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ANNALES AGRICULTURAE FENNIAE, VOL. 28: 285—295 (1989)

Seria PHYTOPATHOLOGIA N. 107 — Sarja KASVITAUDIT n:o 107

THE DISTRIBUTION AND INCIDENCE OF POTATO MOP-TOP VIRUS IN FINLAND AS DETERMINED IN 1987 AND ON THE VARIATION OF DISEASE SYMPTOMS IN INFECTED POTATOES

AARNE KURPPA

KURPPA, A. 1989. **The distribution and incidence of potato mop-top virus in Finland as determined in 1987 and on the variation of disease symptoms in infected potatoes.** Ann. Agric. Fenn. 28: 285—295. (Agric. Res. Centre, Inst. Pl. Protect., SF-31600 Jokioinen, Finland.)

The incidence of potato mop-top virus PMTV was investigated in Finland immediately upon its detection and found to be responsible for spraing symptoms in potato tubers grown for the starch industry. Sampling of tuber lots and field soils was focused on the areas in western, southern and southeastern Finland where potatoes are basically grown for industrial use. For warranty purposes, also all of the fields used in the production of basic and elite seed potatoes at the premises of the Seed Potato Center at the Agricultural Research Centre, as well as samples from all tuber lots were examined. The remaining tuber and soil samples were randomly collected. Soil samples were tested by the bait plant method and tuber samples by visual symptom observation after storage at periodically varied temperatures. The results were partially confirmed by electron microscopy or by immunosorbent electron microscopy. In addition, data from ca. 4750 potato lots grown by 878 farmers were collected by the processing industry.

PMTV was not detected in soil or tuber samples at the Seed Potato Center. The fields in table potato production were also still basically non-infested. On the contrary, the virus was isolated in 41 % of inspected soil samples from the fields of starch potato growers. Overall, the data suggest that at least 22 % of the farms growing process potatoes already have fields infested by potato mop-top virus. Until now, the virus has been confined to one particular cultivar namely, cv. Saturna. There are, however, some commonly grown table potato cultivars with greater susceptibility to the virus than cv. Saturna. Therefore there is a continuous potential risk around the country in the production of high quality potatoes.

Symptoms induced by PMTV in tubers and haulms are illustrated by numerous photographs included herein. Usually both skin and flesh symptoms are present but in some cultivars only internal spraing is found. Secondary foliar symptoms including heavy stunting may develop in the most susceptible cultivars.

Index words: potato mop-top virus, PMTV, soil-borne viruses, spraing, *Spongospora subterranea,* soil tests, bait plant method, potato cultivars.

INTRODUCTION

Potato mop-top virus (PMTV) is transmitted in the soil by the potato powdery scab fungus *Spongospora subterranea* (Wallr.) Lagerh. and is retained for a number of years in the resting spores of the fungus (JONES and HARRISON 1969). In Europe, PMTV has been reported to occur in the British Isles (GALVERT and HARRISON 1966, McKAY 1969), in the Netherlands (van HOOF and ROZENDAL 1969), Norway (BJÖRNSTAD 1969), Sweden (RYDEN et al. 1986) and Finland (KURPPA 1987). In South America it is found in the region characterized by rather cool climate and high rainfall (SALAZAR and JONES 1975). The virus causes a variety of symptoms in the haulms and tubers of potato plants, but these are seldom typical enough for definite visual detection.

In Finland, PMTV was identified in 1987 by isolating it from infested soil to bait plants, but reliable documentation on its incidence here at least five years earlier is now available. A high incidence of spraing symptoms in the tubers of the potato cv. Saturna was commonly found in connection with the processes of the food industry during autumn 1986, and particularly in 1987, thus confirming the existence of severe quality problems.

This paper describes investigations to assess the distribution and incidence of potato mop-top virus in Finland illustrating its primary and secondary symptoms in potato cultivars. Finally, the importance of PMTV in potato production for different purposes, is discussed.

MATERIAL AND METHODS

To assess the incidence of potato mop-top virus in different soils, a large number of soil samples was collected and investigated. For warranty purposes, the potato fields of all growers under contract with the Seed Potato Center at Tyrnävä were sampled as well. Otherwise the soil samples originated mainly from the fields of professional potato growers. These samples also included such soils, in which potato had not been grown for a number of years as well as virgin soils. A few other soil samples were received from various sources in the case of spraing affected tubers. The samples used for testing consisted of 50 subsamples, that were pooled afterwhich ca. 800 grams of soil was taken for investigation. The total number of soil samples studied was 239.

All soil samples were divided into two parts. One part was directly utilized for virus isolation by the bait plant method (JONES and HARRISON 1969, KURPPA 1989). Two seedlings of the test plants, one of *Nicotiana clevelandii* and one of *N. debneyi*, were planted in a pot or a cardboard box lined with a plastic bag. The plants were grown in growth chambers at a constant temperature of 14 °C under illumination of ca. 3000 lux from light tubes 16 h/d. The other part of the soil sample was dried at room temperature for two weeks, passed through a 1 mm sieve, moistened with tap water whereupon the bait plants were planted. Otherwise, the treatment continued as described above. Bait plants were uprooted after 8 weeks of growth, their roots washed with tap water then ground in 0.06 M phosphate buffer pH 7.2. Two replicates of four carborundum dusted leaves of *Chenopodium amaranticolor* and *C. quinoa* were inoculated in each case. Test plants were grown at 14 °C under ca 3000 lux of artificial light 16 h/d and symptoms observed three and four weeks after inoculation. Approximately halfway through the tests the use of *C. amaranticolor* was discontinued due to a rather weak reaction to virus infection.

PMTV incidence in potato tubers was determined by inspection of different samples. A uniform group of potatoes grown as seed material for industrial purposes in western and south-eastern Finland totalled 46 stocks. The tubers (200/each stock) were washed, inspected visually and then stored first for two weeks at 18 °C and then another two weeks at 8 °C. After that, the tubers were cut into halves, spraing symptoms recorded and the halves again stored for three weeks at 8 °C before the final observation (see KURPPA 1989). The Seed Potato Center, employed the same method for inspection of the stocks of basic or elite seed potatoes, which totalled 257.

In autumn 1987, data from ca. 4750 lots of potatoes grown by 878 farmers were collected at various potato processing factories. More than one third of the tuber samples were double samples (ca. 10 kg each), of which one was analysed in November and the other in January after storage treatment at 18 °C and 8 °C. Otherwise the tuber samples from the process potatoes were observed immediately on receipt the material for processing.

Occasional tuber samples received for investigation totalled 26. The photographs in this report chiefly represent symptoms in the potatoes grown in field experiments in naturally infested soils.

RESULTS

All 142 soil samples obtained by the Seed Potato Center at Tyrnävä were tested and found to be free of potato mop-top infestation. On the contrary, infestation was rather common in the rest of the samples. 37 samples out of 90 fields of professional growers of industrial potatoes tested PMTV positive. The virus was present in five of the occasionally received soil samples, which totalled seven. In most cases, the bait plants remained symptomless and PMTV was detected by inoculation of their root extracts onto the indicator plants. If foliar symptoms were present in the bait plant, virus particles for definite identification by electron microscopy or serology, were present without exception. Tobacco rattle virus was not found in any of the soil samples studied in the growing season of 1987.

No tubers infected by PMTV were found in the stocks of basic or elite seed potato grown for the Seed Potato Center. Infected tubers were commonly found in several stocks of industrial seed potatoes, in cv. Saturna (Table 1). The highest infection incidence in the inspected material was 84 %, and in seven cases it was over 10 %. Spraing symptoms were also commonly present in tuber material designated for industrial processing at the factories. The data show that approximately 12 % of the potato stocks had spraing symptoms and ca. 16 % of the farms with cv. Saturna as the principal cultivar, already have mop-top virus infestation in

Table 1. Incidence of seed stocks infected with potato mop-top virus in the inspected material and their distribution in different classes of the level of infection.

Potato cultivar and number of seed stocks		Number of seed stocks in different classes of the level of infection (%)				
		0.0	0.5—2.0	2.5—10.0	10.5—40.0	>40.0
Bintje	(2)	2	0	0	0	0
Pito	(1)	1	0	0	0	0
Record	(1)	1	0	0	0	0
Sabina	(2)	2	0	0	0	0
Saturna	(39)	25	3	5	3	3
Tanu	(1)	1	0	0	0	0
Totals	(46)	32	3	5	3	3

the soil. The virus was rather rarely encountered in cultivar other than Saturna. Among a total group of 1443 industrial potato stocks PMTV was found three times in cv. Bintje and four times in cv. Record and eight times in cv. Posmo. The symptoms did not appear in the tubers of these cultivars before storage at periodically varied temperatures. On the average, one incubation cycle at 18 and 8 °C increased the number of potato stocks with spraing symptoms by 60 %.

Other records of PMTV in tubers include 26 stocks from southern and central Finland. The cultivars represented were Saturna (10), Sabina (4), Olympia (4), Eigenheimer (2), Ostara (1), Hertha (1) and »unknown» (4).

A summary of the distribution and incidence of potato moptop virus in Finland, as determined by soil and tuber investigations in 1987, is presented in Fig. 1.

Spraing symptoms in the tubers were often very severe rendering them unfit for use. If no symptoms were present at harvest, they typically appeared within two weeks under cool storage. Usually spraing symptoms were manifest both in the skin and flesh of an infected tuber. There are, however, a few cultivars with different tuber symptomalogy. For example, cv. Saturna typically has a wide light brown ring or a collar on the tuber skin, and dark brown rings or arcs are only found in the flesh. In the tubers of cvs. Posmo and Prevalent, superficial symptoms are normally absent. Among all cultivars there is an increased incidence in symptom appearance in infected tubers if they are cut into halves and then stored in cool conditions for two weeks or longer.

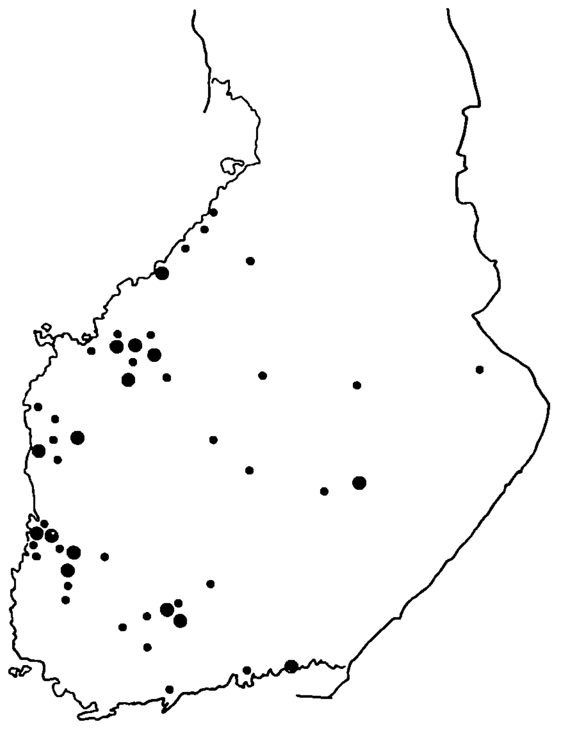
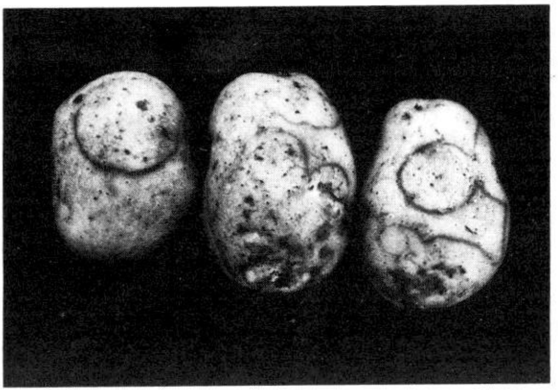


Fig. 1. Distribution and incidence of potato mop-top virus in Finland as determined by soil and tuber investigations in 1987. A small dot indicates 1—4 infested farms in a commune, a large dot indicates 5 or more infested farms.

The present paper presents numerous photographs showing primary and secondary symptoms in potato tubers and plants typical to a particular cultivar.



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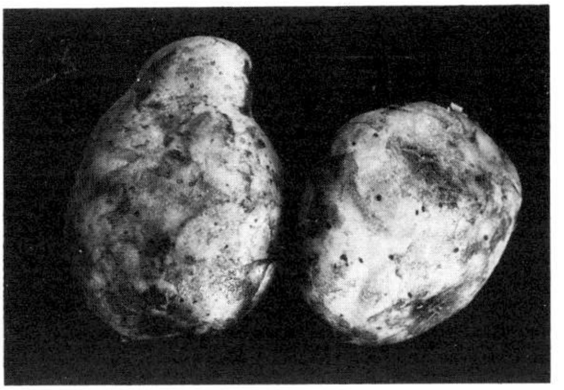

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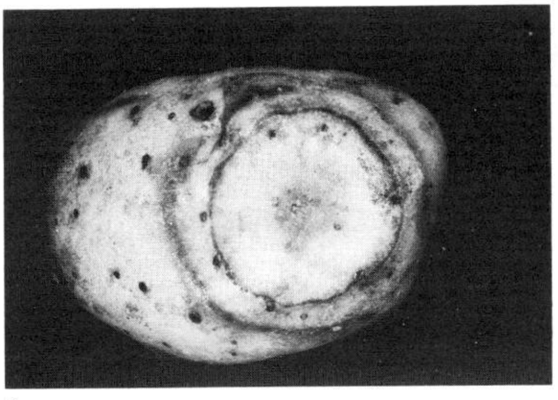

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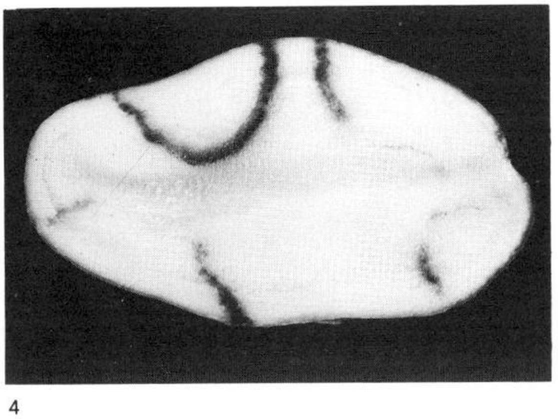

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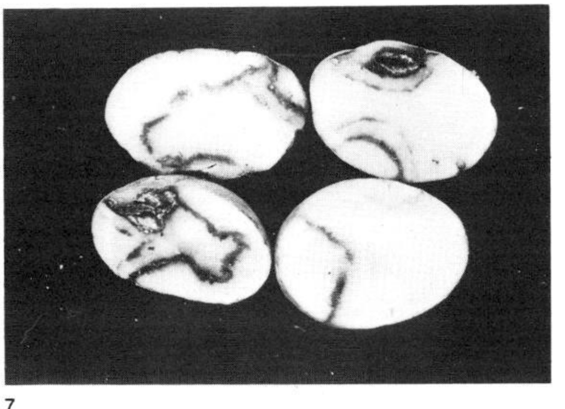

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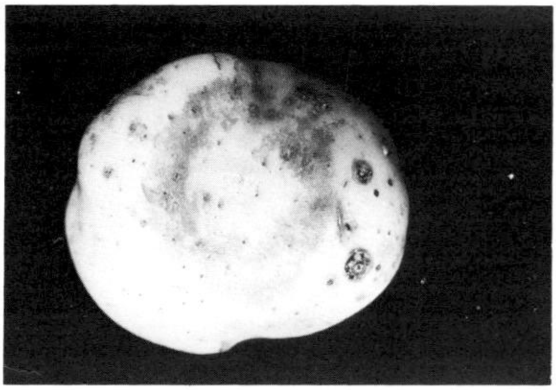
Figs. 2—7. Spraing symptoms in the tubers of cvs. Sabina (Figs. 2—4) and Olympia (Figs. 5—7). Typical external spraing after one (Fig. 2) and two incubation cycles at 18/8 °C (Fig. 3). Spraing in the tubers of cv. Olympia is rather mild at first (Fig. 5) but may become extremely severe during storage (Figs. 6 and 7).



