while the plant continued very weak growth from the top. The margins of tomato leaflets darkened and dried, fading was also apparent and necrotic spots appeared on the blade (Fig. 10 b). The older leaves dried completely and the growth of the plant was retarded. In the test series 11 and 12, more than 2½ years after the treatment of the splints, pentachlorophenol continued to cause some marginal and intervenial fading and necrosis in the leaves of cucumber and tomato. The growth of cucumber was distinctly stunted (Fig. 18). Nevertheless, the plants continued to grow and towards the end of the experiment the symptoms began to decrease. In their experiments Kaufert and Loerch (1955) found that, depending on the solvent used pentachlorophenol became harmless to tomato two or three years after the treatment.

The leaves of c i n e r a r i a darkened, beginning with the margins and dried, and necrotic spots formed on the blades. The death of the leaves and the entire plant followed in about a week (Fig. 19).

The symptoms of poisoning in c y c l a m e n differed in some respects from those described above. The leaves withered to start with and lost their green colour in about a week only, becoming entirely reddish-grey, with brown margins, partly darkened; the whole plant died (Fig. 19).

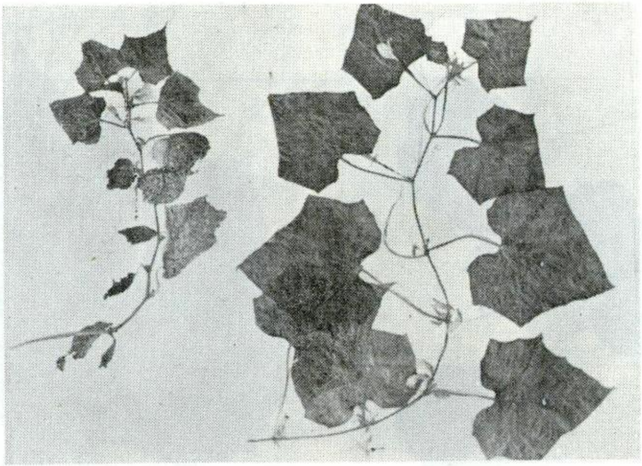
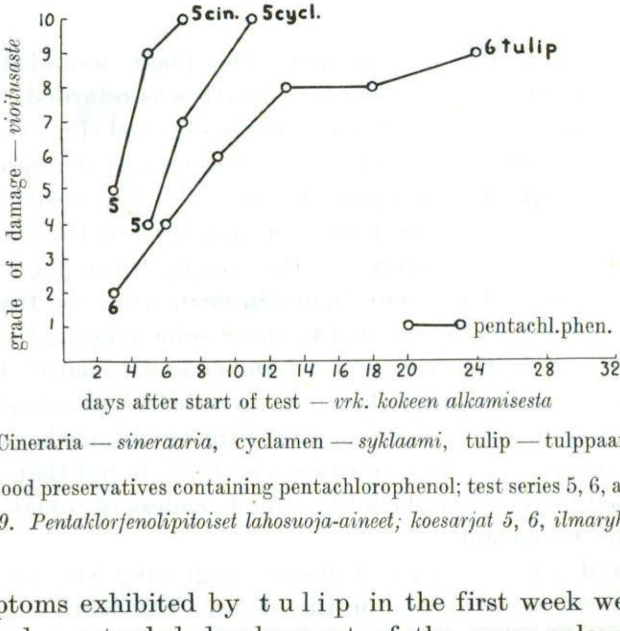


