TWO CEREAL VIRUS DISEASES IN FINLAND

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In several districts in Finland damage to oats and other spring cereals has been discovered at various times, and various views have been expressed as to the cause of the damage. It has been observed that the extensive damage to oats in the western coastal region is associated with the occurrence of the leafhopper *Calligypona pellucida* Fabr. (4). It is assumed that the leafhopper distributes a virus (2), although this has not been proved by experiments. Another view is that the damage is phytotoxaemia caused by the saliva of the leafhopper (6). In the region of Mikkeli in Savo, as well as in southern Ostrobottnia and in Satakunta, JAMALAINEN (3) found in the summer 1956 a disease in oats which in its symptoms was like cereal yellow dwarf.

A disease in oats similar to that found in Finnish western coastal regions has also been found in Sweden. LINDSTEN (5) has established three cereal virus diseases there. Two are spread by the leafhopper *C. pellucida*. One disease resembles European wheat striate mosaic and the other is propably a new virus disease. The third virus disease which is transmitted by the aphids *Rhopalosiphon padi* L. and *Macrosiphum granarium* Kirby resembles cereal yellow dwarf (5). A disease characterized by excessive tillering in oats and which is spread by the leafhopper *C. pellucida* has also been observed in Czechoslovakia (8).

The bird cherry aphid (*Rhopalosiphon padi* L.) occurred in exceptionally great quantities in Finland last summer. Plants attacked by these aphids resembled plants infected by barley yellow dwarf (= cereal yellow dwarf). It is known that this disease is transmitted by the bird cherry aphid (12), and in Finland the disease has been found previously in rye grass (9). Thus it was important to study whether the disease found in Finland last summer in oats was a virus disease transmitted by the bird cherry aphid.

Experiments were also made with the leafhopper *C. pellucida* in order to find out if it transmits viruses also in this country.

Materials and methods

In order to determine the virus diseases, infected plants and vector insects were collected from Uusimaa, South Finland, where bird cherry aphids (*Rhopalosiphon padi*) attacked oats severely and from Peräseinäjoki and Laihia in West-Finland, where the disease associated with the occurrence of the leafhopper (*Galligypona pellucida*) has been found in oats.

Diseased plants infected by the bird cherry aphids were collected from four districts in Uusimaa for preparing infection feed. Two or three plants which exhibited very clear symptoms were selected from the samples taken from each district. The leaf or half a leaf of the infected plant was placed in a test tube on moist filter paper, and the aphids were transfrred to the leaf with a hair brush. The aphids in the first transmissions from samples collected from Helsinki and Tikkurila were allowed to feed on the infected leaves for periods of 24 or 48 hours. After the infection feed the aphids were transferred to healthy plants, 5—10 aphids on each plant. In two experiments barley was infected; in the other experiments oats were used. Plants to be inoculated were in the 1—2 leaf stage. Two days after inoculation the aphids were removed with insecticide sprays. The infected plants were kept in a glasshouse for observation and were sprayed with insecticide once a week.

Leafhoppers were collected from fields at Laihia and Peräseinäjoki, West-Finland in the summers 1958 and 1959. In 1959 leafhoppers were collected also from Tikkurila, South Finland. The leafhoppers were mainly adults or nymphs of the last stage. They were reared on winter wheat and barley grown in pots containing 10—12 plants. The leafhoppers were confined on the seedlings with celluloid cages. The upper end of the cage and the two »ventilation» holes on the sides were covered with thin cotton cloth. The open base was pressed into the soil. Small celluloid tubes were used to confine individual leafhoppers on single plants. The cages as well as the plants were labelled with numbers for identifying the insect. Transferring the leafhoppers from the plants was accomplished by means of a suction apparatus. The leafhoppers originating in different localities were kept in their own separate groups. Some leafhoppers at the nymphal stages from each group were reared singly. After their emergence the adults were mated, and each couple was placed in a single cage. The couples, as well as the large colonies, were transferred each week to new plants which were kept in the glasshouse for observation. The progeny of each couple was collected immediately after hatching and formed into a separate group.

Leafhoppers which themselves as well as their parents had not caused disease were chosen for the transmission tests. For later transmission tests it was possible to use leafhoppers whose parents' infection ability was known for several generations. For each experiment the progeny of one mother was used; half of them were given the infection feed, while the other half were control insects. Plants infected by leafhoppers in the field were used for the infection feeds; the feeding continued from 3 to 10 days generally. In most tests the infection feed was given to half-

grown nymphs. The leafhoppers were subsequently transferred to new plants, one leafhopper per plant once a week during approximately one month. The infected plants were kept in a glasshouse and sprayed once a week with insecticide.