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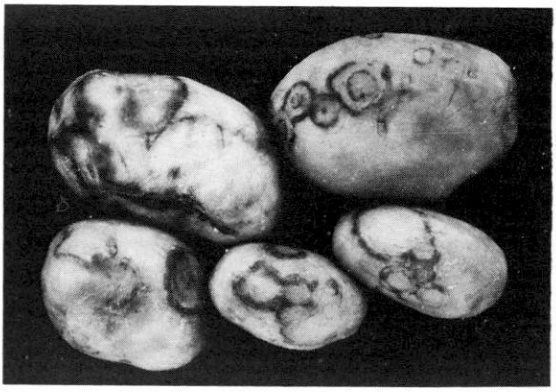

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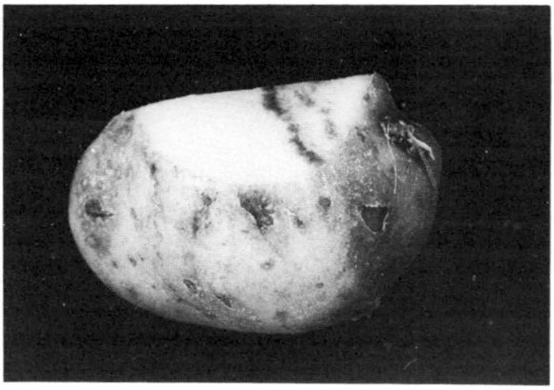

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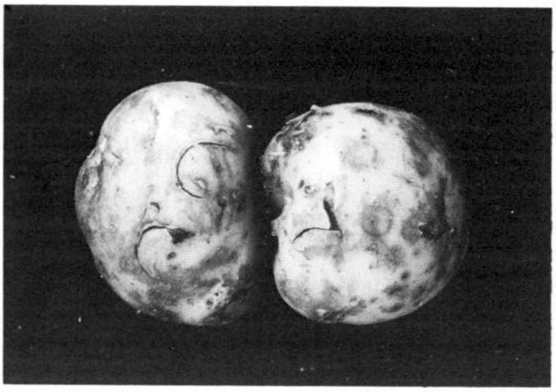

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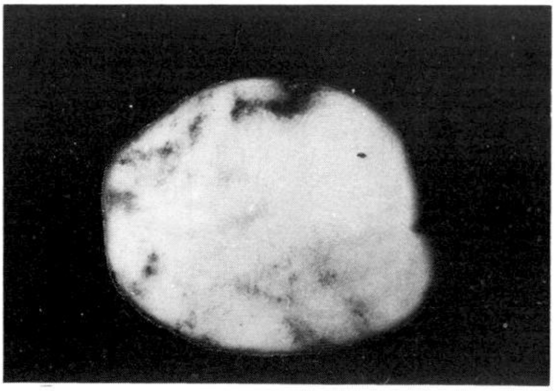

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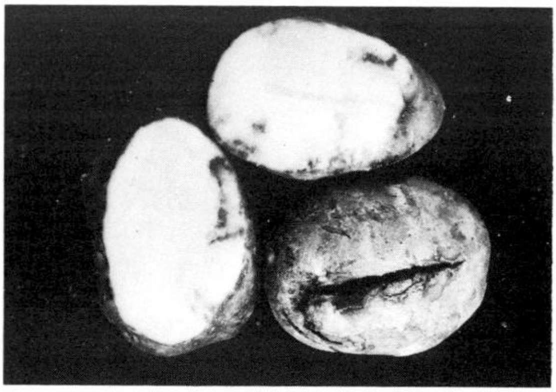

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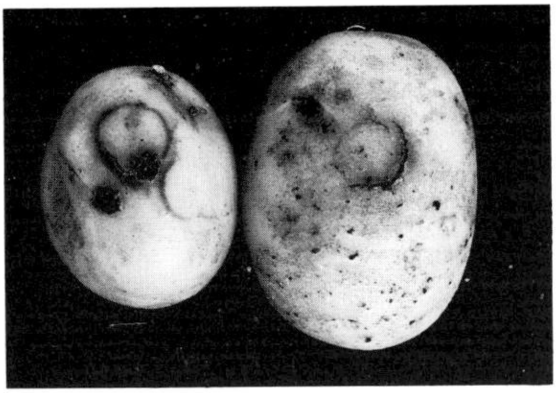
Figs. 8—13. Variation of the symptoms in the tubers of cv. Saturna. Skin symptoms are often nearly absent (Figs. 8 and 9) but internal damage is already severe (Figs. 9 and 10). Extremely severe internal necrosis in peeled tubers (Fig. 11). Secondary infection may also result in different kinds of cracks and deformation (Figs. 12 and 13).



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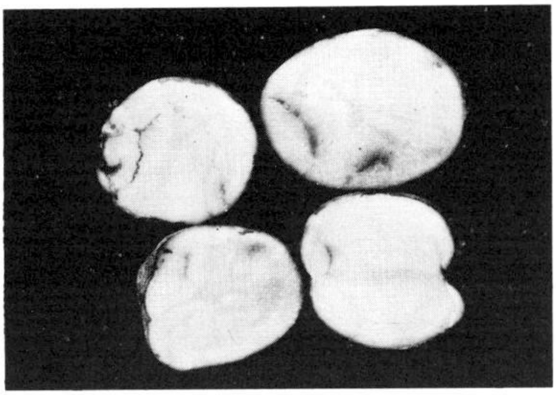

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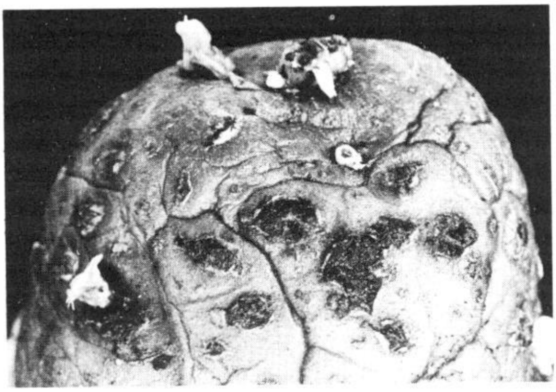

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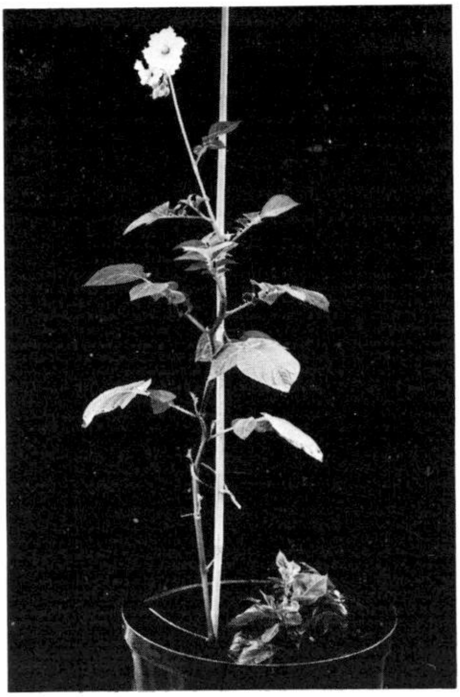
Fig. 14. Cv. Matilda is highly susceptible to skin damage by spraing.

Fig. 15. Internal arc necrosis is typical to the tubers of cv. Prevalent after primary infection by PMTV.

Fig. 16. Cystosori of *Spongospora subterranea* are most easily seen in the spring after a long storage period.



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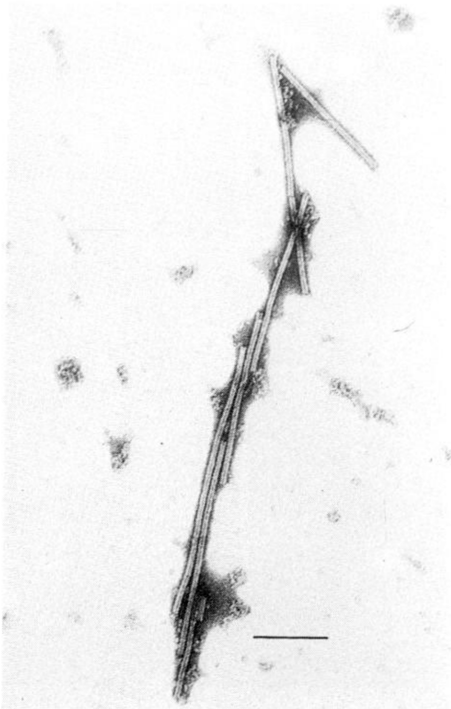
Figs. 17 and 18. Secondary infection induces severe stunting in the haulms of susceptible cultivars but the disease commonly remains localized; cvs Olympia (Fig. 17) and Sabina (Fig. 18).



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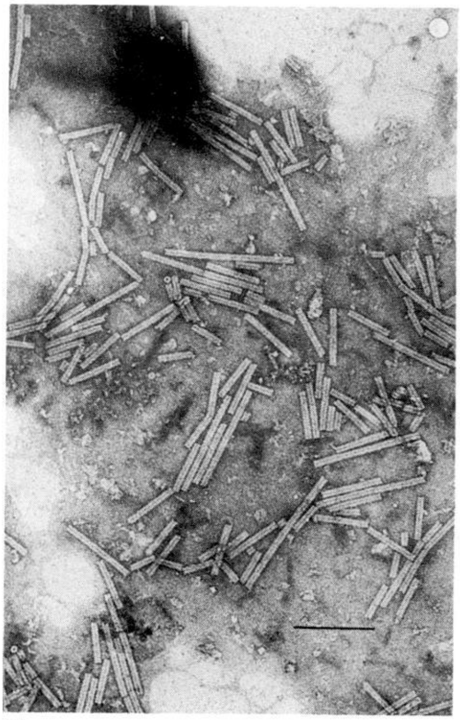

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Figs. 19 and 20. Electron micrographs of PMTV particles. Preparations were stained with 2 % ammoniummolybdate, pH 6.5. Particles in *Nicotiana clevelandii* sap (Fig. 19) and in partially purified preparation (Fig. 20). Bar represents 200 nm.

DISCUSSION

The high incidence of spraing manifestation tubers in industrial potatoes grown in the season of 1987 was finally due to wet and cool growing conditions. The source of the disease, however, can be found in the soil, which had been previously infested by potato mop-top virus. In addition to the weather and soil, other factors such as cultivar, have an important role in spraing incidence and severity in the tubers as also reported by COOPER and HARRISON (1973) and KURPPA (1989). At present, potato mop-top virus is rather commonly found in soils where cv. Saturna has been grown for the potato industry. This confirms the theory of viral introduction to Finland via this particular cultivar. Incidence of the virus in the other cultivars has been limited, and whenever it has been detected, cv. Saturna either is or has been commonly grown on the farm, too.

The data collected in the season of 1987, which favoured primary tuber infection, may overestimate the importance of potato mop-top virus on the average. The data, however, possibly underestimate its occurrence and potential importance during the next few years. The percentage of infected tuber lots as well as that of infested potato fields is notably higher than the figures presented in the text. The data from the starch industry are too low, due to the immediate inspection of the samples after receipt of the material for processing. To be corrected, these figures should be multiplied approximately by the factor 1.60, which derives from new findings of tuber lots affected with spraing after storage at varied temperatures of 18 and 8 °C. According to this calculation, it is thus likely that at least 22.5 % of farms, that grow potato cv. Saturna for industrial purposes already have PMTV infested fields in potato production.

Due to increased inoculum levels in the infested soils and a high incidence of newly infested fields via seed potatoes or contaminated soil after the 1987 season, the number of infested potato fields in the country is probably higher at present than that estimated in this report. Moreover, the long viability of the virus in the resting spores of *S. subterranea* as reported by JONES and HARRISON (1969), may result in a very high inoculum potential in the soil by spore accumulation. This phenomenon was found several times in soil tests.

Typical tuber symptoms include dark brown rings or arcs in the skin and flesh. These symptoms may, however, vary conciderably depending on the cultivar in question, growing conditions and storage. The most pronounced skin symptoms found resembled those in cv. Evergood as described by COOPER and HARRISON (1973) and RYDEN et al. (1986). Absent skin symptoms with brown arcs in tuber flesh, which were typical of the cvs. Prevalent and Posmo, and were also reported by RYDEN et al. (1986) in cv. Ukama, may easily result in an underestimation of the virus in tuber yield. Visual observation of previously halved tubers could be considered as a highly reliable method to detect mop-top virus if tobacco rattle virus (TRV) is not present, which is the case in Finland. This is very different from the situation in Sweden, where TRV is commonly found in potato fields as reported by ERIKSSON and INSUNZA (1986).

The importance of potato mop-top virus is strongly related to how the tuber yield will be utilized. PMTV does not pose a problem to the growers of first early table potatoes due to lack of tuber symptoms at the early stage of tuber maturity. Similarly, it is not a major problem to growers of starch potatoes, because tuber quality is of minor importance. The virus may, however, be the cause of notable economic losses if infected seed potatoes are used for planting, as demonstrated by KURPPA (1989). PMTV is a continuous potential quality risk for potatoes grown for processed products and table potatoes. At present, the virus is only occasionally found in areas other than where starch potato cultivars are grown. In order to prevent further viral establishment at new sites in the country, an effective policy for the quality control of seed potatoes is necessary. This should also include inspection of the soil in which tubers are transported. Also, the cultivation of potatoes designated for industrial and table use should be completely separated. At present, the possibilities to control PMTV by means other than by the avoidance of it, are rather limited.

Acknowledgements — I wish to thank the staff of the Seed Potato Center, at Tyrnävä, the Potato Research Station, at Lammi and the potato industry for supplying research material. Special thanks are due to Mr. Heikki Tiirola, Raisio Ltd. (Vihanti) and Mr. Jukka Saarinen, Raisio Ltd. (Kokemäki) for providing valuable supplementary data.

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SELOSTUS

Perunan mop-top-viruksen esiintyminen Suomessa ja sen aiheuttamaan tautiin liittyvät oireet

AARNE KURPPA

Maatalouden tutkimuskeskus

Maltovikaisia eriä on tavattu teollisuusperunassa jo joidenkin vuosien ajan. Syksyn 1986 sadossa mukuloissa esiintyi tummanruskeita renkaita ja kaaria siinä määrin, että niiden syytä alettiin tehokkaasti selvittää. Näytti varsin todennäköiseltä, että vioitusten aiheuttaja on kuorirokkoa aiheuttavan maasienen *(Spongospora subterranea)* levittämä perunan mop-top-virus (PMTV), mutta varmistus asiaan saatiin vasta kesällä 1987, jolloin virusta onnistuttiin eristämään maanäytteistä. Tämän jälkeen virusta on eristetty yleisesti maista, joissa kasvaneissa mukuloissa on esiintynyt kuvatunlaisia maltovikoja.

Kasvukausi 1987 oli perunan mop-top-virusta siirtävälle kuorirokkosienelle erittäin suotuisa, joten virus pääsi yleisesti tartuttamaan mukuloita aiemmin valtaamissaan peltomaissa. Virus pääsi leviämään edelleen syksyllä, jolloin perunaa kuljetettiin pahimmille katoalueille myös niiltä seuduilta, joilla sitä oli jo todettu esiintyvän yleisesti.

Mop-top-viruksen kartoitustutkimuksissa keskityttiin tärkkelys- ja ruokateollisuusperunan tuotantoalueille Satakuntaan, Pohjanmaalle, Etelä-Hämeeseen ja Kymenlaaksoon, missä perunanviljely on paikoin monokulttuurin omaista ja missä maltovioituksia oli todettu perunoissa. Varmuustoimenpiteenä tutkittiin myös siemenperunakeskuksen ja sen sopimusviljelijöiden peltolohkot, joissa perus- tai valiosiementä tuotettiin kasvukauden aikana. Maa-analyysejä täydentävät satonäytetutkimukset tehtiin siemenperunakeskuksessa annettujen ohjeiden mukaisesti. Muualta hankittuja tai satunnaisesti saatuja maa- ja mukulanäytteitä tutkittiin lisäksi useita kymmeniä. Maanäytteitä tutkittiin yhteensä 239. Teollisuuden siemenperunanäytteitä tutkittiin 46 erää ja tutkimusanalyysit saatiin 257:stä Maatalouden tutkimuskeskuksen siemenperunakeskuksen perus- tai valiosiemenerästä. Lisäksi saatiin tarkastustulokset 878:n viljelijän tuottamasta noin 4750:sta teollisuusperunaerästä. Suuri osa mop-top-viruslöydöksistä varmistettiin jälkitarkastuksen avulla.

Kaikki siemenperunakeskuksen perus- ja valiosiemennäytteet samoin kuin myös maanäytteet olivat puhtaita. Sen sijaan teollisuusperunan käyttösiemenessä mop-top-virusta esiintyi Saturna-lajikkeessa yleisesti. Huonoimmassa erässä viroottisia oli 84 kappaleprosenttia. Teollisuusprosessiin tulleista perunaeristä todettiin alkutarkastuksessa noin 12 % viruksen tartuttamiksi. Jälkitarkastuksen yhteydessä viruksen tartuttamia eriä todettiin 60 % enemmän. Tällöin virusoireita havaittiin myös lajikkeissa Bintje, Posmo ja Rekord, kun ensitarkastuksessa oireita todettiin vain lajikkeessa Saturna. Satunnaisista mukulanäytteistä viroottisia on todettu lajikkeissa Saturna (10), Sabina (4), Olympia (4), Eigenheimer (2), Ostara (1), Hertha (1) ja lisäksi 4 kertaa tunnistamattomassa lajikkeessa.

Tärkkelys- ja ruokateollisuusperunaa tuottavilta tiloilta otetuista maanäytteistä 41 % oli mop-top-viruksen tartuttamia. Viruksen todellinen esiintyminen on tätäkin runsaampaa, koska puhtaista näytteistä useita oli otettu lohkoilta, joissa perunaa ei ole viljelty. Viruksen esiintyminen liittyy lähes poikkeuksetta Saturna-lajikkeen viljelyyn. Tutkimustulokset puoltavat vakuuttavasti otaksumaa, että perunan mop-top-virus on saatu maahamme tuodun Saturna-lajikkeen siemenperunan mukana 1970-luvun puolivälissä. Ensimmäiset oirehavainnot ovat Kymenlaaksosta, mutta maltovikaisia mukuloita alettiin tavata nopeasti myös Pohjanmaalta Saturnan viljelyn myötä. Tällä hetkellä mop-top-virusta onkin vielä pidettävä vain Saturnan ongelmana, mutta sen merkitys saattaa olla hyvinkin suuri, koska lajike on keskeinen perunalastujen valmistuksessa.

Yleisimmistä ruokaperunalajikkeistamme Sabina ja Olympia ovat Saturnaakin alttiimpia. Erittäin altis on myös Matilda. Näiden kolmen lajikkeen mukulat vioittuvat pahoin, usein jopa käyttökelvottomiksi. Viroottisesta siemenperunasta kehittyvät kasvit pensastuvat epämuotoisiksi ja tuottavat heikon sadon. Keskimääräistä enemmän oireita on esiintynyt lisäksi lajikkeissa Ostara, Prevalent ja Tuomas, mutta ne ovat yleensä jääneet heikoiksi. Prevalent-lajikkeelle on tyypillistä kuorioireiden puuttuminen ja mallonsisäisetkin oireet jäävät osin epämääräisiksi. Myös lajikkeissa Saturna ja Posmo malto-oireet ovat osin epämääräisiä.

Vaikkei perunan mop-top-viruksen esiintymistä kartoittava tutkimus kata yhtäläisesti koko maata, yksistään lajikeominaisuuksien tuntemisen perusteella on selvää, että virusta esiintyy vasta hyvin satunnaisesti ammattimaisessa ruokaperunan tuotannossa tai kotitarveviljelyssä. Vaara viruksen leviämisestä on kuitenkin suuri, minkä vuoksi erityisesti siemenkantojen terveydestä on ehdottomasti huolehdittava. Ruokaperunan viljely olisi pidettävä kokonaan erillään teollisuusperunan viljelystä, ettei tartuntaa levitetä esimerkiksi perunassa siirtyvän maa-aineksen mukana. Virus säilyy vuosikymmeniä kuorirokkosienen lepoitiöissä maassa tartuttavana, mikä aiheuttaa pysyvän uhan alttiiden perunalajikkeiden viljelylle. Vioitusten runsaus ja voimakkuus saastuneessa maassa vaihtelevat vuosittain, sillä tartunta vaatii runsasta maan kosteutta mukulankasvun alkuvaiheissa.