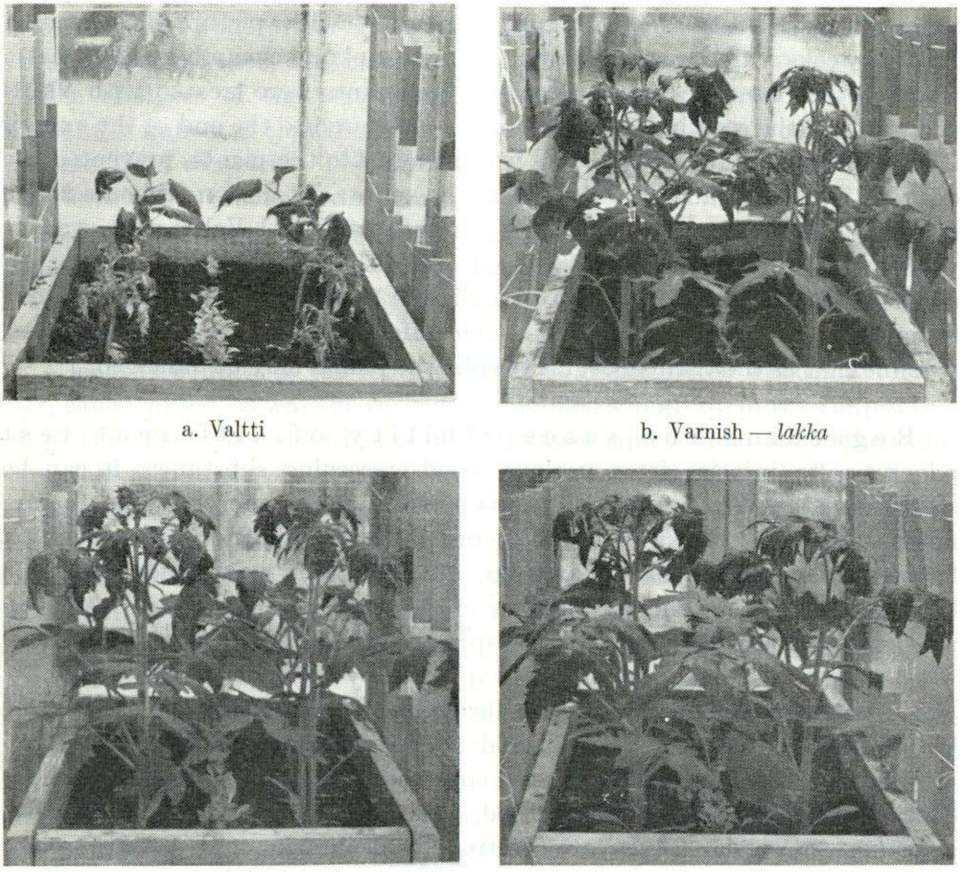
Fig. 18. Left, pentachlorophenol damage through air in cucumber nearly 3 years after impregnation; right, control. Test series 12 (b).
*Kuva 18. Vas. pentaklorfenolivioitusta ilman kautta kurkussa lähes 3 v. kuluttua kyllästämisestä. Oik. kontrolli. Koesarja 12 (b).*




Cineraria — *sineraaria*, cyclamen — *syklaami*, tulip — tulppaani

Fig. 19. Wood preservatives containing pentachlorophenol; test series 5, 6, air groups (b).
*Kuva 19. Pentaklorfenolipitoiset lahosuoja-aineet; koesarjat 5, 6, ilmaryhmät (b).*

The symptoms exhibited by t u l i p in the first week were bending of the leaves and a retarded development of the green colour as compared with the control. Some glossiness appeared in the leaves, while the bending continued to increase (Fig. 19). In about 10 days drying was to be noted in the margins and tips of the leaves, and the growth began to slow down (Fig. 12 b). The budding flowers were almost white, with only a slight violet



a. Valtti b. Varnish — *lakka*

c. Valtti & varnish *(lakka)* d. Control — *kontrolli*

Fig. 20. The injurious effect of pentachlorophenol (Valtti) through air prevented by using varnish. Test series 8 (b).

*Kuva 20. Pentaklorfenolin (Valtti) haitallinen vaikutus ilman kautta voidaan estää lakkauksella. Koesarja 8 (b).*

tint. At the end of the experiment the greatest part of the blades had turned brown and dried, and the parts that were still green were abnormally glossy. The flowers were brownish, while the control plants were in full bloom with normal-sized violet flowers. The height of the plants was about 45 cm., compared to the 70 cm. of the control plants.

The possibilities of controlling the damage from pentachlorophenol through air by varnishing the pentachlorophenol treated wood were investigated in the series 8—12. Splints treated with Valtti as well as unimpregnated splints were painted twice over with boat varnish. Figures 20 present a clear picture of the results. In 2—3 weeks Valtti severely damaged the test plants cucumber and tomato. On the other hand, in the cases where the splints were treated with Valtti and varnish, the seedlings remained quite uninjured to the end of the experiment. The varnish, which in itself was harmless to the plants, prevented the evaporation of pentachlorophenol from the splints. In the experiments 9—12 the same varnished and unvarnished splints treated with Valtti were used. It was found that while still 14—28 months after the treatment Valtti damaged cucumber and tomato, although to a slighter degree, the varnish continued to protect the plants against the toxic effects of Valtti. It is, however, possible that as the varnish begins to split the plants may be damaged.