Results

Transmission tests with Rhopalosiphon padi. The inoculated plants exhibited the first symptoms 14—25 days after the removal of the aphids. The tips of the youngest leaves showed, especially when viewed against light, yellow-green blotches and pale roundish spots. Somewhat later the leaf tips began to turn yellow. The colouring gradually spread from the tips downwards, and the colour of the leaves turned from yellow to reddish yellow, often also bright red or brownish red (Fig. 1). The tips of the leaves curled up. Serrations of the margins could often be seen in young leaves already before the colour changes (Fig. 4). At the stage when only the tips were yellow, the leaves were thick and stiff. The leaves of barley did not exhibid other changes in colouring than yellowing beginning at the tips and spreading finally over the entire leaf. The plants became stunted and some

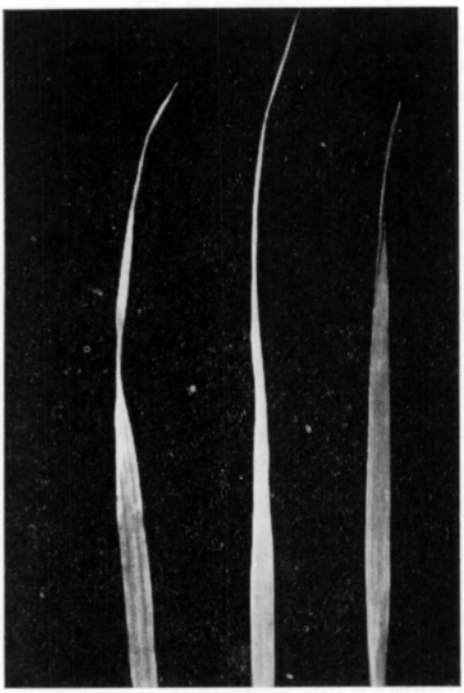

Fig. 1. Oats leaves infected by cereal yellow dwarf. On the right a healthy leaf.

Fig. 2. Three oats plants infected by cereal yellow dwarf one month after inoculation. On the right a healthy plant.

developed abundant tillers (Fig. 2). Panicle emergence was retarded and the florests in the panicles were often blasted. The control plants remained healthy in all the experiments as did the plants on which the aphids were allowed to breed.

Under the same external conditions the symptoms appeared similar after each inoculation. In conditions of low-temperature and low light intensity the symptoms were delayed and the amount of discoloration was less than in plants grown under conditions of high temperature and high light intensity. Isolations of plants collected from different localities varied only slightly in their symptoms.

Transmission tests with bird cherry aphids are presented in the following table. The sources of infection in experiments I consisted of diseased plants collected from fields, while plants infected in the transmission tests from this original material were used for the infection feed in experiments II, and so on. The transmissions were carried out at 4—5 week intervals. In addition to the experiments listed in the table, succesful transfers were also made on barley collected at Inkoo, Vestankvarn. In continued transmissions it was found that the causal agent of the disease remained easily transferable.

Transmissions	Helsinki Tali estate No. of plants		Helsinki, parish Tikkurila No. of plants		Inkoo Vestankvarn No. of plants		Snappertuna Raseborg No. of plants		Control No. of plants	
	inoculated	infected %	inoculated	infected %	inoculated	infected %	inoculated	infected %	infested with virusfree aphids	infected %
I	20	70.0	29	72.5	24	83.2	12	91.5	20	0
II	67	76.1	10	100.0	22	45.4	10	100.0	30	0
III	40	62.5	23	78.0	10	70.0			20	0
IV	20	60.0	30	73.3					10	0
Total	147	69.4 %	92	77.0 %	56	80.5 %	22	95.8 %	80	0

The disease described above is similar to cereal yellow dwarf in its symptoms and in the length of its incubation period. It has been found that the bird cherry aphid acts as a vector of cereal yellow dwarf in England and in Netherlands (12). Since the disease under investigation is spread by the same vector as cereal yellow dwarf and since its symptoms and incubation period are similar, the disease was identified as cereal yellow dwarf.