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REACTION OF FOUR TABLE POTATO CULTIVARS TO PRIMARY AND SECONDARY INFECTION BY POTATO VIRUSES Y^o AND Y^n

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Reaction of four table potato cultivars against primary and secondary infection by potato viruses Y^o (PVY^o) and Y^n (PVY^n) was investigated. Three of the cultivars, Bintje, Record and Sabina are widely grown and cv. Matilda is a new promising candidate in Finland. During the first experimental year, potato seedlings were mechanically inoculated with two PVY isolates at two different dates relatively early (June 25th) or late (July 23 rd) only with PVY^n. Only cv. Matilda reacted with local necrotic rings or spots to early inoculations. Later, some of the plants died due to necrosis. The remaining cultivars became readily infected but manifested only systemic vein clearing or mosaic symtoms without necrosis. The late inoculation did not induce any symptoms at all.

Tubers produced by inoculated plants of cvs. Record and Sabina were nearly totally infected with PVY following any of the inoculations. Cv. Bintje had some resistance against PVY^o and minor mature-plant resistance against PVY^n was also observed. No more than ca. 4 and 2 % of the tubers of cv. Matilda became infected following early inoculation with PVY^o and PVY^n, respectively, and the late inoculation did not infect any of the tubers.

Secondary infection by PVY significantly decreased tuber yields of all cultivars in the experiments. Yield reduction was 29—59 % depending on the cultivar and virus strain, if the crop was totally infected. Due to compensation by the surrounding healthy plants, incidences of 10 to 20 % infected plants in the crop did not result in significant losses in tuber yield. Yield reduction became significant if about one half of the plants were infected and at an incidence of 80 % infected plants, yield reduction of 16 to 40 % was reached.

Six combined sprays with mineral oil (Sunoco 11 E/3, 8 l/ha) plus deltamethrin (Decis EC 25, 200 ml/ha) at weekly intervals resulted in effective virus control but also in a slight yield reduction with all cultivars. It had, however, no effect on tuber number in any of the cultivars.

Index words: potato virus Y, PVY^o, PVY^n, primary infection, secondary infection, tuber infection, tuber yield, tuber number, compensation, mineral oil spray, deltamethrin.

INTRODUCTION

Commonly grown table potato cultivars are dominantly highly or moderately susceptible to infection by potato virus Y (PVY). In growing conditions with high pressure for virus transmission caused by aphids, primary plant and tuber infection incidence may reach nearly

100 % in originally healthy potato crops during the growing season (KURPPA, unpublished). The use of infected seed potatoes for planting results in tuber yield reduction of 10 to 80 % depending on the virus strain, potato cultivar and growing conditions (de BOKX and PIRON 1977).

The main strains of potato virus Y, Y^o and Y^n, are both common in Europe (de BOKX and HUTTINGA 1981) but their relative proportions are different in different countries. In the Netherlands (van HOOF 1977) and in Germany (WEIDEMANN 1987) Y^n strain isolates are dominating but e.g. in Sweden Y^o (SIGVALD 1987) is most frequently distributed. In Finland Y^n strain isolates are clearly dominating (KURPPA 1983).

PVY^n strain is more stable than PVY^o by its physical properties and also its relative concentration in infected plant tissue is higher (BAGNALL and BRADLEY 1958, de BOKX et al. 1978, KURPPA 1983), which also leads to higher potential rate of transmission by aphids due to the non-persistant manner of transmission. It also seems to be clear that translocation of PVY^n into the tubers after primary infection is faster than that of PVY^o, while mature plant resistance develops later against PVY^n than PVY^o (BEEMSTER 1972, 1976, VENEKAMP et al. 1980, SIGVALD 1987).

There is a great number of publications about PVY as a disease inducing agent in the potato. The information on the reactions of a given potato cultivar to the main PVY strains or their minor variants is, on the contrary, rather limited. This information is, however, very important when cultural practices including disease control for each cultivar are planned.

This paper discribes investigations to assess susceptibility of three most commonly grown table potato cultivars and one new promising cultivar to primary and secondary infection by PVY strains distributed in Finland. Because combined sprays with mineral oil and insecticide were used to prevent primary infection to some controls, réactions of the cultivars to this treatment are also reported and discussed.

MATERIAL AND METHODS

The cultivars in the experiments included three most commonly grown table potato cultivars in Finland, namely cv. Bintje (Netherlands), Record (Netherlands), and Sabina (Sweden). The fourth cultivar was Matilda (Sweden), which according to available information is rather resistant to potato virus Y.

A field experiment to study susceptibility of the cultivars to primary infection by PVY^o and PVY^n strains (YFS11, KURPPA 1983 and F43, KURPPA and VUENTO 1987, respectively) was planted in late May with a semiautomatic planter. The plot size was 12 m × 1.5 m (two hills) and between every plot there was an empty space of 1.5 m to prevent virus contamination. Four replicates were done. The treatments were as follows:

1. control
2. control with combined spray with mineral oil (Sunoco 11 E/3, 8 l/ha) and deltamethrin (Decis EC 25, 200 ml/ha) six times at one week intervals, the first application on July 10th
3. mechanical inoculation of the plants with PVY^o, June 25th
4. mechanical inoculation of the plants with PVY^n, June 25th
5. inoculation with aphids (*Myzus persicae* Sulz., 5 aphids/plant, PVY^n July 7th
6. mechanical inoculation of the plants with PVY^n, July 23rd

Data from the treatment 5 are not reported due to a very low frequency of successful virus transmission.

All mechanical inoculations were performed in late evenings by rubbing three leaves / plant previously dusted with carborundum with a cotton tipped stick wetted with inoculum in 0.06 M phosphate buffer pH 7.0, 30 plants / plot were inoculated. Leaf symptoms were observed at two to three days intervals and the plants were tested with the ELISA (CLARK and ADAMS 1977) three weeks after inoculations by sampling three non-inoculated leaves growing in different stems. All control plants including the sprayed ones were tested with the ELISA ca. a week before harvest but tuber yields from these treatments were not tested after harvest.

The field experiment was hand lifted. Tuber number of each individual plant was counted and tuber yield weighed. The tuber yield from all inoculated plants were stored separately until they were tested for the presence of PVY. Two tubers (one big, one small) / plant were tested with the ELISA after Rindite treatment (GUGERLI and GEHRIGER 1980). The remaining tubers were stored and according to the test results graded for seed potato classes to study secondary effects of PVY infection in the following season.

The yielding capacity of secondarily infected seed tubers was evaluated with a field experiment at Jokioinen in the following year. Practical tuber yields produced by potato crops with increasing incidences of secondarily infected plants were investigated as well. For the experiment, the following treatments were formed:

a. healthy control seed
b. healthy control seed with six combined sprays with mineral oil (Sunoco 11 E/3, 8 l/ha) and deltamethrin (Decis EC 25, 200 ml/ha) to the crop at one week intervals starting July 6th

c_1, c_2. ca. 10 % of the seed tubers infected with PVY^o (1) or PVY^n (2), respectively

d_1, d_2. ca. 20 % of the seed tubers infected with PVY^o (1) or PVY^n (2), respectively

e_1, e_2. ca. 40 % of the seed tubers infected with PVY^o (1) or PVY^n (2), respectively

f_1, f_2. ca. 80 % of the seed tubers infected with PVY^o (1) or PVY^n (2), respectively

Treatments g_1 and g_2 were formed later by selecting and marking 10 infected plants/replicate (from f_1 and f_2) in groups in which they were surrounded by infected plants. In the case of cv. Matilda, all infected plants in the treatments c_1 and c_2 were needed for g_1 and g_2.

The plot size in the experiment was 12 m × 1.5 m (two hills) and four replicates were used. Planting (80 seed tubers/plot) was done on June 2nd and soon after emergence all seedlings were tested for PVY by the ELISA. After testing, accurate data for PVY infection (%) in the seed could be calculated and they were as follows:

	a, b	c_1	c_2	d_1	d_2	e_1	e_2	f_1	f_2
Bintje	0.0	12.1	12.9	22.9	21.6	42.7	40.9	79.6	80.3
Matilda	0.0	13.6	14.7						
Record	0.0	12.6	10.8	21.3	22.0	43.2	42.0	79.2	83.6
Sabina	0.0	12.0	12.7	22.1	20.2	40.9	41.2	79.2	82.8

During the growing season, weeds were controlled by spraying with terbutryn (Igran 4 l/ha) slightly before potato emergence and one application to control late blight was done with metalaxyl + mancotzeb (Ridomil MZ 2.5 l/ha) in late July.

The experiment was harvested by hand in September 14th to 21st. Tuber number of every plant was counted and tuber yield weighed. PVY infection incidences in tuber yields of treatments a and b were tested from random samples (100 tubers/treatment) but tubers from the other treatments were not tested.

Analysis of variance was used to confirm the significance of the data whenever they were free of known major variation sources inside the treatments.

The early growing season 1986 was warm and dry but the weather turned rather cool and rainy at the end of July. In 1987, the monthly mean temperatures were continuously ca. 2 to 3 °C below normal. The late summer was particularly rainy.

RESULTS

Primary infection

Localized necrotic lesions or rings were observed in inoculated leaves of cv. Matilda within 7 to 10 days from mechanical inoculations (Fig. 1). Necrosis spread along the leaf veins during the following week and three to four weeks after inoculation, systemic necrosis was found all over the plants (Fig. 2). Necrosis became very severe and many of the infected plants died prematurely before harvest. Early inoculation with PVY^{o} and PVY^{n} strains resulted in 32 % and 5 % infection, respectively, in the treated plants. Late inoculation with PVY^{n} infected only a few plants of cv. Matilda.

No local symptoms following inoculation were developed in the leaves of the remaining cultivars. Systemic vein clearing was first time found ca. three weeks after early inoculation with either of the virus isolates. In cv. Sabina the symptoms remained relatively mild but in cv. Bintje particularly PVY^{o} and in cv. Record PVY^{n} induced distinct vein clearing and mosaic (Fig. 3). Following the late inoculation, mild systemic mosaic could be seen in the top leaves of cv. Record but the other cultivars remained symptomless.

Systemic PVY infection was detected by the ELISA in nearly all leaf samples of cv. Record taken three weeks after the early inoculation of the plants, while 60 % and 52 to 55 % of the plants of cvs. Bintje and Sabina, respectively, were found infected (Table 1). The late inoculation resulted in slow translocation of the virus and non-homogenous systemic infection of the plants which was unreliably detectable on the basis of three leaf samples / plant (Table 1).

The harmful effect of combined oil/insecticide treatment to the leaves of cv. Matilda was found soon after the third application. Necrotic leaf spots resembling those induced by early blight, grew larger by time but did not completely destroy the leaves. The remaining cultivars did not manifest any symptoms due to the applications.

The early inoculation resulted in high and homogenous tuber infection in the cvs. Record and Sabina and most plants carried infected

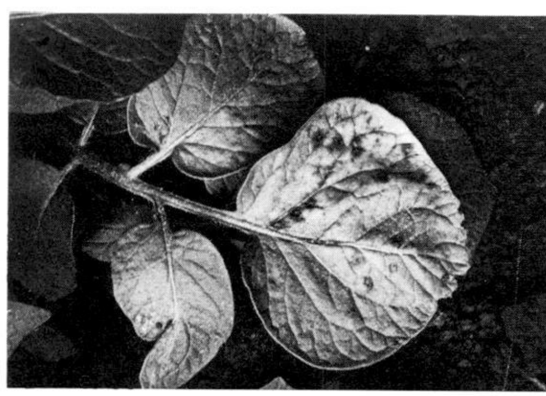

Fig. 1. A leaf of potato cv. Matilda manifesting localized necrotic rings and spots 10 days after mechanical inoculation with PVY^{o}.

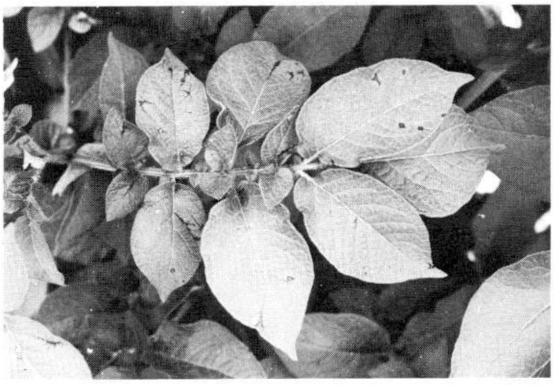

Fig. 2. Veinal necrosis at early stage in a noninoculated leaf of potato cv. Matilda.

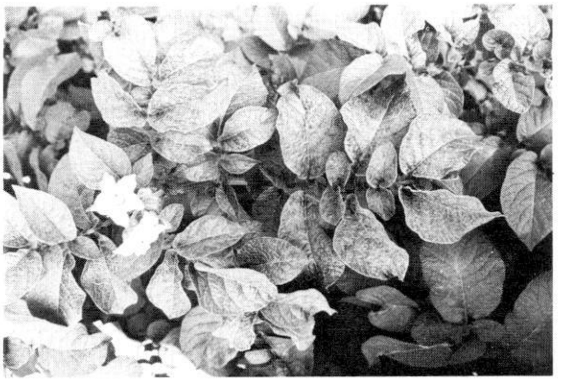

Fig. 3. Systemic vein clearing and mosaic in potato cv. Bintje four weeks after mechanical inoculation with PVY^{o}.

tubers following the late inoculation, too (Table 1). Cv. Bintje was proved to be susceptible or moderately susceptible to PVY infection but the tuber yield was less homogenously infected and the plants commonly produced both healthy and infected tubers. A higher tuber infection incidence was due to PVY^{o} than PVY^{n}. The late inoculation with PVY^{n} also resulted in relative high tuber infection incidence (Table 1). Cv. Matilda was found rather resistant to primary tuber infection by both PVY strains. Particularly low tuber infection frequence was detected in the plants inoculated with PVY^{n} isolate. No tubers infected with PVY were detected in the plants of cv. Matilda after the late inoculation.

Primary infection or spray treatments had only a minor effect on tuber number of the potato cultivars investigated (Table 2). The response of tuber yield to virus infection or combined oil/insecticide treatment was, however, noticeable in some cases. Oil and insecticide applications significantly decreased tuber yields of cvs. Matilda and Sabina. Inoculations with PVY always slightly decreased tuber yields but only in cv. Record, inoculated with PVY^{n} at early stage, yield reduction was significant.

In the tuber yields of non-inoculated controls PVY incidence was detected as follows: Record control 6.25 %, Record sprayed 2.08 % and Sabina sprayed 1.04 %. All remaining controls had produced healthy tuber yields.

Table 1. Percentage of infected plants as tested three weeks after mechanical inoculation and incidences and uniformity of tuber infection in inoculated plants.

Classification	% of plants in different classes														
	Bintje			Matilda			Record			Sabina			Mean		
	1 +	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Infected plants	60.0	60.0	3.3	31.7	6.7	1.7	93.3	88.3	20.0	51.7	55.0	0.0	59.2	52.5	6.2
Both tubers healthy	35.0	21.7	28.3	95.0	95.0	100.0	0.0	3.3	3.3	0.0	1.7	5.0	32.5	30.4	34.2
One tuber infected	23.3	15.0	41.7	3.3	5.0	0.0	18.3	15.0	25.0	20.0	15.0	28.3	16.2	12.5	23.7
Both tubers infected	41.7	63.3	30.0	1.7	0.0	0.0	81.7	81.7	71.7	80.0	83.3	66.7	51.3	57.1	42.1

+ treatments 1 = PVY^{o} inoculation 25.6
2 = PVY^{n} inoculation 25.6
3 = PVY^{n} inoculation 22.7

Secondary infection

Secondary symptoms caused either PVY^o or PVY^n became commonly recognizable in all cultivars within ca. two weeks after emergence. The diseased plants remained smaller in size than healthy ones and their leaves were mottled and crincled (Fig. 4). Systemic necrosis (leaf drop) was only present in a few plants of cv. Matilda infected with PVY^o. The differences between diseased and healthy plants became more distinct towards the end of the growing season. Cultivars Record and Sabina seemed to suffer more from infection by PVY^n than PVY^o but in the case of the other cvs. the reaction was opposite. Secondary infection by PVY decreased tuber number/plant (Table 3). PVY^o typically affected strongly on cv. Matilda, while PVY^n had the major effect on cv. Record. Increasing incidences in infected tubers in planting seed resulted in overall decreasing trend in average tuber number/plant.

PVY also significantly decreased tuber yields of all cultivars tested (Table 4). PVY^n caused a greater yield reduction than did PVY^o in cvs. Record and Sabina but cv. Matilda suffered particularly from PVY^o. Both virus strains caused approximately the same reduction to the tuber yield of cv. Bintje. If all seed tubers were infected with PVY, the reduction in tuber yield may reach 29 to 59 % depending on the cultivar. An incidence of 10 or 20 % of infected tubers in planting seed had rather limited effect on the mean tuber yield per plant or per plot but if diseased plants were distributed at an incidence of more than 40 %, the yielding capacity of the crop decreased rapidly.

Fig. 4. Secondary symptoms of PVY^n infection in potato cv. Sabina at blooming stage.

Variability in tuber size was not recorded but relations of tuber yield/tuber number of individual plants indicate a great variability in average tuber sizes in the treatments with high disease incidences. PVY may thus have an important role as a quality factor if tubers of equal size are wanted.

Table 2. Tuber number (T) and yield kg/plant (Y) in treated and control crops.