Regarding the susceptibility of different test plants to injuries from various wood-preserving substances it can be established that the soft-leaved plants cineraria, cucumber and tomato, are more susceptible than swede, cabbage or cyclamen, which have leaves with a harder surface. It appears that tulip, which with its waxy epidermis could be expected to resist the toxic effects of vapours as well as chemicals which are deposited on to the shoots in the sprays, suffered very severe injury from wood-preserving substances. This is explained by the type of growth of tulip, which only develops a few leaves during its period of growth. The same leaves thus continue to be subjected to the chemical influences, resulting in such severe damage that the shoots die. Cyclamen forms new leaves continuously during a longer period, and these enable it to stay alive, although the older leaves are destroyed. Cucumber and tomato, plant species that in themselves are very susceptible to chemical damage, are able to survive if subjected to slight poisoning from vapours and during spraying treatment. This is due to the way of growth and rapid development of these plants, since they are able to develop new shoots sufficiently quickly to replace the damaged ones.

## Discussion

With the aid of the experimental technique evolved for and applied in the present study it has been possible to show, on the one hand, the harmlessness of certain wood preservatives to plants, and, on the other hand, the different ways in which the wood preservatives and their solvents can cause damage to plants in greenhouse and bench cultivations.

All the wood preservatives tested contain phytotoxic substances. Why are some of them, then, quite harmless while the others cause damage under certain conditions? One of the essentials of wood preservatives is their effective adherence to wood. This characteristic affects not only their effectiveness as wood preservatives, but also the possibilities of using them in greenhouse and bench constructions.

The analyses of the water extracts from wood preserved with salt compounds indicated that the adherence of the substances to wood is in some cases far from complete. The fact that the considerable amounts of phytotoxic substances that may dissolve from Boliden and Wolman salts did not, in general, cause damage to the plants through soil in the experiments, may be partly explained by the effective sorption capacity of the soil constituents. It is also possible that in soil the substances are converted into compounds which are harmless to plants.

A lengthy contact of the root system with impregnated wood may, however, cause injury, as was the case in the Boliden soil group in the tulip series (cf. p. 11). The other tested salts did not cause injury when under the same conditions. In their studies on the possibilities of preventing the soil pathogens from being transferred from one cultivation to another by treating the sowing flats with wood preservatives, Roistacher and Baker (1954) also found that Wolman salt and Erdalith (containing arsenic, copper and chromium, i.e., the same substances as Lahontuho) are non-injurious to plants. The roots were not damaged even if in contact with the pressure-treated flats.

The fact that some constituents of the salt wood preservatives are cell poisons appears quite distinctly in the spraying groups of the experiments, in which the compounds as water solutions are in direct contact with the shoots of the plants. According to the analyses of the extracts[1]) the amounts of the dissolved substances vary considerably in different cases despite the fact that a uniform method of impregnation and extraction of the splints was aimed at. The extracts used in the experiments contained the following amounts of arsenic, chromium, copper and dinitrophenol:

| Extract | | mg./100 ml. | | | |
|---|---|---|---|---|---|
| | | As | Cr | Cu | dinitrophenol |
| No. 1 | Boliden salt | 15.6 | rests | — | — |
| » | Lahontuho | 5.1 | 0.6 | 1.9 | — |
| » | Wolman salt | 7.1 | 5.9 | — | 76.0 |
| No. 2 | Boliden salt | 24.8 | rests | — | — |
| » | Lahontuho | 6.4 | rests | 5.8 | — |
| » | Wolman salt | 7.2 | 8.9 | — | not analysed |
| No. 3 | Boliden salt | 24.8 | rests | — | — |
| » | Celcure | — | 1.6 | 1.2 | — |
| » | Lahontuho | 3.2 | 0.2 | 1.0 | — |
| » | Wolman salt | 2.3 | 13.4 | — | 60.0 |

[1]) The analyses were performed by Miss Aini Wallén, M. Sc., at the Wood Preservation Section of the State Institute for Technical Research, Helsinki.

At the end of the experiment the sprayed plants in the tulip series (except those treated with Celcure) were analysed[1]) to determine the amounts of As, Cr, Cu and Zn in the shoots.

| | Average amount per plant micrograms | | | |
|---|---|---|---|---|
| | As | Cr | Cu | Zn |
| Control .................... | 2.1 | 0.73 | 24.1 | 23.5 |
| Boliden salt ................ | 4.6 | 3.7 | — | 68.0 |
| Lahontuho ................ | 3.9 | 4.0 | 80.4 | — |
| Wolman salt ............. | 3.0 | 50.6 | — | — |

Considerable accumulations of chromium in the Wolman sprayings, copper in the sprayings with Lahontuho, and zinc in the Boliden sprayings, were to be found in the shoots. In all cases the arsenic content had distinctly increased.