Transmission tests with Galligypona pellucida. Health, experimental plants, on which leafhoppers collected from fields at Laihia and Peräseinäjoki had fed, exhibited disease symptoms 10—21 days or sometimes as much as 40 days after the start of feeding. These symptoms were chlorotic spots and threadlike, broken streaks on the leaves which gradually enlarged and finally caused the leaf to turn completely yellow (Fig.3). The chlorosis was first apparent on the youngest leaves. The infected plants became heavily stunted and some developed abundant side

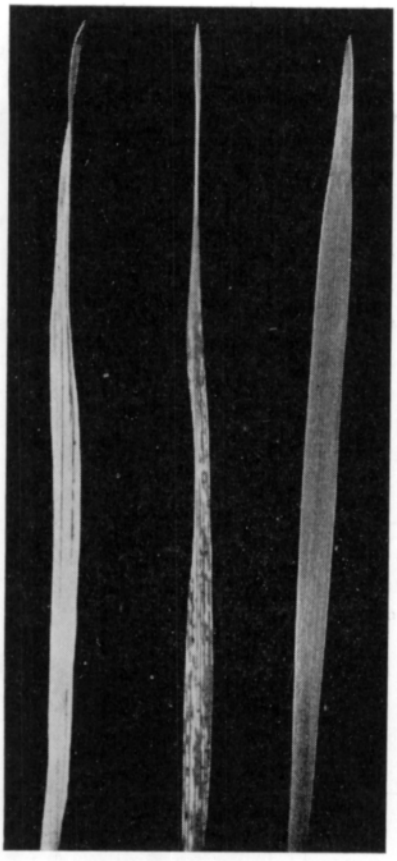

Fig. 3. Winter wheat leaves infected by European wheat striate mosaic. On the right a healthy leaf.

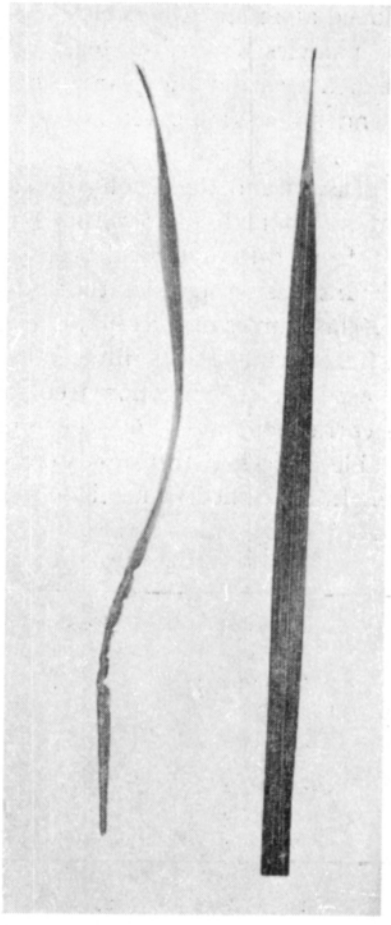

Fig. 4. Serrations on barley leaves. On the right a healthy leaf.

shoots. Most plants that had been infected at the seedling stage died within 1—2 months after infection. The symptoms were similar both in winter and spring wheat and in barley. Young barley leaves often exhibited serrations. Chlorotic streaks were found also on oats leaves 15—30 days after the infection. These, however, soon disappeared and the leaves as well as the whole stem turned reddish yellow or red. The panicle remained in the sheath, and finally the entire plant shrivelled and died.

Since these symptoms greatly resembled those caused by the European wheat striate mosaic virus, transmission tests were made with leafhoppers, which act as a vector for this virus.

The transmission tests showed that leafhoppers which had not infected plants in two previous generations, and in some tests in three preceding generations,

transmitted the virus from diseased plants to healthy ones. The control insects which descended from the same mothers did not cause the disease.

The leafhoppers became capable of infecting plants 15—21 days — or sometimes even later — after the start of the infection feed, but once the leafhopper became infective, it remained so for almost the rest of its life.

Only a part of the progeny of each mother proved capable of transmitting the virus, and the different colonies varied greatly in this respect. In preliminary tests the leafhoppers of some colonies did not transmit the virus at all; in other colonies only about 3—8 % of the leafhoppers given infection feed were able to transmit the virus. In one colony about half of the leafhoppers proved to be able to transmit the virus. This variation is typical of many species of leafhoppers which transmit viruses: among the same leafhopper species colonies vary greatly in their virus-transmitting ablity (1, 11,13).

The European wheat striate mosaic virus is transmitted from infective females through the eggs to their offspring (10, 13). In the present tests this was not observed. This may be due to the fact that for the transmission experiments, leafhopper colonies which were inefficient to transmit the virus had been chozen. According to WATSON and SINHA (13) the inefficient colonies do not transmit the virus to their offspring, or, if so, only to a very limited extent. On the other hand, with colonies in which many leafhoppers were able to transmit the virus, precise tests were not made to establish the transmission of the virus, to the offspring. It appeared, however, that in certain cases some leafhoppers had received the virus from their mother.