Treatment	Bintje		Matilda		Record		Sabina		Mean	
	T	Y	T	Y	T	Y	T	Y	T	Y
Control	8.42	1.47	9.15	1.42b	8.08	1.25b	9.96	1.36b	8.90	1.37
Oil + insecticide	8.83	1.23	8.40	1.11a	8.20	1.09	9.89	1.04a	8.83	1.11
PVY^o 1)	7.91	1.35	8.50	1.24	8.28	1.17	10.43	1.18	8.78	1.23
PVY^n 1)	8.27	1.30	8.47	1.26	7.65	0.99a	10.71	1.23	8.77	1.19
PVY^n 2)	9.25	1.41	9.98	1.34	8.42	1.22b	10.05	1.26b	9.42	1.31
Mean	8.53	1.35	8.90	1.27	8.13	1.14	10.21	1.21	8.94	1.24

1) = inoculation 25.6
2) = inoculation 22.7
a,b = a significantly different ($P < 0.05$) from b

Table 3. The mean tuber number of potato plants grown from healthy seed and seed containing increasing incidences tubers infected with potato virus Y.

Potato cultivar	Mean tuber number in the tuber yields of individual potato plants											
	a^x	b	c_1	c_2	d_1	d_2	e_1	e_2	f_1	f_2	g_1	g_2
Bintje	12.65	11.73	11.02	12.20	10.23	10.86	10.53	10.50	9.62	9.15	9.90	8.68 s
Matilda	14.55	14.65	12.88	13.07							10.07	12.19 s
Record	10.42	11.77	10.73	10.12	9.38	9.40	9.88	8.90	9.75	7.93	9.20	7.63 z
Sabina	14.88	14.53	12.73	14.08	12.43	11.77	12.43	11.86	11.75	11.12	11.82	11.00 z
Means (cv. Matilda not included)	12.65	12.67	11.49	12.13	10.68	10.67	10.94	10.42	10.37	9.40	10.30	9.10

[x] indicates seed potato classes and crop treatments
a = healthy control
b = healthy control, crop sprayed six times with mineral oil plus insecticide
c, d, e, f, g = ca. 10, 20, 40, 80 or 100 % of the tubers infected with PVY, respectively
1 = infected with Y^o strain isolate
2 = infected with Y^n strain isolate
All g_1 and g_2 figures are significantly different from their controls a and b; s indicates $P<0.05$, z $P<0.001$.

Table 4. The average relative tuber yield / plant produced by healthy seed and seed containing increasing incidences tubers infected with potato virus Y.

Potato cultivar	Average tuber yield of individual potato plants											
	a^x	b	c_1	c_2	d_1	d_2	e_1	e_2	f_1	f_2	g_1	g_2
Bintje	100.0 (1078 g)	85.6	82.6	98.1	83.3	96.2	88.3	72.4	78.2	76.5	71.0	73.0
Matilda	100 (1143 g)	93.4	81.8	87.5							41.2	53.9
Record	100 (973 g)	100.2	106.5	95.4	90.7	86.3	89.6	82.9	77.8	59.8	77.3	56.0
Sabina	100 (912 g)	89.4	96.0	102.2	88.8	86.2	93.4	91.7	84.6	74.0	71.3	59.5
Means (cv. Matilda not included)	100.0	91.7	95.0	98.5	87.6	89.5	90.4	82.3	80.2	70.1	73.2	62.8

[x] indicates seed potato classes and crop treatments
a = healthy control
b = healthy control, crop sprayed six times with mineral oil plus insecticide
c, d, e, f, g = ca. 10, 20, 40, 80 or 100 % of the tubers infected with PVY, respectively
1 = infected with Y^o strain isolate
2 = infected with Y^n strain isolate
All g_1 and g_2 figures are significantly ($P<0.001$) different from their controls a and b.

DISCUSSION

Reactions of the potato cultivars to primary infection by PVY were rather different but not unexpected. In the field experiments, the local conditions, such as the temperature may have had a considerable effect firstly on foliar symptoms and secondly on virus transportation to the tubers as de BOKX and PIRON (1977) have reported. Therefore results obtained in very different conditions are not completely comparable. Disease symptoms development in cv. Bintje, however, was much alike that described by de BOKX and PIRON (1977). Also in some other respects, behaviour of cv. Bintje could be compared to previous information published by BEEMSTER (1972, 1976) according which the cultivar is highly or moderately susceptible to primary infection by PVY, but Y^n strain can infect the tubers more rapidly and uniformely than Y^o strain does. Building up of mature-plant resistance against Y^o could not be confirmed in the experiments but against Y^n it definitely remained incomplete.

Cultivars Record and Sabina, which have been found highly susceptible to PVY also in practical cultivation, reacted rather similarly to primary infection by both virus strains used for inoculation of the plants. Very weak mature plant resistance to PVY^n was found which is supported by investigations of BEEMSTER (1976).

Reaction of cv. Matilda was typical to a cultivar with high resistance to PVY. Due to a rapid necrotic reaction in the infected leaves, leaf veins and often in the whole haulms, virus transportation into the tubers is strongly inhibited. In our experiment only a few tubers produced by diseased plants were infected, and nearly complete mature-plant resistance also to PVY^n could be demonstrated. These data indicate excellent field resistance of cv. Matilda, because according to BEEMSTER (1965), a higher proportion of the tubers are infected following mechanical inoculation than by natural spread by aphids.

Primary infection by PVY in potato plants has been detected in Sweden (RYDEN et al. 1983) normally from the middle of June to the middle of July although the highest aphid peaks are found in late July. As reported by KURPPA and RAJALA (1985) this is also the situation in Finland. In spite of relative late aphid flight, PVY transmission to potato crop and incidence of primary tuber infection is potentially high in Finland, because of the dominance of PVY^n strain isolates as shown by KURPPA (1983). The latest data of HASSI and KURPPA (unpublished) strongly support this theory, because in 1988 only PVY^n strain isolates were detected when field samples were tested for the presence of primary infection by PVY using the ELISA with monoclonal antibodies (GUGERLI and FRIES 1983).

Primary infection by PVY has a minor influence on tuber number in normal Finnish conditions due to relatively late infection time in relation to tuberization. It may, however, significantly decrease tuber yield in case of a susceptible cultivar, like cv. Record.

The highest reduction of nearly 60 % in tuber yield caused by secondary infection by PVY is close to the data calculated by BORCHARDT et al. (1964). Their proposal of 0.54—0.61 % yield reduction per every 1 % of infected plants showed, however, some overestimation in our experiment, if only a limited number of the plants were diseased. This is due to compensation of the surrounding healthy plants to yield produced by the crop and this compensation had not been taken account in the investigations of BORCHARDT et al. (1964). In most cases the neighbour plants will give a higher yield and practical yield losses in the field are 10—40 % according to REESTMAN (1970). VORSATZ (1961) has reported that a potato crop may include up to 15 % open spaces without significant losses in tuber yield. A reasonable number of diseased plants in the crop could not be completely compared with open spaces due to their ability to produce harvestable tuber yields, too. In our experiments definite reduction in tuber yield was demonstrated if more than 40 % of the plants were diseased but for a reduction of 20—30 % in tuber yield, an incidence of ca. 80 % of secondarily infected plants were needed.

According to REESTMAN (1970), the conditions for nearly maximal compensation were fullfilled in our experiments: high fertility soil was rich in water and the plantings were rather dense. In addition, rather long, cool and cloudy growing season 1987 was favourable for haulm development of potatoes.

Cultivars Record and Sabina typically suffered more from PVY^n than PVY^o but in the case of Matilda it was opposite. The reaction of cv. Bintje was similar to both virus strains. Yield reduction originated both from lower tuber number and smaller tuber size, which has also been reported by REESTMANN (1970).

Our investigations and previously published information clearly demonstrates the great importance of potato virus Y as a disease inducing agent in potato. In our conditions, PVY^n is dominant over PVY^o and thus the potential damage due to PVY is continuously high. To control PVY^n, a combination of different control methods are needed. One of the basis for effective control is to keep the proportion of infected plants, which may act as infection sources in seed crops, as low as possible as stated by WEIDEMANN (1987).

The negative effect of repeated sprays with mineral oil on the tuber yield, as also reported by CORNU and GEHRINGER (1981) and BOITEAU and SINGH (1982), may be of rather minimal practical importance, because no reduction in tuber number could be detected. No data of the effect and phytotoxicity of the combination of paraffinic oil/deltamethrin, used in our experiments, are available but combined sprays with the same oil plus a related pyrethroid cypermethrin, as reported by GIBSON and CAYLEY (1984), have given more effective control of PVY than the oil or insecticide when used separately without any increase in phytoxicity. As shown by TIILIKKALA and KURPPA (1988), the better quality of seed tuber yield will manyfold cover the cost due to oil applications and minor losses in yield. In seed potato production of resistant cultivars, such as Matilda, probably no protective oil applications are needed if aphid flight remains relatively late.

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SELOSTUS

Neljän ruokaperunalajikkeen reagointi perunan Y-viruksen rotuihin Y^o ja Y^n

AARNE KURPPA ja ANJA HASSI

Maatalouden tutkimuskeskus

Maatalouden tutkimuskeskuksen kasvitautiosastolla tutkittiin vuosina 1986 ja 1987 neljän ruokaperunalajikkeen alttiutta Y-viruksen primääri- ja sekundääritartunnalle. Koelajikkeina olivat yleisimmin viljellyt Bintje, Rekord ja Sabina sekä uusi lupaava tulokas Matilda. Primääritartuntaherkkyyden määrittämistä varten kenttäkokeeksi istutettu kasvusto tartutettiin ensimmäisenä koevuotena kahdella Y-viruksen päärotujen (Y^o ja Y^n) isolaatilla kahtena eri ajankohtana. Seuraavana kasvukautena tutkittiin istutusmukuloiden tartunnan vaikutusta satokomponentteihin viroottisuudeltaan vaihtelevissa kasvustoissa. Kumpanakin koevuotena osa terveistä kontrollikasvustoista suojattiin kirvatartunnalta ruiskuttamalla ne paraffiiniöljyn (Sunoco 11 E/3, 8 l/ha) ja pyretroidi-insektisidin (Decis EC 25, 200 ml/ha) seoksella kuusi kertaa viikon välein heinäkuun 6.—10. päivästä alkaen. Ruiskutuksissa käytetty vesimäärä oli 800 litraa hehtaarille. Virustartutuksen onnistuminen ja eteneminen kasveissa selvitettiin lehti- ja mukulanäytteiden välityksellä määrittämällä niistä Y-virus ELISA-testillä. Kokeet nostettiin käsin ja mukulamäärä sekä -sato määritettiin kasviyksilöittäin. Myös virusmääritykset tehtiin pääosin yksilötasolla.

Ainoastaan lajike Matilda reagoi voimakkain paikallisoirein mekaaniseen virustartutukseen. Sen lehtiin ilmaantui ruskeita umpi- tai rengaslaikkuja noin 7—10 vuorokauden sisällä. Näistä virus levisi nopeasti lehtisuoniin tappaen ne. Virus eteni edelleen vain osassa kasveista tappaen ne ennenaikaisesti. Muissa lajikkeissa varhainen tartunta johti systeemisiin selkeäsuonisuus- ja mosaiikkioireisiin. Myöhäinen tartutus (24. 7.) ei enää aiheuttanut selkeitä oireita missään lajikkeessa.

Varhainen virussiirrostus tartutti lajikkeiden Rekord ja Sabina kasvustot lähes totaalisesti. Bintjen kasvustosta infektoitui 60 % ja Matildasta enimmillään 32 %. Y^n-rotu tartutti vain vajaa 7 % Matildan kasvustosta. Myöhäinen virussiirrostus tartutti perunan versot niin epätasaisesti, että kolmen lehden näytteen perusteella kasvin viroottisuuden määritys oli epävarmaa.

Molemmat virusrodut tartuttivat varhaissiirrostuksena Rekordin ja Sabinan mukulasadon lähes täydellisesti. Y^n-rotu tartutti Bintjen mukuloista yli 70 % ja Y^o-rotu jonkinverran vähemmän. Matildan mukulasadossa viroottisia mukuloita oli alle 4 %. Myöhäinenkin Y^n-rotusiirrostus tartutti

Rekordin, Sabinan ja Bintjenkin mukulasadon pääosin. Sen sijaan Matildan sato säilyi täysin terveenä. Primäärinen virustartunta ei vaikuttanut kasvien tuottamien mukuloiden lukumääriin, ja sadonalennus oli merkittävä vain Rekordilla.

Viroottisen perunan käyttö istutussiemenenä aiheutti sadonmenetyksiä. Mikäli koko kasvusto oli viroottinen, sadonalenema oli 29—59 %. Terveet yksilöt käyttivät tehokkaasti hyödykseen osittain viroottisessa kasvustossa sairailta kasveilta jäävää kasvutilaa. Tämän kompensaatiovaikutuksen johdosta 10—20 %:n viroottisten kasvien osuus kasvustossa ei vielä merkittävästi alentanut satoa. Sato alkoi laskea nopeasti kun viroottisten kasvien osuus ylitti 40 % ja 80 %:sti viroottisen kasvuston tuottama sato jäi 16—40 % tervettä heikommaksi riippuen lajikkeesta ja virusrodusta. Satotappio koostui sekä vähäisemmästä mukulamäärästä että pienemmästä mukuloiden keskipainosta. Viroottisen kasvuston tuottamien mukuloiden koko oli varsin vaihteleva.

Tutkituista lajikkeista Rekord ja Sabina ovat erittäin alttiita Y-viruksen molemmille roduille. Bintje on hieman kestävämpi ainakin Y^{O}-rotua vastaan. Matilda on erittäin kestävä primääritartuntaa vastaan, mutta viroottinen siemen tuottaa heikon sadon. Matildaa ehkä lukuunottamatta näiden lajikkeiden varsinainen siementuotanto on Etelä-Suomessa vaikeata, joinakin vuosina ylivoimaista etenkin, koska vallitsevana virusrotuna on Y^{n}, jota vastaan kasveissa ei muodostu ikä-resistenssiä. Y-virukselle arkojen lajikkeiden viljelyyn sopinee suositukseksi käyttösiemenen lisääminen valiosiemenestä kerran tai käyttösiemenen ostaminen. Ruokaperunan tuottamiseen voi vielä varsin taloudellisesti käyttää siemenperunaa, jonka Y-viroottisuus on noin 20 %, kun se on varmasti tiedossa.

Luontaisen virustartunnan estämiseksi kasvustoihin ruiskutettu mineraaliöljyn ja kirvatorjunta-aineen seos alensi mukuloiden virustartuntaa, mutta aiheutti molempina vuosina ainakin lievät satotappiot. Matildan kasvustossa alkoi kolmannen ruiskutuskerran jälkeen näkyä pistemäisiä poltelaikkuja, mutta muissa lajikkeissa ei oireita todettu. Mukulalukuun öljyruiskutuksilla ei ollut vaikutusta, joten vähäisellä sadonmenetyksellä ei siementuotannossa ole mainittavaa merkitystä.

ANNALES AGRICULTURAE FENNIAE, VOL. 28: 309—315 (1989)

Seria PHYTOPATHOLOGIA N. 109 — Sarja KASVITAUDIT n:o 109

IMPORTANCE OF PERENNIAL GRASSES, AND WINTER CEREALS AS HOSTS OF BARLEY YELLOW DWARF VIRUS (BYDV) RELATED TO FLUCTUATIONS OF VECTOR APHID POPULATION

AARNE KURPPA, SIRPA KURPPA and ANJA HASSI

KURPPA, A., KURPPA, S. and HASSI, A. 1989. **Importance of perennial grasses and winter cereals as hosts of barley yellow dwarf virus (BYDV) related to fluctuations of vector aphid population.** Ann. Agric. Fenn. 28: 309—315. (Agric. Res. Centre, Inst. Pl. Protect., SF-31600 Jokioinen, Finland.)

About sixty percent of samples including the most common perennial species growing in field margins were found to be infected by BYDV in Finland. The great majority of them were symptomless. These are the most probable origins of spontaneous, sporadic infections in areas rich in natural vegetation. On cultivated overwintering hosts, winter cereals and leys, the abundance of viral infections directly followed autumn migrant abundance. For the occurrence of epidemics, strong primary infection is necessary, and because *Rhopalosiphum padi* (L.) is holocyclic, secondary infection during winter is absent. In practice only aphid outbreak makes epidemics possible.

Index words: barley yellow dwarf virus, BYDV, virus host, virus vector, bird cherry-oat aphid, *Rhopalosiphum padi* (L.), cereals, gramineous weeds, ley.

INTRODUCTION

Barley yellow dwarf virus has been reported to cause highly damaging diseases on spring cereals, in Finland (BREMER 1974) and on winter and spring cereals elsewhere in Europe (HINZ et al. 1979) as well as in North America (COMEAU 1987). Epidemics of the virus in Finland have been reported in 1926, 1947, 1954, 1959 (BREMER 1974), 1973, 1975 and, 1988 (KURPPA 1989b). All epidemics after 1959 were evidently connected with outbreaks of the bird cherry- oat aphid, *Rhopalosiphum padi*.

Many, partially cultivated gramineous plants have been widely shown to be natural reservoirs of BYDV (LINDSTEN and GERHARDSON 1969, GRAFTON et al. 1982, HOLMES 1985). The same plant species are hosts for *R. padi*, but with variable preference (RAUTAPÄÄ 1970).

In England, for instance, the winter cereals are known to be primarily infected with BYDV transmitted by autumn migrants, males and gynoparae of *R. padi* (A'BROOK and DEWAR 1980). In areas with mild winters, damage is due to the virus spreading secondarily by aphids overwintering on the crop (HALBERT and PIKE 1985). Such an increase in viral infection does not occur in Finland because of the absence of active overwintering aphids. The second flush of viral transmission is due to the arrival of emigrants of the next year.

In this study the importance of various BYDV sources is focused on the subject of holocyclic and greatly fluctuating *R. padi* populations.

MATERIAL AND METHODS

In July 1986, 599 samples of wild growing perennial grasses were collected from cereal field margins or noncultivated areas inside fields from areas where spring and winter cereals are most frequently cultivated in Finland (Fig. 1). Each sample included the leaves and stems of 5 individual grasses of different species.

In May 1988 samples from 6 fields at Jokioinen and its environs were collected from winter wheat fields which were very scarce that year. In April 1989, 308 samples of winter wheat and cultivated grasses sown during the previous season were collected all over the country (Fig. 2). Each sample (four per field) included fresh leaves from 25 individual plants.