As mentioned above (p. 5), Boliden salt contains 23.8 per cent of sodium arsenate, which is a highly soluble form of arsenic, and 27.3 per cent arsenic acid. In each group more arsenic dissolved into the soaking water from splints impregnated with Boliden salt than from the splints treated with other preservatives. Similarly the arsenic content of the shoots was highest in plants sprayed with the Boliden extract. Several compounds of arsenic have been used as insecticides, particularly at an earlier time. In this connection it has been noted that all water soluble arsenic compounds readily damage plants if sprayed on the leaves. SWINGLE *et al.* (1923) have found in their very thorough study of the spraying damage of arsenic compounds that arsenic is very injurious and sodium arsenate injurious, e.g. to tomato. The treatments caused intervenial necrosis, wilting, browning and shrivelling of the leaf tissue; finally the leaves might die and fall off. The symptoms were thus very similar to those caused by the sprayings of the water extract from the wood preservatives discussed above (p. 12, 14). True, the concentrations applied by SWINGLE *et al.* were relatively large, 3.75 g. arsenic to 1 l. extract. It is worth mentioning that the As- content of the normal (0.1 per cent) spraying extract of an insecticide containing calcium arsenate is 41.6 mg./100 ml. extract; the arsenic content of Boliden extracts is only about a half or a third of this. It must, however, be taken into account that sprayings with insecticides of the former types applied to vegetable plants, for example, are generally carried out only a few times during the growth of the plants, at about fortnightly intervals, whereas the sprayings of wood preservatives in these experiments were done every second day for 3—6 weeks. It is also known that high humidity and high temperature create optimal conditions for arsenical injury (SWINGLE & al. 1923, STRACHITZKII 1932). Conditions like

[1]) The analyses were carried out at the State Agriculturalchemical laboratory, Helsinki.

these have indeed prevailed during the experiments and are common in the greenhouses and benches of many plant cultivations. It is thus likely that the basic reason for the damage sustained by the plants when coming into contact with Boliden extract lies in the arsenic compounds that it contains. ANDRÉN (1949) has reported a case of Boliden damage to cucumber in a greenhouse. It appears, however, that the Boliden salt used also contained sodium chlorate, which is no longer a constituent of this salt. ANDRÉN in fact holds the opinion that the damage was caused by the chlorate.

According to the shoot analysis, plants sprayed with Boliden extract contain almost three times as much zinc as the control plants. It may be supposed that the zinc sulphate in the Boliden salt could be one of the causes of damage, since, for example, KADOW (1934), who has experimented with zinc sulphate as a spray to control some peach diseases, has found that it is injurious to plants.

Among the poisonous substances in Wolman salt, in addition to the arsenic compounds (25 %), there is dinitrophenol. It is known that, the phenols, especially those containing two nitro groups are highly poisonous to higher plants as well as to fungi (FREAR 1949). Evidently the fluorine compounds of the salt contribute to the damage. It is known that sodium fluoride, and Wolman salt contains 25 per cent of this compound, is dangerous when used as an insecticide spray upon foliage, since it readily damages plants (MARTIN 1948). According to EKSTRAND (1941), the formation of hydrofluoric acid accounts for the damage caused in many ornamental plants by the wood preservative Fluralsil, which contains fluorine compounds. SCHWARTZ (1929) also has proved that the hydrofluoric acid volatilizing from certain wood preservatives is injurious to plants.

The arsenic content of Lahontuho extract is generally of the same order as the arsenic content of the Wolman extract in the same group. Differing from Boliden and Wolman salts, Lahontuho contains copper compounds, which dissolve to some extent into the soaking water. Also according to the shoot analysis, the shoots sprayed with Lahontuho contain about three times as much copper as the control plant. Sprays containing copper oxide, which are used to control plant diseases, can cause damage in plants which appears as necrotic spots in the foliage. Lahontuho is stated to contain copper as cupric oxide. In the control of plant diseases cuprous oxide is generally used, but this compound may partly turn into cupric oxide. The amounts of copper that dissolve from Lahontuho are, however, very small, 1.0—1.9 mg./100 ml., compared, for example, to the amounts, 140 mg. to 100 ml., contained in the normal spraying liquid (0.5 %) of certain cuprous oxide plant protectants. In the series 3—5, for example, the amount of copper to the plants in each box in each experiment was only some 10 mg., which can hardly be considered injurious. As regards Lahontuho, it is again to be supposed that the arsenic compounds it contains may have caused the slight injuries that were noted in certain plant species. It is also possible that the total electrolyte concentration of Lahontuho, as well as that of the spraying extracts of Boliden and Wolman salts, was so high that it could cause burnt spots in the leaves at certain stages of growth.