Since the disease described above is spread by the same vector as European wheat striate mosaic and since its symptoms and incubation period are similar, the disease was identified as European wheat striate mosaic.

Discussion

It appears probable that the European wheat striate mosaic virus, transmitted by *Calligypona pellucida*, has been partly the cause of the damage to oats in West Finland. The symptoms of this damage and those of this virus disease in their later stages in oats are similar, for example stunting and reddening of the plants and retardation or complete inhibition of the development of the panicle. The extent of European wheat striate mosaic in the country is not known.

The aphid-transmitted cereal yellow dwarf disease, whose symptoms are dwarfing, excessive tillering and reddening in oats, was common in Finland in the summer 1959. A similar disease has been observed previously in this country, also in the region of damage to oats in West Finland (3), but no attempt was made then to determine the cause.

It seems likely that these virus diseases which to a certain extent resemble one another in their symptoms have been involved as the cause of the damage to oats in West Finland.

Summary

In many regions in Finland damage to oats and to other spring cereals has been discovered at various times, and various views have been expressed as to the cause of this damage.

In order to determine the virus diseases which were thought to take part in this damage, diseased plants and vector insects were collected from South and West Finland.

The results of the experiments made with *Rhopalosiphon padi* L. indicated that it transmits a virus disease. On the basis of its symptoms, incubation time and vector, the disease was identified as cereal yellow dwarf.

The results of the experiments made with *Galligypona pellucida* Fabr. indicated that it transmits a virus disease. On the basis of its symptoms, incubation time and vector, the disease was identified as European wheat striate mosaic.

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SELOSTUS:

KAKSI VILJAN VIRUSTAUTIA TODETTU SUOMESSA

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Monilla paikkakunnilla on kaurassa ja myös muissa kevätviljoissa esiintynyt aika ajoin vioitusta, jonka aiheuttajista on esitetty erilaisia tietoja. Läntisellä rannikkoalueella esiintyneen »kaurantuhon» aiheuttajaksi on todettu viljakaskas *Calligypona pellucida* Fabr. (4). Mikkelin tienoilla Savossa samoin kuin Etelä-Pohjanmaalla sekä Satakunnassa on Kasvitautien tutkimuslaitoksen toimesta (3) kesällä 1956 todettu kaurassa *Cereal yellow dwarf*–virustaudin kaltaista tautia.

Ruotsissa on esiintynyt kaurassa samankaltaista tautia kuin läntisella rannikkoalueellamme. Taudin esiintymisalueelta kootusta materiaalista on todettu kolme viljan virustautia, joista kahta levittää viljakaskas. Kolmas on kirvojen levittämä ja muistuttaa *Cereal yellow dwarf*ia (5).

Viime kesänä tuomikirva (*Rhopalosiphon padi* L.) esiintyi maassamme poikkeuksellisen runsaana. Tuomikirvan saastuttamissa viljapelloissa monet kasvit olivat *Cereal yellow dwarf*in tartuttamien kasvien kaltaisia. Kävi siis aiheelliseksi selvittää onko meillä kaurassa viime kesänä esiintynyt tauti virustauti, jota tuomikirva levittää. Kun myös viljakaskaan on arveltu meillä levittävän virustautia (2) ja Englannissa (10) sekä Ruotsissa (5) on viljakaskaan todettu toimivan *European wheat striate mosaic*-viruksen sekä Ruotsissa vielä toisen, mahdollisesti ennestään tuntemattoman viruksen vektorina, otettiin tutkittavaksi myös viljakaskaan aiheuttama tauti.

Virustautien määrittämistä varten kerättiin aineistoa sekä Uudeltamaalta että Vaasan läänin alueelta. Sairastuneita kasveja hankittiin tuomikirvojen saastuttamilta pelloilta neljältä paikkakunnalta Uudeltamaalta. Tuomikirvoja koottiin Tikkurilasta ja viljakaskaita Tikkurilasta, Laihialta ja Peräseinäjoelta. Tuomikirvoista kasvatettiin OSWALDIN ja HOUSTONIN (7) kuvaaman menetelmän mukaisesti jälkeläistö, johon kuuluvat yksilöt eivät olleet virusten kantajia.