All samples were tested by enzyme-linked immunosorbent assay (ELISA) using a 1 to 5 dilution of pressed sap in sample buffer, respectively. In 1986 and 1988 commercial ELISA reagents 'B' and 'F' to BYDV (see PLUMB 1974) (Bioprepa, Switzerland) were employed. In 1989 the plates were coated with a mixture (1/1) of a Swedish antisera to BYDV isolates 27/77 and 39/78 (EWEIDA and OXELFELT 1985) as a total concentration 1 µg IgG/ml. The virus was detected with the enzyme conjugates 'B' and 'F' from Bioprepa.

Alate aphids were monitored by a suction trap set at 12 meters height at Jokioinen and apterae aphids were counted on cereal crops once a week. Of the cereal aphids, *R. padi* formed the great majority and, therefore, the data presented is restricted to this species.

RESULTS AND DISCUSSION

BYDV on wild perennial grasses

Over 60 % of the samples of wild perennial grasses obtained from all over the country were virus infected, in 1986 (Table 1). All grass species received from each area were infected in 25 % of the sampled localities and no infection was detected in any grass species from 15 % of the localities (Fig. 1).

The highly infected couch grass, *Elymus repens,* (see Table 1) is a common weed in cereal fields. It remains dark green and is obviously a preferable host also for *Sitobion avenae* occurring later in the season than *R. padi,* which might be a reason for high percentage of MAV-type in the infections. The importance of couch grass as a source of BYDV was easily demonstrated in 1988, when patches of BYDV damage were very often seen spreading around occasional couch grasses growing among cereal crops. Less than 10 % of sampled couch grasses showed any symptom of infection.

Timothy, *Phleum pratense,* and meadow foxtail, *Alopecurus pratensis,* were here found to be much more commonly infected than timothy in leys in Sweden (LINDSTEN and GERHARDSON 1969). These species are common in cereal field margins. Hair grasses, *Deschampsia* spp., and reed bent grasses, *Calamagrostis* spp., are typical weeds of pastures and wet areas. Fescue grasses, *Festuca* spp., and meadow grasses, *Poa*

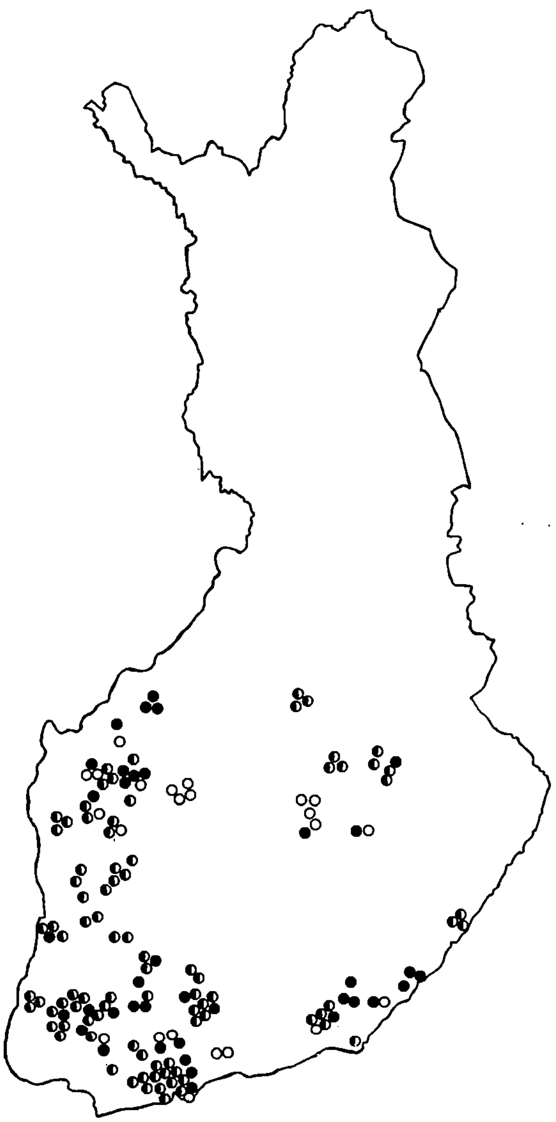

Fig. 1. Distribution of BYDV infections in wild perennial grasses in 1986. Open circles indicate localities from which only uninfected samples were received, half solid circles indicate localities with 1—4 infected grass species out of five required from each site and solid circles indicate localities with all five grass species infected.

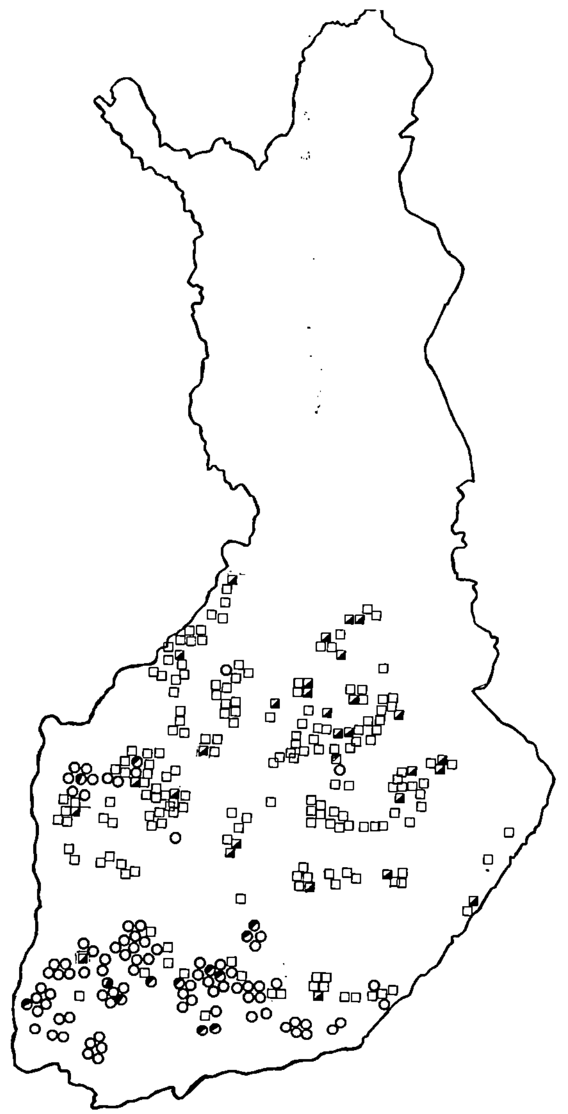

Fig. 2. BYDV- infections on winter cereals (circles) and leys (squares) sown in 1988. Open figures indicate localities from which only uninfected samples were received, half solid figures indicate fields where 1 to 3 of the four required samples were found infected.

spp., are used in plant mixtures grown for pasture. The abundance of viral infections on fescue grasses in the present study was about 20 % less than the reported in Missouri, USA (GRAFTON et al. 1982).

The infections detected in 1986 must have been initiated in 1985 or earlier, because in 1986 the populations of cereal aphids were extremely low (KURPPA 1989a). This data indicates the presence of a permanent, fairly abundant

Table 1. Abundance of BYDV infection of wild perennial grasses in 1986 and the relative abundance of two types of BYDV in infected samples.

	Species of grass								
	Elymus repens	*Phleum prat.*	*Desch.* spp.	*Alopec. prat.*	*Calamagr.* spp.	*Poa* spp.	*Festuca* spp.	Other	Total
BYDV inf. %	92	44	44	78	65	45	42	33	61
Strains									
MAV	51	34	21	5	27	6	27	0	33
PAV	49	66	79	95	73	94	73	100	67
N	159	154	109	54	40	38	36	9	599

source of BYDV in the wild vegetation of Finland.

BYDV in winter cereals and leys

In the spring of the 1988 *R. padi* outbreak, BYDV was detected in absolutely every sample of winter cereals from Jokioinen and its environs. This occurred prior to the arrival of vector aphids via wind currents reported elsewhere (KURPPA 1989a). The effect of the strong viral sources was easily visible in the form of exceptionally high viral infections in spring cereals neighbouring winter cereals. Yield losses of 50 % or more were common. In this case, the importance of the viral infections originating from local overwintering cereals or from distant crops or abroad, presented to be highly significant by CLEMENT et al. 1986, are impossible to differentiate.

In the following year 1988—89, winter cereals were remarkably more common, and of these 13 % were found to be BYDV infected (Fig. 2). All of the samples included only 1—2 infected subsamples out of four subsamples per field. 37.5 %, of infections were mixtures of MAV- and PAV-type (14 from leys, 1 from cereals), 45 % MAV-type (10 from leys, 8 from cereals) and 17.5 % PAV-type (all from leys). Such extremely high variability in the abundance of BYDV infections refers to the importance of vector abundance.

Fluctuations of *R. padi* populations as related to the spread of BYDV to leys and winter cereals

In the exceptionally cool and rainy year of 1987, the summer migration of *R. padi* was one month later than average and even later compared to year of an aphid outbreak, e.g. 1988. Summer and autumn migration fused forming a period of two months with high number of alate aphids (Fig. 3), presumably including alate exules heading to fresh gramineous plants, at first, and males and gynoparae heading to the primary host, later. Strong infections could even be expected on winter cereal seedlings that emerged in the middle of this period.

Weather conditions in 1988 were opposite to those of 1987, and *R. padi* spring migration occurred at the beginning of May as usual, when the overwintering population is very high (see KURPPA 1989a). This situation facilitated the rapid spread of BYDV infection within winter cereals and into spring cereals and resulting in a high abundance of virus in spring cereals throughout the country (KURPPA 1989b). Summer migration occurred early after which the population crashed. The peak of autumn migration (at Jokioinen about 800 aphids per week) was about 1/20 of the peak number of migrants found in 1988. Only a few, sporadic fields of leys and winter cereals grown and emerging during this period were found to

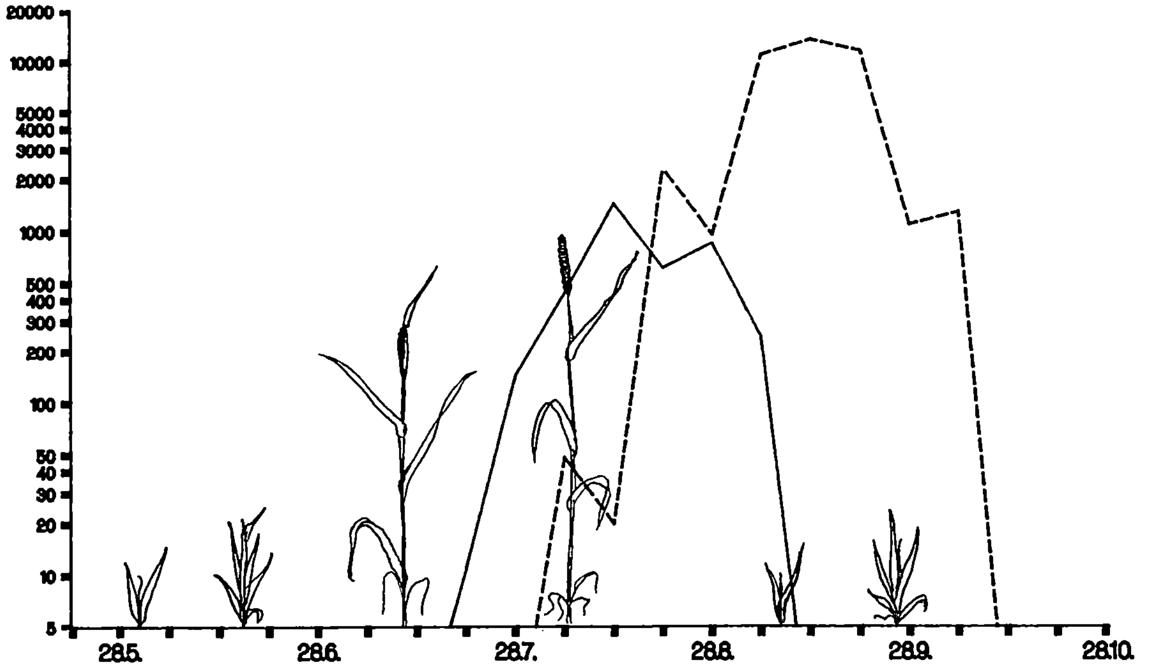

Fig. 3. Abundance of *R. padi* on ten cereal plants (solid line) and in suction trap samples (broken line) counted once a week in 1987. Scale log(n + 1).

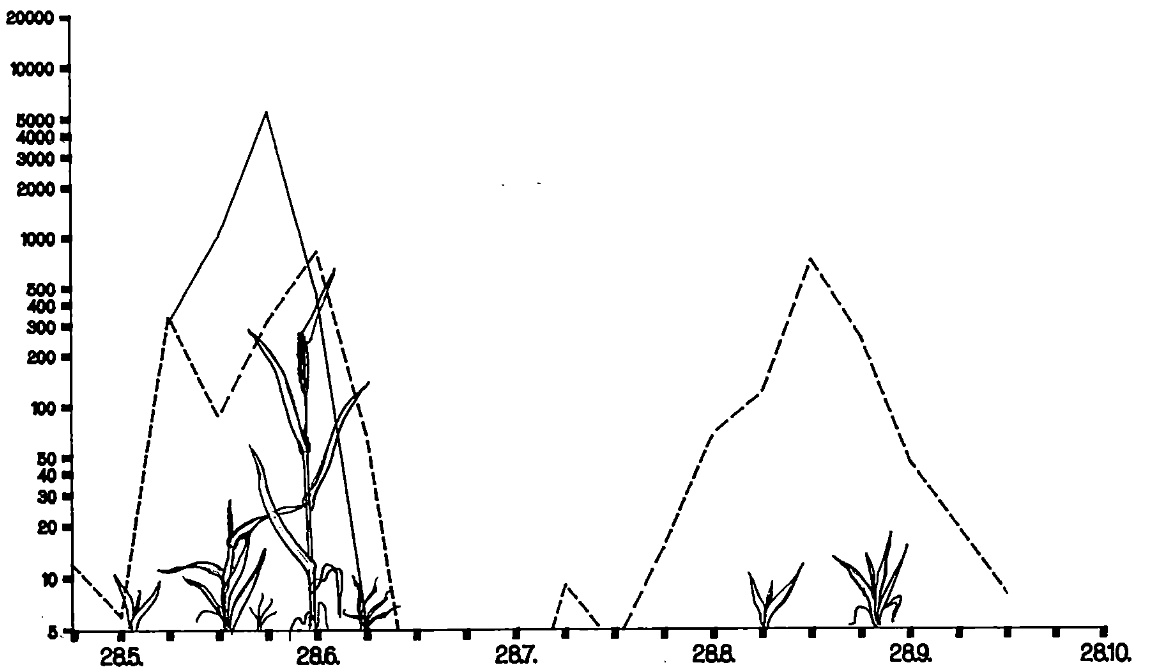

Fig. 4. Abundance of *R. padi* on ten cereal plants (solid line) and in suction trap samples (broken line) counted once a week in 1988. Scale log(n + 1).

be BYDV infected. Numerous aphids found on spring cereals must have left them for summer migration without touching the emergent grasses underneath. The abundance of autumn migrants, all over the country, was obviously too low or the period of migration too short to facilitate BYDV infection on winter cereals and leys. Actually, nobody has shown the preference of males and gynoparae between primary and secondary host.

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SELOSTUS

Tuomikirvan populaatiovaihtelujen vaikutus heinäkasvien ja syysviljojen merkitykseen kääpiökasvuviroosin (BYDV) säilyttäjinä

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Maatalouden tutkimuskeskus

Viljan kääpiökasvuvirusta eristettiin vuosien 1986 ja 1988 luonnonvaraisista ja viljellyistä heinäkasveista ja syysviljoista. Tarkoituksena oli selvittää eri viruslähteiden merkitystä aikana, jolloin virusta levittävän tuomikirvan populaatioiden vaihtelut olivat äärimmäiseri voimakkaita.

Monivuotisista heinäkasveista yli 60 % osoittautui viljan kääpiökasvuviruksen tartuttamaksi. Niillä alueilla, joissa luonnontilaiset heinäalueet ovat yleisiä, vuodesta toiseen säilyviä viruslähteitä näyttää siten olevan runsaasti ja niistä saattaa levitä paikallisia saastuntoja kevätviljoihin.

Syysviljoissa viljan kääpiökasvuviroosin yleisyys vaihteli voimakkaasti tuomikirvan syyspopulaatioiden vaihtelujen mukaan. Kun tuomikirvan siivekkäiden yksilöiden määrät nousivat äärimmäisen suuriksi elo-syyskuussa 1987, viroosia esiintyi jo talvehtineissa syysviljoissa hyvin yleisesti. Kun tuomikirvakanta jäi syksyllä 1988 noin kahdenteenkymmenenteen osaan edellisen vuoden määrästä eli putosi tasolle, joka on yleinen massaesiintymien välivuosina, viruksen tartuttamien syysviljakasvustojen määrän todettiin samalla pudonneen viruksen leviämisen kannalta merkityksettömän pieneksi. Syysviljojen osuus kääpiökasvuviruksen säilyttäjänä näyttää siten rajoittuvan selvästi kirvojen massaesiintymävuosiin ja viljan viljelyyn keskittyneille viljelyalueille.

ANNALES AGRICULTURAE FENNIAE, VOL. 28: 317—333 (1989)

Seria ANIMALIA NOCENTIA N. 142 — Sarja TUHOELÄIMET n:o 142

CHEMICAL CONTROL OF EUROPEAN RED SPIDER MITE *PANONYCHUS ULMI* (KOCH). I. EVALUATION OF FLUBENZIMINE

TUOMO TUOVINEN

TUOVINEN, T. 1989. **Chemical control of European red spider mite *Panonychus ulmi* (Koch). I. Evaluation of flubenzimine.** Ann. Agric. Fenn. 28: 317—333. (Agric. Res. Centre, Inst. Pl. Protect., SF-31600 Jokioinen, Finland.)