If wood is treated with Celcure, very little of the copper and chromium compounds it contains dissolves in the water. Since the compounds in this preparate are not among the strong plant poisons, it is natural that no injuries should appear in the plants.

In this connection it should be pointed out that the experimental results yield an exaggerated picture of the danger of poisoning to plants from the salt compounds. In the first place, the water which condenses on the window frames or wall constructions of greenhouses, or the irrigation water washing off them, is never in practice so long in contact with the preservative-treated wooden parts that the salt concentration of the water dripping down on to the plants would become as high as in the extracts used in the experiments. The amounts of water dripping down on to the plants in a given period of time do not easily become as great as those in the spraying experiments described above, either.

As has been pointed out (cf. p. 16), oily and oil-soluble substances do not injure plants through the soil. The volatilization of these substances insoluble in water from impregnated wood is apparently rather slow in the soil, while the amounts are so insignificant that the roots endure them without injury. On the other hand, the soil absorbs the substances relatively effectively, since a layer of soil as small as 0.5 cm. on the splints already completely prevented volatilization into the air space in the test cases, so that the shoots above soil surface also remained without injury.

The injuriousness to plants of some wood preservatives of this type, as well as their solvents, was clear and strong in those test groups where there was direct volatilization into the air from the splints. The injuries caused in plants, particularly in their leaves, by creosote, pentachlorophenol, wood tar and petroleum were similar in kind, although considerable differences in effectiveness occasioned by the specific characteristics of each substance were to be seen. This is only natural, since all the examined oil type substances contain in part the same chemical compounds. The phytotoxic characteristics of substances of this type have, to a certain degree, been examined in connection with their uses as insecticides and herbicides. It has been found that unsaturated compounds with a high boiling point are the most toxic compounds to plants (Martin 1948, Ahlgren & al. 1951). Of the oily compounds used as wood preservatives, the composition of creosote oil, the high boiling fraction (230—270°C) of coal tar, and that of wood tar, vary considerably, but among their most important constituents phenol and cresol are known to be strong plant poisons (WIELER 1925, GOETZE 1931, TIEGS 1934). Anthracene, which generally exists in small quantities in creosote oil, is considered the most phytotoxic of the compounds contained in coal tar (EWERT 1917). The organic alkalis in tar substances may also cause injuries to leaves, in particular abnormal glossiness (GOETZE 1931). HATFIELD (1935) noted when studying the fungistatic qualities of the aromatic hydrocarbons to wood-destroying fungi that the chlorination of phenols considerably increased their toxicity, at times even by 100 per cent. It is thus not surprising that in the test presented in this paper in most cases the higher plants also suffered most serious injury from pentachlorophenol.

Some information on the toxicity to plants of oily wood preservatives and some of their solvents has been published in the U.S.A. In the main this information tallies with the results achieved in the present study, although some differing opinions have also been presented.

It is unanimously agreed that creosote damages plants. JONES (1945) reports that creosote fumes from treated wood cause injury to growing plants, but no injury is, however, caused through the roots. HICOCK and OLSON (1947, 1954) maintain that damage from creosote is to be found when tender plant growth comes in contact with treated wood, and also without direct contact when greenhouses and hot beds impregnated with creosote are used, since fumes from creosote may injure plant growth. Judging by the test report of KAUFERT and LOERCH (1955), damage in their tests has apparently been caused through air.

According to HICOCK and OLSON (1954), injury by pentachlorophenol to tomato is similar to damage suffered by plants in the air group of the present study: in the early stages the leaf edges turn brown and curl, becoming entirely shrivelled later, and frequently the stems collapse. In their so-called cage test method, pentachlorophenol in a petri dish was placed in a closed container near the test plant. In the so-called flat tests, the test seedlings were grown without container in miniature flats of red pine, which had been treated by cold soaking in pentachlorophenol. Damage in both cases had apparently taken place through the air. Also KAUFERT and LOERCH (1955) have found that pentachlorophenol (with Stoddard Oil or Fuel Oil No. 2 as solvent) is as injurious to tomato as creosote. EASTWOOD (1943), on the other hand, points out that in certain conditions pentachlorophenol is harmless to plants. POST (1952) also mentions that phenol compounds are satisfactory after proper drying. What the conditions referred to are like does not appear from the references available.