Tuomikirvoilla suoritetuissa siirrostuskokeissa annettiin kirvojen imeä 1—2 vrk:n ajan sairaita kasveja, minkä jälkeen kirvat siirrettiin terveille kauran oraille 2 vrk:ksi. Inokuloituihin kasveihin ilmaantuivat ensimmäiset symptomit 14—25 vrk:n kuluttua kirvojen poistamisen jälkeen siten että kaurojen nuorimpien lehtien kärkiosissa oli kellanvihreää kirjavoitumista. Vähän myöhemmin lehtien kärjet alkoivat kellastua (kuva 1). Kellastuminen levisi vähitellen kärjestä alkaen yhä alemmas tyveä kohden. Samalla lehtien väri muuttui keltaisesta punakeltaiseksi, punaiseksi tai ruskeanpunaisiksi. Nuoriin lehtiin ilmaantui usein jo ennen värin muutoksia nirhamia (kuva 4). Siinä vaiheessa, jolloin vain lehtien kärkiosat olivat kellastuneet, lehtilavat olivat paksuuntuneet ja jäykät. Ohran lehdissä ei ilmennyt muita värin muutoksia kuin kärjistä alkava ja lopulta yli koko lehtien ulottuva keltaisuus. Kasvien pituuskasvu hidastui ja jotkut kasvit muodostivat runsaasti sivuversoja (kuva 2). Röyhylle tulo viivästyi ja muodostuneissa röyhyissä oli surkastuneita tähkylöitä. Kontrollikasvit, joilla oli pidetty tuomikirvoja, jotka eivät olleet saaneet infektioruokintaa 2 vrk:n ajan, pysyivät täysin terveinä kai-

kissa suoritetuissa kokeissa. Näin ollen kirvat siirsivät taudinaiheuttajan sairaista kasveista terveisiin, jotka sairastuivat n. 2—3 viikon pituisen inkubaatioajan kuluttua. Edellä kuvattu tauti on symptomien, inkubatioajan ja vektorin perusteella *Cereal yellow dwarf*-virustaudin kaltainen, ja sitä on pidettävä samana tautina.

Viljakaskaista kasvatettiin yhden emon jälkeläistön käsittäviä ryhmiä, jotka saivat lisääntyä useamman sukupolven ajan. Siirrostuskokeita varten valittiin sellaisia kaskasryhmiä, jotka itse samoin kuin niiden emotkaan eivät ennen infektioruokintaa olleet aiheuttaneet tautia kasveihin. Infektioruokinnan jälkeen kaskaat siirrettiin terveille kasveille 1 kaskas kasvia kohden. Noin 15—21 vrk:n, joskus vasta 40 vrk:n kuluttua infektioruokinnan alkamisesta ilmaantuivat symptomit infektoituneisiin kasveihin. Vehnän, kauran ja ohran nuorimpiin lehtiin ilmaantui tällöin kloroottisen solukon muodostamia pisteitä ja viiruja, jotka laajenivat vähitellen niin, että lopulta koko lehti oli täysin keltainen (kuva 3). Sairastuneiden kasvien pituuskasvu hidastui, ja jotkut kasvit muodostivat runsaasti sivuversoja. 1—2-lehtiasteella infektoiduista kasveista useimmat kuolivat 1—2 kk:n kuluessa infektoinnista.

Ohran nuoriin lehtiin ilmaantui jo varhain samanlaisia nirhamia kuin kasveihin, joita tuomikirvat olivat imeneet.

Kloroottiset viirut hävisivät kauran lehdistä pian, ja lehdet sekä lopulta myös koko korsi muuttuivat punakeltaisiksi ja myöhemmin punaisiksi. Röyhy jäi tupen sisään, ja kasvi kuihtui.

Siirrostuskokeet osoittivat, että viljakaskaat, jotka eivät olleet kahden edellisen, eräissä kokeissa jopa kolmen edellisen sukupolven aikana aiheuttaneet tautia kasveihin, siirsivät sairaista kasveista taudin aiheuttajan terveisiin kasveihin. Sen sijaan samojen emojen jälkeläisistä ne, jotka eivät olleet saaneet infektioruokintaa, eivät aiheuttaneet tautia kasveihin.

Kuvattu tauti on symptomien, inkubaatioajan ja vektorin perusteella samanlainen kuin *European wheat striate mosaic*-virustauti (10, 13), ja sitä on pidettävä samana tautina.

On varsin todennäköistä että *European wheat striate mosaic* ja *Cereal yellow dwarf* ovat Länsi-Suomessa esiintyneen »kaurantuhon» aiheuttajia. Vielä ei voida sanoa miten suuri osuus näillä taudeilla on kaurantuhossa, jonka symptomit ovat monessa suhteessa samanlaiset kuin mainittujen virustautien symptomit kaurassa.