Good control of *P. ulmi* was achieved with flubenzimine (150—250 g a.i./100 l water, 0.45—0.75 kg a.i./ha, mistsprayer 300—400 l/ha) when sprayed just before or during blossom and, if necessary, in late June or July. If sprayed only once, the recommended time for spraying in spring is when the effective temperature sum of 200 dd above +5 °C has been reached. A high density mite population may need another spray later in July. Later treatments result in a low overwintering population, facilitating mite control also in the next season. When sprayed in low concentrations (25—85 g a.i./100 l water) several times, almost complete control of *P. ulmi* was achieved. Flubenzimine was also effective against the apple rust mite *Aculus schlechtendali*. It had a harmful effect on predatory phytoseiid mites and one spray diminished the number of phytoseiids by more than 90 %; when flubenzimine was sprayed several times during the season, phytoseiids disappeared almost entirely. Flubenzimine reduced the number of spiders (Araneida) but had only slight effect on the numbers of predatory anthocorid bugs.

The reference acaricides chinomethionate (37.5—62.5 g a.i./100 l water, 0.12—0.22 kg a.i./ha), dicofol (140 g a.i./100 l water, 0.4 kg a.i./ha), fenbutatinoxide (250 g a.i./100 l water, 0.75 kg a.i./ha) and oxydemetonmethyl (132 g a.i./100 l water, 0.4 kg a.i./ha) were generally not as effective as flubenzimine. In most cases, satisfactory control can be achieved also by these compounds, but often two or even three treatments are then necessary.

Index words: chinomethionate, dicofol, fenbutatinoxide, flubenzimine, oxydemetonmethyl, acaricides, European red spider mite, *Panonychus ulmi*, Phytoseiidae.

INTRODUCTION

The European red spider mite (ERM), *Panonychus ulmi* (Koch), has become a more serious pest on commercially grown apple trees in Finland. The ERM control strategy with regard to chemical control, is to lower the population in the spring before the beginning of fruit development either by early spring sprays with ovicidal oil preparates, pre-blossom sprays with organophosphate insecticide oxydemetonmethyl, or pre-blossom and blossom sprays with chinomethionate and dicofol. However, in many cases additional sprays are required in July. Growers are aware of the common demand to reduce pesticide use, but so far, no acaricide has provided good control with a single spray, especially, if the season is warm and favourable for ERM.

Successful biological control methods against main insect pests would resolve the major problems in ERM control. In particular, insecticides have adverse effects on phytoseiid mites and other beneficial arthropods (e.g. SWIFT 1968, KARG et al. 1987). In small home gardens where no insecticidal, acaricidal or fungicidal treatments have been carried out, ERM is not a problem. This is mostly due to predatory phytoseiid mites which are common in these orchards (KROPCZYNSKA and TUOVINEN 1988). In Finland, the main insect pest on apple is the apple fruit moth *Argyresthia conjugella* Zell., which is controlled by spraying broad-spectrum insecticides. Studies on the integrated control of the apple fruit moth are in progress, but before any successful methods are available, the use of acaricides against ERM will continue. The most common acaricides, chinomethionate and dicofol, have been also found to have harmful effect on phytoseiids (HASSAN et al. 1987).

Effective, yet safer for natural enemies, acaricides would be of great importance in Finnish conditions where apple gardens are quite small and surrounded by wild herbaceous trees and bushes from which predators may easily move to apple trees. Flubenzimine, which acts as a chitin synthesis inhibitor (ZOEBELEIN et al. 1979), is an interesting acaricide owing to a different mode of action compared to that of earlier acaricides. In some earlier tests, flubenzimine has proved to be quite harmless to beneficial insects and predatory mites, thus supporting possible use of the compound in intergrated control (BONESS 1983). Chinomethionate, dicofol or oxydemetonmethyl were included in tests. The aim of this study is to combine the results of the field tests with flubenzimine and to summarize the situation of ERM control in Finland.

MATERIAL AND METHODS

Flubenzimine was used as 50 % WP formulation Cropotex, produced by Bayer.

As reference products, chinometionate as 25 % WP formulation (Morestan, Bayer), dicofol as 18.5 % WP formulation (Kelthane, Rohm and Haas), fenbutatinoxide as 50 % WP formulation (Torque, Shell) and oxydemetonmethyl as 26.5 % liquid formulation (Metasystox, Bayer) were used. Sprays were carried out using the recommended concentrations and doses.

Experimental orchards

Experiments were carried out in four orchards in 1981—88. Two of the orchards were commercial cultivations where insecticidal and fungicidal sprays were performed, too.

Pohja 1981—84. A commercial orchard comprising 7 ha of apple trees. The location is situated near the southern coast. The experimental area was 0.5 ha and the main cultivar 'Lobo'. The area was divided into 6 two-row sectors, each including about 60 trees. 10 trees per sector were randomly chosen for sampling leaves and twigs. Treatments were carried out by a tractor-driven mistsprayer (Hardi). Some insecticidal and fungicidal sprays were performed in 1982—1984. The nearest meteorological station is Salo (36 km).

Pälkäne 1982—86. The experimental area, consisting of 100 apple trees (cv. Huvitus), was part of the Häme Research Station orchard. A randomized block design with four 4-tree replicates and untreated shelter trees between treatments was used in 1982 and 1986, in 1983—84 the single tree replicates (3—12) employed were arranged in groups according to the treatments in the previous year. Treatments were done with a knapsack mistsprayer (Solo). A meteorological station is situated 0.3 km from the experimental area.

Bromarv 1986. An experiment was carried out in a commercial orchard using two 1 ha blocks. Sprays were performed using a tractor-driven mistsprayer, and insecticidal and fungicidal sprays were also carried out.

Jokioinen 1988. An experiment in an experimental orchard was performed using fully randomized design and single trees as replicates. Sprays were done with a knapsack compression sprayer and a knapsack mistsprayer.

Sampling and observations

Normally, sampling was carried out by collecting 5—10 spur leaves/tree, from 10—20 trees per treatment, selected randomly from each tree from the same height (1.5—2 m). Sampling was performed usually once before spraying and 2—6 times afterwards. Leaves from each tree were kept separately in plastic bags and stored at +5 °C temperature. Numbers of living mobile mites and eggs were counted immediately or after 1—3 days under a stereomicroscope. During inspection, occurrence of natural enemies was also observed. Samples of twigs were collected to count winter eggs: 5 pieces of 20 cm 2—3 year old branch from 10—20 trees per treatment were collected in late October and in November.

In 1982, samples of arthropods occurring in trees were collected by beating 10 branches (in 10 trees/treatment) over a sampling net with an opening of 0.1 m^2. Samples were preserved in alcohol and studied later.

Monthly effective temperature sums (in day-degrees over +5 °C) were recorded by the nearest weather stations (Figs. 1—2).

The significance of differences between treatments (in Pohja and Pälkäne) was tested by analysis of variance using Duncan's multiple range test (STEEL and TORRIE 1980) on log(x + 1)-transformed data for each checking date both for eggs and mobile stages. In other orchards, the t-test or analysis of variance using Duncan's multiple range test was employed for calculation. All calculations were performed using the SPSSX-statistical package.

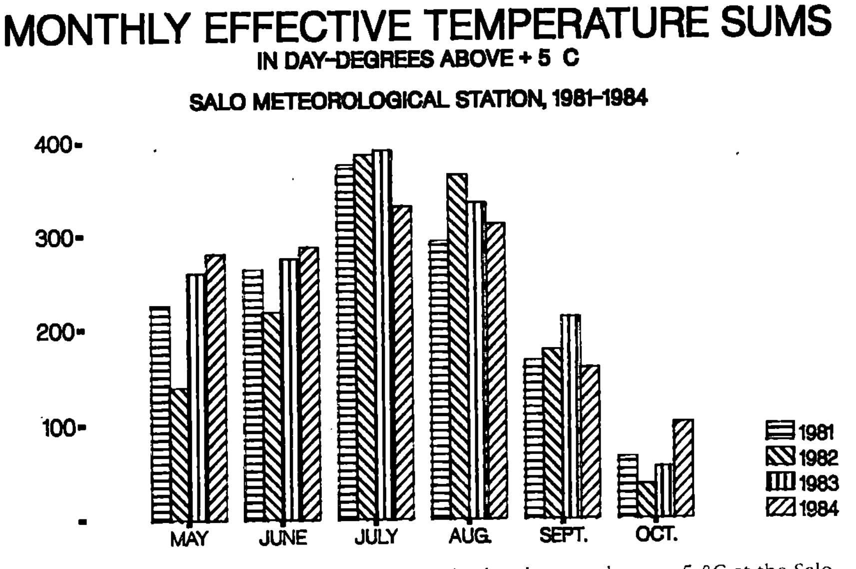


Fig. 1. Monthly effective temperature sums in day-degrees above +5 °C at the Salo meteorological station, 1981—1984.

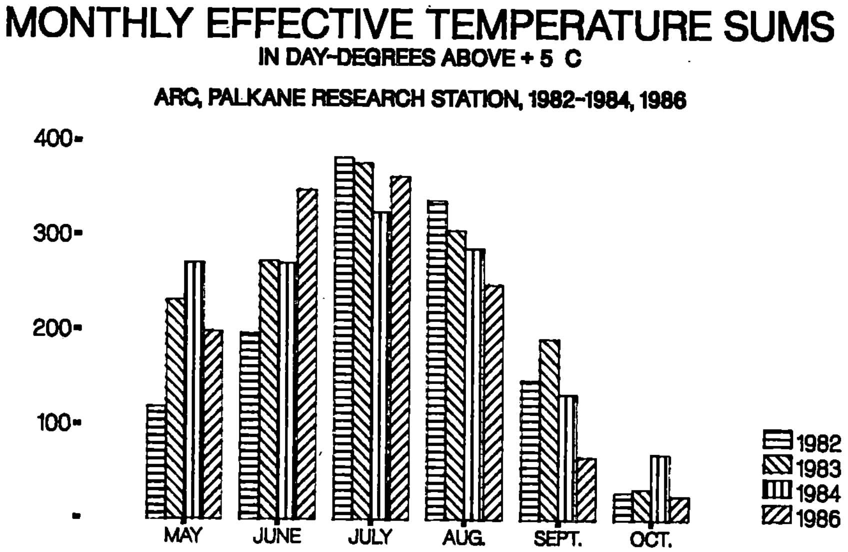


Fig. 2. Monthly effective temperature sums in day-degrees above + 5 °C at the Pälkäne research station, 1982—1984, 1986.

RESULTS

Pohja

Results of the leaf and winter egg counts from Pohja are arranged in a continuous series of experiments to show the yearly changes in mite density after different treatments (Figs. 3a and 3b).

In 1981, two sprays with flubenzimine killed ERM almost completely (block A). One late application (8.7., block C) had a similar effect for the rest of the season. One early spring application (27.5., sprayed when 189 day-degrees above + 5 °C was reached, block B) had a long lasting effect also although the number of mobile mites was significantly higher than in other trees sprayed with flubenzimine. Chinomethionate (blocks D-F) also had a good effect although the numbers of mobile mites and summer eggs were higher than in respective flubenzimine treated trees. Winter egg counts show that the late application of both acaricides resulted in significantly lower egg numbers than the earlier applications.

In 1982, block A, sprayed in -81 twice with flubenzimine, was left as a non-treated block because of low ERM density. Although not sprayed, the number of mites did not exceed the control threshold of 10 mites/leaf before September. Flubenzimine was applied once, on 1.6. (140 dd, block B) and on 28.6. (blocks D and F). In block B, ERM density was quite high but one spray was enough to maintain the number of mites under 5/leaf until August. The later applications resulted in almost the same population level in September. Chinomethionate, when sprayed on 1.6. (block E) did not have as good an effect as flubenzimine, although the initial ERM population was lower. In the untreated blocks (A and C), which had the late spray with flubenzimine in the previous year, the number of ERM stayed under 10 mobile mites/leaf throughout the whole season.

According to the summer egg counts (Fig. 3b) there were three complete ERM generations in 1982. The effective temperature sum of the whole season was 1313 dd, which is about the normal rate (mean 1951—1980). In other years, no clear picture of the numbers of generations could be obtained because of fewer inspections.

In 1982, beat samples were collected from each block to check the occurrence of other arthropods. Very few beneficial insects belonging to Heteroptera, Neuroptera or Coleoptera (Coccinellidae) as well as spiders (Araneida) were caught (Table 1). No doubt this is due to a spray with dimethoate against the codling moth *Cydia pomonella* (L.) and the apple fruit moth *Argyresthia conjugella*.

In 1983, oxydemetonmethyl was sprayed over the whole experimental area (23.5., 190 dd). Furthermore, one spray with flubenzimine was performed on 26.5. (220 dd, blocks A, D and F). The initial numbers of ERM in each block were quite low and stayed low during June, but ERM densities increased on a very high level in blocks treated only with oxydemetonmethyl. The effect of flubenzimine lasted almost through the whole season, but later in the autumn ERM numbers increased which is expressed in the high numbers of winter eggs. In 1983, September was unusually warm and favourable for ERM egg laying (Fig. 1).

In 1984, only flubenzimine was sprayed over the whole experimental area (24.5., 190 dd). ERM density remained low, except at the end of the season. The effective temperature sum of the season was higher than normal, 1461 dd, favouring ERM reproduction.

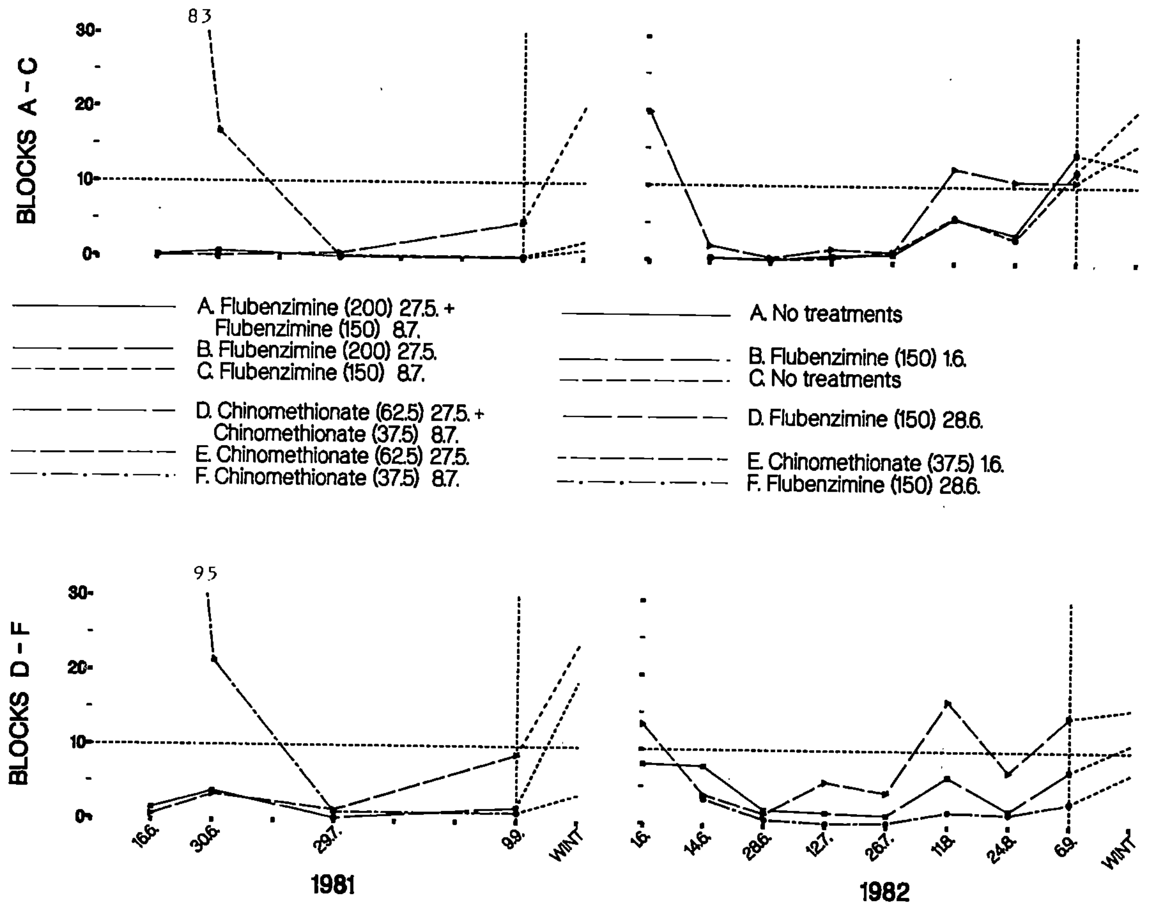
Pälkäne

The results of the experiments in Pälkäne are presented in Tables 3—6. Tables 4 and 5 are arranged so that also the treatments of the previous year are taken into account.

In 1982, the initial ERM population was very uniform in the experimental area (Table 3). The effect of flubenzimine, when sprayed quite late (29.6.) was satisfactory. The numbers of mobile ERM in untreated blocks did not increase substantially, which may be due to predatory bugs (Heteroptera: Anthocoridae) present in the orchard. The weather was quite cold in 1982, and the effective temperature sum of the whole season was only 1207 dd. No sprays with broad-spectrum insecticides were performed, but half of the trees were sprayed with diflubenzuron (Dimilin) which did not have any effect on mites during the season except on 2.8., when the number of mobile mites was even higher than in the control trees.

In 1982, beat samples were collected to check the occurrence of other arthropods than mites. Of the beneficial arthropods, *Anthocoris* spp. was found to be present in all blocks, but not in large numbers (Table 2). Spiders were quite common but flubenzimine clearly diminished their number. The apple sucker *Psylla mali* (Schmiedb.) (Homoptera: Psyllidae) was the most common insect pest; only a spray with diflubenzuron diminished the number of apple suckers to some extent.

In 1983, ERM numbers were very high in late July, except on trees sprayed the previous year with flubenzimine (Table 4). Flubenzimine, fenbutatinoxide and a pyrethroid insecticide, deltamethrin, were sprayed very late on 29.7. In trees treated with flubenzimine both in 1982 and 1983, or with fenbutatinoxide in 1983, ERM density in August and the number of winter eggs were significantly lower than in other blocks. Flubenzimine sprayed on trees with a high density of ERM (block B), while diminishing the number of mobile stages, could not prevent winter egg laying later. The effect of fenbutatinoxide was not as good as that of flubenzimine. Although deltamethrin at first lowered mobile ERM numbers, it later caused a clear outbreak of ERM when winter egg numbers are taken into consideration. The whole season was warm (1404 dd) and especially September was warmer (190 dd) than usual which explains the high winter egg densities.