Copper naphthenate, which in the present study was found entirely non-injurious to the tested plant species, is generally considered as a useable wood preservative in greenhouses, benches, flats and pots, although the organic solvents most commonly used with it are, according to the opinions of most research workers, slightly toxic to more sensitive plant species at least (JONES 1945, POST 1952, HICOCK & OLSON 1954, ROISTACHER & BAKER 1954, KAUFERT & LOERCH 1955). As stated above, in the tests carried out in connection with the present study, benzene (cf. p. 6) and turpentine were solvents that could be used as solvents of copper naphthenate in the impregnation of wooden parts of greenhouses without danger of injury.

## Summary

Research on the possibilities of using wood preservatives on the Finnish market in the impregnation of greenhouses and bench constructions has been carried out in 1952—56 at the Plant Pathology Department of the Agricultural Research Centre, Tikkurila.

Applying a technique evolved for this work, the following matters were investigated: a) what types of preparations are injurious to plants, b) in what way the injuries are caused, and c) what the symptoms of injury consist of in different types of vegetable and ornamental plants.

The following substances were used in the tests:
Water soluble, salt compounds: Boliden salt (BIS), Celcure, Lahontuho K 33 and Wolman salt (Tancas). Contents p. 5.
Oily and oil-soluble: copper naphthenate, creosote and pentachlorophenol compounds, and wood tar.
Solvents: petroleum and turpentine.

Injuries can be caused as follows: when substances from wood treated with preservatives pass directly into the mould; when substances volatilize directly into the air in greenhouses or benches; when substances dissolve into drip or irrigation water which drips on the shoots.

Water-soluble salt compounds did not generally damage plants through soil or air. From wood treated with Boliden and Wolman salts, preparates having a smaller capacity of adherence to wood, such quantities of substances toxic to plants dissolved into water that when the solution was continuously dripping on the shoots necrotic spots appeared on the leaves, their margins dried, and growth was retarded. Celcure and Lahontuho compounds proved almost harmless to plants.

Oily and oil-soluble substances and solvents did not damage plants if the treated part of the wood was entirely covered by mould. Some wood preservatives injured plants when volatilizing directly into the greenhouse air. Creosote and pentachlorophenol caused fading of leaves, necrosis, abnormal glossiness, bulging, drying and general stunted

growth, and in more severe cases of poisoning the rapid death of the plant. The more sensitive plant species exhibited injuries, although slight, as late as in the third year after the treatment of the wood. The damage could be prevented by varnishing the treated parts of wood. Wood tar and petroleum caused in some cases slight fading, drying and dying of the tissue in the leaf blade. - Copper naphthenate compounds, and turpentine of the solvents, in no way injured plant growth.

The susceptibility of different plants to the toxic effects of wood preservatives varied. Among the test plants cucumber, cineraria and tomato proved the most susceptible to injury. Because of its type of growth, tulip also suffered considerable damage. Cabbage, swede and cyclamen were the least susceptible of the tested plants.

## References


Ahlgren, G. H., Klingman, G. C. & Wolf, D. E. 1951. Principles of weed control. 368 p. New York, London.

Andrén, F. 1949. Ett par fall av kloratskada i växthus. Växtskyddsnotiser 1949, 3:7—9.

Eastwood, T. M. 1943. Chemical preservative helps growers extend life of benches, flats. Florists' Rev. 91 (2354): 15—16. (Ref. Biol. Abstr. 17, 2 (22573): 2197.)

Ekstrand, H. 1941. Förgiftning av växter genom ett fluorhaltigt träimpregneringsmedel. Stat. Växtskyddsanst. Medd. 36:1—32.

Ewert, R. 1917. Das Anthrazen als pflanzenschädlicher Bestandteil des Teers. Jahresber. Vereinig. angew. Bot. 15:170—172.

Frear, D. E. H. 1949. Chemistry of insecticides, fungicides and herbicides. 417 p. Toronto, New York, London.

Goetze, G. 1931. Untersuchungen über Obstbaumkarbolineen. Zbl. Bakt. II, 83: 136—164.