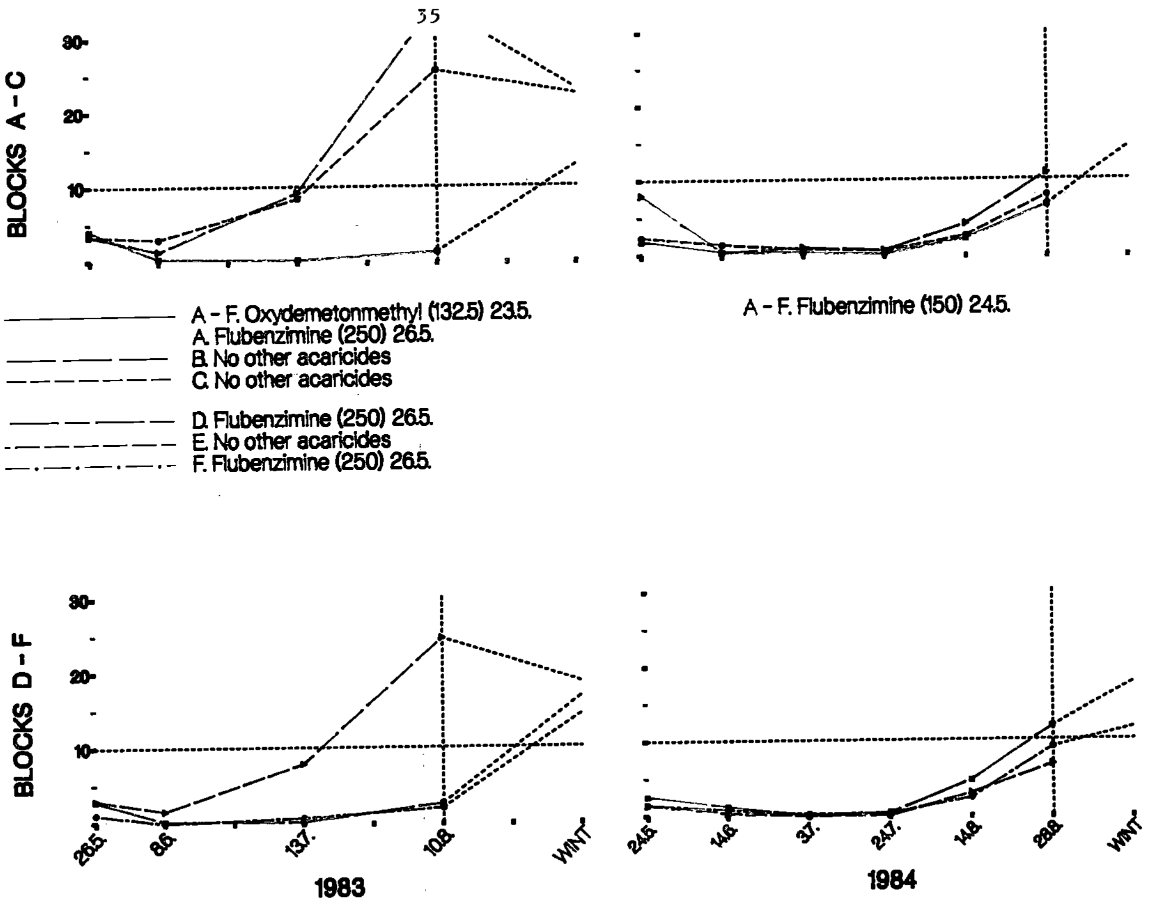
Signif. differences:

16.6.	F,C>B,A,E,D
30.6.	C,F>B,A,E,D
29.7.	E>A,C,D,
	F>A,C,D,B
9.9.	E>A,C,F,D,B
	B>A,C,F,D
WINTER	E,B,D>F,A,C

Signif. differences:

1.6.	N.S.
14.6.	D>A,C,B,F
	E>A,C
28.6.	D,E>A,C,B,F
12.7.	E>F,C,B,A,D
26.7.	E>F,A,B,D,C
11.8.	E,B>F,D,A,C
24.8.	B>F,D
6.9.	A,E>F,D
	C,B>F
WINTER	C>F,D
	E>F

Fig. 3 a. Results from the field experiments at Pohja in 1981—1984. Mean numbers of mobile mites (larvae, nymphs and adults) per one leaf and mean numbers of winter eggs/1 cm twig. Treatments (g a.i./100 l water) with a mistsprayer, 300 l/ha, on both sides of the rows. For apple scab control, dithianon (225 g a.i./100 l) was sprayed 5—7 times/year. For moth control, dimethoate (120) was sprayed 20. 6. 1982 and 15. 6. 1984 and deltamethrin (10) was sprayed 2. 7. 1984. Significant differences (p = 0.05) according to Duncan's multiple range test on log-transformed data for each inspection date.



Signif. differences:

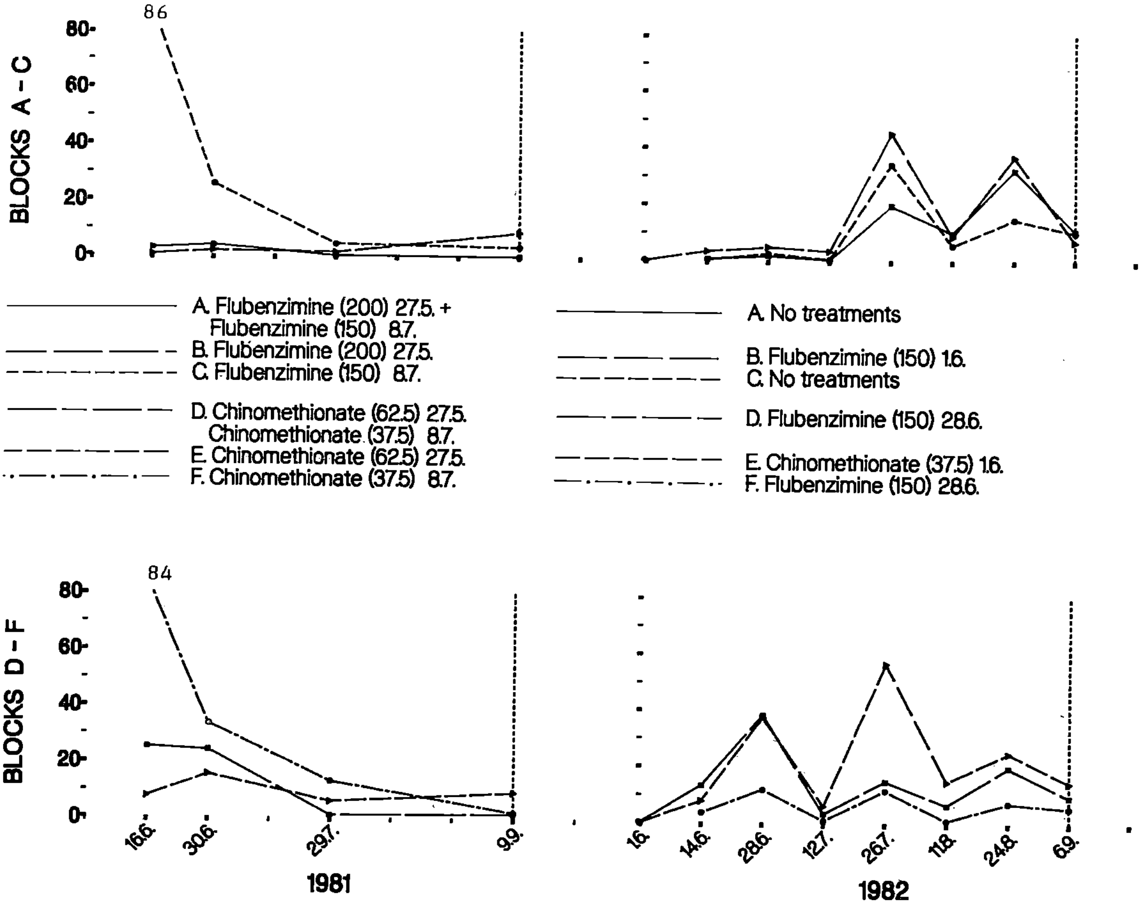
26.5.	A>F
8.6.	C,E,B>F,D,A
13.7.	B,C,E>D,A,F
10.8.	B,E,C>A,F,D
WINTER	B>A

Signif. differences:

24.5.	B>A,E,F
14.6.	N.S.
3.7.	B>D,E
24.7.	N.S.
14.8.	D>A,C,F
28.8.	N.S.
WINTER	D>F

Table 1. Number of some predatory and other arthropods collected by the beating method in Pohja 1982. Treatment letters refer to Fig. 3. Samples were collected from 10 branches/treatment.

	Anthocoridae						Neuroptera						Araneida						Other arthropods (mites not included)					
Treatment:	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F
14.6.	0	1	2	1	2	3	0	0	0	0	0	0	1	1	0	0	1	2	75	36	62	76	31	50
28.6	4	2	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	18	12	7	13	6	9
26.7.	1	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	5	3	7	3	8	0
10.8.	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	6	3	4	43	10
24.8.	0	0	0	0	1	0	0	0	0	0	1	4	0	0	1	0	2	3	14	4	12	13	13	9



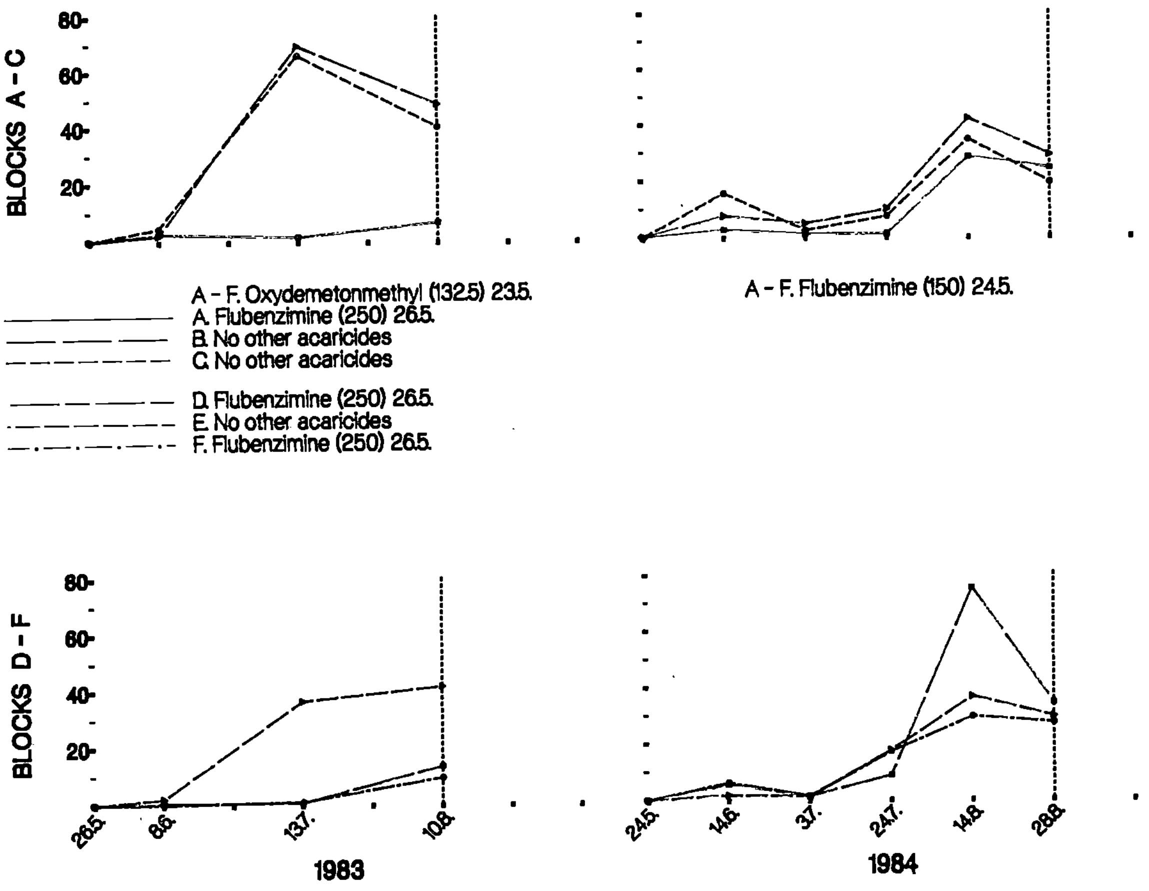
Signif. differences:

16.6.	F,C>B,A,E,D
30.6.	F>B,A,E
	C,D>B,A
29.7.	F>A,D,B,C,E
	E>A,D,B
9.9.	E,B>A,D,C,F

Signif. differences:

1.6.	—
14.6.	D>C,A,B,F,E
	E>C,A
28.6.	D,E>A,C,B,F
12.7.	E>A,C,B,F
26.7.	E>F,D,A
	B>F,D
11.8.	E>F,C,D
	B>F
24.8.	B>F,C
6.9.	E>F,B

Fig. 3 b. Results from the field experiments at Pohja 1981—1984. Mean numbers of ERM summer eggs per one leaf. Treatments as in Fig. 3 a.



Signif. differences:

26.5.	—
8.6.	C>F
13.7.	B,C,E>D,F,A
10.8.	B,C,E>A,F,D

Signif. differences:

24.5.	—
14.6.	C>E
3.7.	N.S.
24.7.	E,F,B,D>A
14.8.	D>A,F
28.8.	N.S.

Table 2. Number of predatory and other arthropods collected by the beating method in Pälkäne 1982. Treatment letters refer to Table 3. Samples were collected from 10 branches/treatment.

	Anthocoridae				Neuroptera				Coccinelidae				Araneida				Other arthropods (mites not included)			
Treatment:	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
19.7.	3	8	10	10	0	0	0	0	0	0	0	0	0	1	6	7	72	14	10	26
16.8.	1	2	5	0	0	0	0	0	0	1	2	1	3	3	6	7	92	49	30	60
30.8.	5	12	11	5	1	1	0	1	1	0	6	0	21	20	39	25	129	121	56	75

Table 3. Results of the field experiment in 1982 (Häme Exp. Sta., Pälkäne). 0.3—0.4 l/tree was sprayed with a knapsack mistsprayer. Numbers of mites were counted from 5 leaves/tree and numbers of winter eggs from 5 twigs/tree.

Treatment and rate (g a.i./100 l)		No. of mites/leaf (mobile and eggs)												Winter eggs/10 cm
		21.6.		6.7.		19.7.		2.8.		16.8.		30.8.		
	Date	M	E	M	E	M	E	M	E	M	E	M	E	
A. Flubenzimine (150)	29.6.	7.7	19.5	1.1A	17.8A	1.8A	6.4A	0.0A	3.6A	3.7A	8.9A	1.7A	6.1A	42.5A
B. Flubenzimine (150) + Diflubenzuron (125)	29.6. 13.7.	9.2	18.6	0.7A	15.9A	2.9A	9.1A	0.2AB	3.0A	3.3A	12.0A	2.6B	6.7A	55.8A
C. Diflubenzuron (125)	13.7.	6.5	15.6	4.4B	28.8B	10.2B	18.4B	5.2C	20.2B	15.9B	43.4B	12.5C	29.8B	164.0B
D. No treatment		8.1	17.8	5.4B	30.8B	13.5C	14.6B	0.6B	33.7B	21.6B	35.3B	11.9C	22.2B	367.0B

Means with different letters in columns denote significant differences (P = 0.05) according to Duncan's multiple range test on log-transformed data. Columns without letters indicate a nonsignificant F-test (P = 0.05).

Table 4. Results of the field experiment in 1983 (Häme Res. Sta., Pälkäne). 0.3—0.4 l/tree was sprayed with a knapsack mistsprayer, on 29.7. Numbers of mites were counted from 5 leaves/tree, and numbers of winter eggs from 5 twigs/tree.

Treatment and rate (g a.i./100 l)	Treatm. in 1982[1]	No. of mites/leaf (mobile and eggs)				Winter eggs/10 cm
		29.7.		17.8.		
		M	E	M	E	
A. Flubenzimine (250)	A	6A	43A	0.0A	11A	11A
B. Flubenzimine (250)	—	44B	249B	0.7A	106BC	104B
C. Fenbutatinoxide (250)	B	17A	56A	2.8A	39A	196B
D. Fenbutatinoxide (250)	—	71C	270B	1.7A	77BC	389C
E. Deltamethrin (2.5)	—	35B	82A	11.0B	68C	675D
F. No treatment	—	27B	100A	22.0C	102B	447CD

Means with different letters in columns denote significant differences (P = 0.05) according to Duncan's multiple range test on log-transformed data.
[1] Letters refer to table 3 (— indicates untreated trees in 1982).

In 1984, great differences in initial densities among groups of trees were found (Table 5). Except acaricides, the pyrethroids deltamethrin and cyfluthrin, and an insect growth regulator, diflubenzuron, were included to test their effect on the apple fruit moth. All acaricides, sprayed on 11.6. (377 dd) had a good effect on ERM, and only small differences could be found in winter egg counts in the autumn. May was very warm (270 dd) favouring the rapid development of ERM, but in June, soon after the treatments, a colder period began, lasting several weeks. In addition to the sprays, cold weather might have influenced on mite numbers, which later in the season remained quite low in all treatments.

In 1985, the density of ERM was low and no experiments were carried out. In 1986, flubenzimine was sprayed on 17.7. on two areas having different initial ERM densities (Table 6). Flubenzimine had a good effect for the rest of the season and winter egg numbers were very low. Also phytoseiid mites *Euseius finlandicus* (Oud.) and *Phytoseius macropilis* (Banks) (Acari: Phytoseiidae) were found to be present in the orchard. In trees sprayed with flubenzimine the number of predatory mites was much lower than that in untreated trees.

Bromarv 1986

The effect of flubenzimine and chinomethionate was compared in a commercial orchard (Table 7). Flubenzimine was sprayed only once (30.5., 180 dd), and chinomethionate three times in May and June (first on 23.5., 147 dd). Neither flubenzimine nor chinomethionate gave satisfactory control of ERM.