Hatfield, I. 1935. Toxicity in relation to the position and number of chlorine atoms in certain chlorinated benzene derivatives. Amer. Wood-Pres. Assoc. 31:57—66. (Ref. Horsfall, J. G. 1945.)

Hicock, H. W. & Olson, A. R. 1947. The preservative treatment of fence posts and other structural materials. Conn. Agr. Exp. Sta. Bull. 509:1—19.

—»— 1954. The toxity to plants of wood preservatives and their solvents. Conn. Agr. Exp. Sta. Circ. 189:1—4.

Horsfall, J. G. 1945. Fungicides and their action. 239 p. Waltham, Mass.

Jones, L. H. 1945. Toxic effect on plants by wood preservatives. Mass. Agr. Exp. Sta. Bull. 428:23.

Kadow, K. J. 1934. Zinc sulfate as a fungicide and bactericide, together with its effect on peach growth and on peach spray injury. Trans. III. Sta. Hort. Soc. 68:240—257.

Kaufert, F. H. & Loerch, K. A. 1955. Treated lumber for greenhouse use. Minn. For. Note 36:1—2.

Linnasalmi, A. 1956. Lasinalaisen vihannesviljelyn terveydenhoidosta. Maatalous ja koetoiminta 10:116—122.

Martin, H. 1948. The scientific principles of plant protection. 385 p. London.

Post, K. 1952. Use Cuprinol for treating wood. N. Y. Sta. Flower Growers Bull. 80, 8. (Ref. Chem. Abstr. 46, 2:6786.)

Roistacher, C. N. & Baker, K. F. 1954. Disinfesting action of wood preservatives on plant containers. Phytopath. 44:65—69.

Schwartz, G. 1929. Vorsicht bei Anwendung von Holzimprägnierungsmitteln im Gewächshaus. Gärtner Börse. Jahrg. 11, Nr. 17, s. 261. (Ref. Ekstrand, H. 1941).

Strachitzkii, K. 1932. On the factors causing the appearance of burns on the leaves of plants treated by the arsenic-containing preparations. Plant Protection 8:421—432.

Swingle, D. B., Morris, H. E. & Burke, E. 1923. Injury to foliage by arsenical spray mixtures. Jour. agric. Res. 24:501—537.

Tiegs, E. 1934. Rauchschäden. Handbuch der Pflanzenkrankheiten, 1, 2:243—309. (Begr. P. Sorauer 6. Aufl., hrsgb. O. Appel & L. Laub.) Berlin.

Wieler, A. 1925. Über die Ursache der bei Teerschäden an den Blättern auftretenden Verfärbungen. Bot. Arch. 11:272—314.

# Selostus:

## Lahosuoja-aineiden myrkyllisyydestä kasveille sekä niiden käyttömahdollisuuksista kasvihuone- ja lavarakenteissa

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Tutkimus maassamme markkinoitavien lahosuoja-aineiden käyttömahdollisuuksista kasvihuone- ja lavarakenteiden kyllästämiseen on suoritettu v. 1952—56 Kasvitautien tutkimuslaitoksella Tikkurilassa.

Tutkimuksen tarkoituksena oli selvittää a) minkä tyyppiset valmisteet ovat kasveille vaarallisia, b) millä tavoin vioitukset syntyvät ja c) minkälaiset ovat vioitukset erityyppisissä vihannes- ja koristekasveissa.

Kokeissa olivat seuraavat aineet ja valmisteet:
Vesiliukoiset kyllästyssuolat: Boliden-suola (BIS), Celcure, Lahontuho K 33, Wolman-suola (Tancas) (koostumukset s. 5).
Öljymäiset ja öljyliukoiset: kuparinaftenaatti, Aspergol KT (vaikuttava aine Cu-naftenaatti), kreosootti, Rusko (vaik. aine kreosootti), pentaklorfenoli, Valtti (vaik. aine pentaklorfenoli), Woodlife (vaik. aine pentaklorfenoli).
Liuottimet: petroli, tärpätti.

Kokeita varten käsiteltiin männyn pintapuusta tehtyjä tikkuja tutkittavilla aineilla. Vesiliukoisilla aineilla kyllästettiin tikut käyttämällä painemenetelmää, öljymäisillä ja öljyliukoisilla upottamalla tikut aineeseen tai aineen bentseeniliuokseen. Terva-, petroli- ja tärpättikäsittelyt suoritettiin sivelemällä tikut. Käsittelyn jälkeen kuivattiin tikut pitämällä niitä kaksi viikkoa 22° C:n ja 1 vrk. 45° C:n, liuottimilla käsiteltyjä tikkuja 2 vrk. 22° C:n lämpötilassa.

Kokeet suoritettiin kasvihuoneessa lasihäkeissä. Koekasveina olivat erilaisia kasvityyppejä edustavat vihannes- ja koristekasvit, kupukaali, kurkku, lanttu, tomaatti, sineraaria, syklaami ja tulppaani (taulukko 1).

Koska kasvivioitusta voi aiheutua lahosuojatusta puusta kasvumultaan erkanevien, suoraan ilmaan haihtuvien ja tippa- tai kasteluveteen liukenevien aineiden vaikutuksesta, järjestettiin seuraavat kolme koeryhmää: a) koetikut maassa, b) koetikut ilmassa ja c) kasvien suihkutus vesiliukoisilla aineilla käsitellystä puusta saadulla vesiuutteella (asetelma s. 10, taulukko 1).

Päivittäin tehtyjen havaintojen perusteella arvioitiin vioitusten voimakkuus koekasveissa kymmenasteikolla, jossa:

1—2 = vioitus lievää, vähäistä lehtisolukkojen tummumista tai vaalenemista
3—4 = lehden reunojen tai lavan suonien välissä vähäistä kuivumista, kellastumista, kiiltoa, käpertymistä, lievää kasvun hidastumista
5—6 = edellä esitetyt oireet voimakkaampina
7—8 = lehdistön kuivumista ja kuolemista, kasvu hidasta
9—10 = koko kasvit kuolevia tai täysin kuolleita

Näin saatujen arvojen perusteella on laadittu piirrokset eri aineiden koekasveissa aiheuttamista vioituksista (kuvat 3, 4, 8, 9, 11, 16, 19).

Vesiliukoiset kyllästyssuolat eivät yleensä vioittaneet kasveja kasvumullan eivätkä ilman kautta. Boliden- ja Wolman-suoloilla käsitellystä puusta liukeni kuitenkin veteen sellaisia määriä kasveille myrkyllisiä aineita, että suihkutettaessa versoja jatkuvasti uutevedellä, lehtireunat kuivuivat ja lapaan muodostui kuivuneita nekroosilaikkuja, kasvu hidastui; Lahontuhon aiheuttamat vioitukset olivat erittäin lieviä. (Kuvat 1—5). Celcure oli kokeissa kasveille vaaratonta.

Öljymäiset ja öljyliukoiset aineet sekä liuottimet eivät vahingoittaneet kasveja, kun käsitelty puu oli kokonaan mullan sisässä (kuva 6). Suoraan kasvihuoneilmaan haihtuessaan vioittivat eräät lahosuoja-aineet kasveja. Kreosootti ja pentaklorfenoli aiheuttivat lehtien vaalenemista, kuivumista, nekroosia, epänormaalia kiiltoa ja kupertumisia sekä yleistä kitukasvuisuutta, ankarammissa myrkytystapauksissa kasvien nopean kuolemisen (kuvat 6—12, 15—19). Vioitusta ilmeni arimmissa kasvilajeissa, joskin lievänä, vielä kolmantena vuotena puun kyllästämisestä. Vauriot voitiin estää parin vuoden ajan lakkaamalla kyllästetty puu (kuva 20). On kuitenkin mahdollista, että lakkauksen alkaessa vähitellen halkeilla, vioituksia syntyy kasveissa. Puuterva ja petroli aiheuttivat joissakin tapauksissa vähäistä lehtisolukoiden kuivumista ja kuolemista (kuvat 8, 9, 11, 13—14). Kuparinaftenaattivalmisteet ja liuottimista tärpätti eivät millään tavoin haitanneet kasvua.

Eri kasvilajien alttius lahosuoja-aineiden myrkkyvaikutukselle oli erilainen. Koekasveista kurkku, sineraaria ja tomaatti vioittuivat herkimmin. Kasvumuotonsa takia myös tulppaani kärsi melkoisesti. Kestävämpiä olivat kupukaali, lanttu ja syklaami.

Kokeilluista aineista soveltuvat kasvihuoneiden ja lavojen puurakenteiden kyllästämiseen puuhun hyvin kiinnittyvät, vesiliukoiset kyllästyssuolat Lahontuho ja Celcure sekä öljyliukoisista ainetyypeistä kuparinaftenaattipitoiset valmisteet.