Jokioinen 1988

Flubenzimine was sprayed 5 times timed according to apple scab control sprays to study also the possible effect of sprays on the apple scab. The concentrations were lower than in other experiments, 25—85 g a.i./100 l water, but the effect of the sprays on ERM was almost complete (Table 8). The initial population density of ERM was low, but predatory mites *E. finlandicus* and *P. macropilis* were numerous. Flubenzimine almost completely killed all mites, including phytoseiids and the apple rust mite *Aculus schlechtendali* (Nal.) (Acari: Eriophyidae).

Table 5. Results of the field experiment in 1984 (Häme Res. Sta., Pälkäne). 0.3—0.4 l/tree was sprayed with a knapsack mistsprayer. Numbers of mites were counted from 5 leaves/tree, and numbers of winter eggs from 5 twigs/tree.

Treatment and rate (g a.i./100 l)	Date	Treatm. in 1983[1]	No. of mites/leaf (mobile and eggs)								Winter eggs/10 cm
			11.6.		26.6.		7.8.		29.8.		
			M	E	M	E	M	E	M	E	
A. Flubenzimine (250)	11.6.	C	0.8AB	12.0AB	0.4AB	0.4	0.0A	0.0A	0.1A	0.5A	4.3AC
B. Flubenzimine (250)	11.6.	E	1.0AC	25.0AC	0.2AB	0.5	1.0BC	3.2B	0.0A	0.3A	5.3AC
C. Flubenzimine (250)	11.6.	—	1.6AD	44.0AC	0.1AB	0.0	0.2AB	0.6A	0.0A	0.3A	2.8AC
D. Flubenzimine (250) + Deltamethrin (6.25)	11.6. 10.7.	B	2.4AD	45.0BC	0.0A	1.0	0.0A	0.0A	0.0A	0.0A	0.4A
E. Flubenzimine (250) + Deltamethrin (6.25)	11.6.	—	3.6BD	94.0C	0.1AB	1.5	0.0A	0.8A	0.0A	0.0A	1.3AB
F. Fenbutatinoxide (250)	11.6.	—	0.6A	7.6A	0.2AB	0.2	1.3C	0.6A	0.5A	1.1A	28.2BC
G. Fenbutatinoxide (250) + Diflubenzuron (125)	11.6. 10.7.	F	3.8CD	38.0AC	1.0B	1.4	0.4AC	0.1A	0.2A	0.1A	14.2BC
H. Fenbutatinoxide (250) + Diflubenzuron (125)	11.6.	—	2.7AD	105.0C	0.1AB	0.0	0.1AB	0.3A	0.2A	2.1A	8.4BC
I. Dicofol (139)	11.6.	D	4.0D	32.0AC	0.5AB	0.6	0.3AC	0.8AB	1.3B	8.3B	33.0C
J. Dicofol (139) + Flucythrinate (10)	11.6. 10.7.	A	1.0AC	5.1AB	0.0A	1.0	0.0A	0.2A	0.0A	0.0A	2.6AB
K. Dicofol (139) + Flucythrinate (10)	11.6. 10.7.	—	1.7AD	29.0AC	0.1AB	0.0	0.1AB	0.4A	0.0A	0.2A	3.3AC

Means with different letters in columns denote significant differences ($P = 0.05$) according to Duncan's multiple range test on log-transformed data. Columns without letters indicate a nonsignificant F-test ($P = 0.05$).

[1] Letters refer to table 4 (— sign indicates untreated trees in 1983).

Table 6. Results of the field experiment in 1986 (Häme Res. Sta., Pälkäne). 0.5 l/tree was sprayed on 17.7. with a knapsack mistsprayer, 10 trees/treatment. ERM and phytoseiid numbers were counted from 5 leaves/tree and numbers of winter eggs from 5 twigs/tree. T-test was calculated separately for the two areas with different initial ERM densities.

Treatment and rate (g a.i./100 l)	No. of mites/leaf (mobile and eggs)						Winter eggs/10 cm
	17.7.			14.8.			
	M	E	Phyt.	M	E	Phyt.	
Area 1.							
A. Flubenzimine (250)	6.8	36.3	1.8	3.2	16.7	0.1	3.7
B. No treatments	7.6	25.3	0.3	36.0	93.8	1.9	142.5
T-test, P =	N.S.	0.036	0.000	0.000	0.000	0.000	0.000
Area 2.							
A. Flubenzimine (250)	1.4	8.4	0.2	0.0	0.4	0.0	3.7
B. No treatments	3.4	17.1	0.1	10.8	51.6	0.9	56.0
T-test, P =	0.000	0.003	N.S.	0.000	0.000	0.013	0.000

Table 7. Results of the field experiment in 1986 (commercial orchard, Bromarv). Blocks of about 1 ha were sprayed with tractor driven mistsprayer (Hardi), 400 l/ha. Numbers of mites (mobile and eggs) were counted from 5 leaves/tree, and winter eggs from 5 twigs/tree.

Treatment and rate (g a.i./100 l)	Date	Mites/leaf 4.7.		Winter-eggs/10 cm
		M	E	
A. Flubenzimine (150)	30.5.	8.7	4.1	336
B. Chinomethionate (55)	23.5.,9.6.,18.6.	12.1	5.0	478
C. Chinomethionate (55)	18.6.	2.0	3.1	56

Other treatments (all blocks): dimethoate (160 g a.i./100 l) 23.5. and 3.7., dithianon (225) 14.5., 23.5., 9.6., 23.6., 3.7. and 13.7. (for scab control).

Table 8. Results of the field experiment in 1988 (Agricultural Research Centre, Jokioinen). Fully randomized apple trees (6 per treatment) were sprayed according to apple scab spraying program, with a compression sprayer, on 23.5., 3.6. and 15.6., and with a knapsack mistsprayer on 21.6. and 27.6. Samples of 20 leaves/tree were checked and number of mites were counted or estimated (Eriophyidae).

Treatment and rate (g a.i./100 l)	Number of mites/10 leaf (mobile and eggs)			
	ERM		Eriophyidae	Phytoseiidae
	M	E	M	M
A. Flubenzimine (3 × 25, 2 × 85)	0.0	0.0	3.0A	0.03A
B. Clofentezine (3 × 25, 2 × 85)[1]	0.67	0.58	3.0A	3.5A
C. Hexythiazox (3 × 5, 2 × 17)[1]	0.17	0.33	83.0B	2.33A
D. Bitertanol (3 × 12.5, 2 × 42.5)[2]	1.25	0.75	95.0B	19.5B
E. No treatments	1.17	0.75	67.0B	17.8B

Means with different letters in columns denote significant differences (P = 0.05) according to Duncan's multiple range test on log-transformed data. Columns without letters indicate a nonsignificant F-test.

[1] New products, not analysed in this article (cf. TUOVINEN 1990).

[2] Fungicide used against the apple scab.

DISCUSSION

The growth of ERM populations strongly depends on temperature. In Finland, ERM has usually 3, sometimes 4 yearly generations (LISTO et al. 1939). During these experiments, the total effective temperature sums varied between 1030 dd in 1987 to 1520 dd in 1983. During the tests, manyfold differences in reproduction capacity of ERM due to temperature variations between years could be expected. The results of the experiments from various years are not directly comparable — on the other hand, one or two years' experiments may lead to erroneous conclusions as to the effect of acaricides on ERM.

Because flubenzimine is most effective against immature stages of ERM (ZOEBELEIN et al. 1980, KOLBE 1981), the timing of sprays is thought to be important especially in early season sprays. In an ideal situation, all winter eggs should have been hatched, but only larval or nymphal stages should be present at the moment when spraying takes place. In practice, the hatching of winter eggs lasts, in Finnish conditions, 2—3 weeks depending on the temperature and the position of eggs on branches (LISTO 1939). According to LEES (1953) the threshold temperature for the embryonic post-diapause development of ERM winter egg is +7 °C. In laboratory experiments (not published), 50 % of ERM winter eggs hatched when 200 dd above +5 °C was reached. For practical purposes, the commonly used plant growth threshold +5 °C can be referred to and may approach the correct value in Finland (cf. LISTO et al. 1939).

In field tests, temperature sums, recorded in the nearest meteorological stations, varied from 130 to 377 dd in early season sprays. In most tests, winter eggs had begun to hatch but no summer eggs had been laid before the spray (exception: Pälkäne 1984, 377 dd, summer eggs were present in abundance). Good results were obtained with flubenzimine in all cases, except in Bromarv 1986 (180 dd). This orchard is situated on a cape surrounded by the sea — in spring the prevailing temperature is much colder than the inland temperature, where the temperatures were recorded. In this case, mites were not counted before spraying, but at least part of the winter eggs had already hatched.

The later sprays in June and July usually resulted in low numbers of mobile ERM. The results show that flubenzimine has a long lasting residual effect so that high numbers of summer eggs present on leaves during spraying or laid later by surviving adults do not lead to a high number of mobile ERM later in the season.

As a summary of all experiments, it is presented that one spray with flubenzimine (150—250 g. a.i./100 l water, 300 l/ha) can keep ERM under the economic threshold level if sprayed when the sum of the effective temperature above +5 °C reaches 200 dd in spring. If temperature recordings are made within the orchard, which is recommended, the sum of 200—250 dd will be accurate enough for timing the spray because of the climatically more favourable situation in the orchards. However, one spring application is not enough to diminish winter egg numbers the next autumn if the weather is suitable for egg laying. High numbers of overwintering ERM do not always lead to high numbers of mites in the summer — rainy weather in the spring may considerably diminish ERM numbers (PUTMAN 1970). Besides, ERM winter mortality in Finland may often be quite high, 30—60 % (LISTO et al. 1939).

One spray with flubenzimine (150 g a.i./100 l water, 0.45 kg/ha) greatly reduced the number of predatory phytoseiid mites. This reduction cannot be explained by a reduction of prey, because the dominating phytoseiid species concerned *Euseius finlandicus* (Oud.), is known to also use other food sources than phytophagous mites, e.g. pollen, and has been found to be quite common on apple leaves also without phytophagous mites as prey (KROPCZYNSKA and TUOVINEN 1988). Another common species was *Phytoseius macropilis* (Banks). The same effect was obtained also by sprays with lower concentrations of flubenzimine (25—85 g a.i./100 l water) when sprayed 5 times per season. VIGL et al. (1985) also noted the harmful effect of flubenzimine to predatory mites. However, COMAI (1985) sprayed flubenzimine in an even lower concentration (10 g a.i./100 l water) and concluded that 6 sprays during the season did not affect coccinellids or a phytoseiid mite *Typhlodromus* spp.

Flubenzimine had no clear harmful effect on predatory insects in orchards. BONESS (1983) stated that anthocorid bugs were not badly damaged by flubenzimine in either larval or adult stages. This was found also in the present study. If no insecticidal sprays are performed, anthocorid bugs belong to the most important insect enemies of ERM in Finland (LISTO et al. 1939). However, flubenzimine diminished spider numbers, which occur quite commonly in apple trees not treated with harmful insecticides.

Because of its harmful effects on predatory mites, at least *Euseius finlandicus* and *Phytoseius macropilis,* flubenzimine cannot be recommended for regular use in integrated control programs in apple orchards. However, because of the lesser effects on predatory insects e.g. anthocorid bugs, the use of flubenzimine may be reasonable also in IPM orchards in situations where quick reduction of ERM is necessary and phytoseiids are scarce.

None of the reference products was as effective as flubenzimine. The effect of chinomethionate was usually satisfactory and chinomethionate controlled even high populations of ERM, at least when applied twice. However, on many occasions, growers have reported an unsufficient effect by this acaricide. Dicofol was tested in only one experiment. The effect of a single spray was satisfactory, although not as good as that of flubenzimine. The effect of fenbutatinoxide was comparable to that of chinomethionate and dicofol. This acaricide is not approved for ERM control in Finland.

Oxydemetonmethyl had a good knock-down effect on ERM when sprayed after winter egg hatching. However, later in the season, an outbreak of ERM may occur, and a spray with an acaricide is needed. Because of the risk of residues, oxydemetonmethyl is not recommended for use in June or later. Although deltamethrin had an immediate effect on ERM, later in the season it caused an outbreak of ERM. This effect has been observed in many studies (e.g. MANTINGER and DIPOLI 1982, ARIAS and NIETO 1983). Because of these findings the use of deltamethrin and other pyrethroid insecticides are not recommended for summer sprays in apple orchards.

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SELOSTUS

Hedelmäpuupunkin kemiallinen torjunta. I. Flubentsimiini.

TUOMO TUOVINEN

Maatalouden tutkimuskeskus

Hedelmäpuupunkin torjunta tuottaa käytännön omenaviljelyksillä usein enemmän ongelmia kuin muiden tuhoeläinten torjunta. Biologisten tai muuten punkkien luontaisille vihollisille haitattomien menetelmien soveltaminen hyönteisten torjunnassa helpottaisi hedelmäpuupunkin luontaista torjuntaa. Ennen kuin tällaiset menetelmät ovat käytettävissä, on punkkien torjunta akarisideilla tarpeen.

Tällä hetkellä Suomessa on käytettävissä vain kaksi akarisidia: dikofoli ja kinometionaatti. Lisäksi oksidemetonimetyyli tehoaa myös punkkeihin. Akarisidien teho käytännössä on osoittautunut vaihtelevaksi, mikä saattaa osittain johtua mahdollisesta resistenssistä runsaasti käytettyjä valmisteita vastaan. Uusia tehokkaita ja luontaisille vihollisille mahdollisimman haitattomia akarisideja tarvitaan.

Flubentsimiini vaikuttaa kehrääjäpunkkien muodonvaihdokseen estämällä kitiinisynteesiä. Valmiste tehoaa punkin nuoruusasteisiin, mutta ei tapa aikuisia punkkeja. Suoritetuissa torjuntakokeissa valmiste osoittautui tehokkaaksi ja yksi ruiskutuskerta (0.45—0.75 kg tehoainetta/ha, sumuruisku) ajoitettuna punkkien talvimunien kuoriutumisen loppuvaiheeseen, riitti pitämään punkkien määrän torjunnan kynnysarvojen alapuolella. Tehoisana lämpösummana (yli +5 °C) mitaten sopiva käsittelyajankohta on kun 200—250 astetta on saavutettu. Punkkien lisääntymiselle edullisissa oloissa, kuivan ja lämpimän sään vallitessa, toinen ruiskutus voi olla tarpeen heinäkuussa. Tällöin talvehtimaan jäävä punkkikanta on pieni ja ruiskutuksen vaikutus tuntuu vielä seuraavanakin vuonna. Maatalouden tutkimuskeskuksen tuhoeläinosasto on antanut Maatilahallitukselle myönteisen lausunnon flubentsimiinin käyttökelpoisuudesta ja tehokkuudesta vuonna 1984.

Jatkotutkimuksissa todettiin flubentsimiinin tehoavan hyvin myös äkämäpunkkeihin, omenalla kellastajapunkkiin. Hedelmäpuupunkin luontaisiin vihollisiin, petopunkkeihin, valmiste vaikutti haitallisesti. Sen sijaan petoluteiden esiintymiseen valmiste vaikutti vain vähän. Flubentsimiinia voidaan käyttää myös integroitua torjuntaa soveltavissa tarhoissa silloin, kun petopunkkeja ei luontaisesti esiinny.

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Seria ANIMALIA NOCENTIA N. 143 — Sarja TUHOELÄIMET n:o 143

PREDICTING OUTBREAKS OF *RHOPALOSIPHUM PADI* IN FINLAND

SIRPA KURPPA

KURPPA, S. 1989. **Predicting outbreaks of *Rhopalosiphum padi* in Finland.** Ann. Agric. Fenn. 28: 333—347. (Agric. Res. Centre, Inst. Pl. Protect., SF-31600 Jokioinen.)

Population levels of *Rhopalosiphum padi* (L.) were studied from 1981—1988. This included years of extreme abundances of the aphid. Winter egg counts formed a reliable basis for an aphid forecast, and years of very low or high risk of damages could be identified directly. Monitoring of emigrants and their arrival time on cereals, which depends on local growing conditions, was necessary for final decisions about the need and timing of control. A feasible correlation between numbers of winter eggs and level of infestation in the field during the following summer was found.

Index words: *Rhopalosiphum padi,* forecast, predict, winter egg, emigrant, migrant, migration.

INTRODUCTION

In Finland, the bird cherry-oat aphid (*Rhopalosiphum padi* (L.)) has occurred abundantly and injuriously on spring cereals about twice a decade (RAATIKAINEN and TINNILÄ 1961, RAUTAPÄÄ 1976 and MARKKULA 1981, 1986). During the years between such outbreaks, the need for control has either been local or totally unnecessary. In addition to being the cause of direct injuries, *R. padi* has also been an important viral vector on cereals (BREMER 1965) and on potato (KURPPA and RAJALA 1986).

An *R. padi* forecast has been found necessary to provide information for advisory services, and has therefore been under development since the beginning of the 1980s. The present forecasting method which has been taken into preliminary use is based on monitoring the overwintering population (LEATHER and LEHTI 1981, LEATHER 1983), migrations (WIKTELIUS 1981) and on the estimation of wingless aphid generation on cereals. This report reviews the preliminary use of the above forecasting method and presents an evaluation of its applicability for predicting the *R. padi* outbreak 1988.

MATERIAL AND METHODS

Overwintering and migrations of *R. padi* populations were monitored annually since 1981. Winter egg counts from the primary host, the bird cherry tree (*Prunus padus*), were performed according to LEATHER (1983) in 29—33 localities with five trees from each. The trees were mostly the same every year. Egg hatch and early development of *R. padi* populations on trees was monitored in Jokioinen, and at 13 of the Research Stations belonging to the Agricultural Research Centre or affiliated with it (later on referred to as the Research Stations).

From 1984 to 1986, the numbers of winged *R. padi* were monitored at the Research Stations employing yellow water trays. Trapping was carried out from the beginning of June to the end of August. Trays were set on a green background, either on cereal or ley. The trays are described in KURPPA and RAJALA (1986). Aphids were removed twice a week for counting and identification. This method was rejected in 1987, and instead, during 1987 and 1988, *R. padi* populations in fields were monitored by counting the wingless aphids on cereal plants. Aphids were counted from a 100 plants chosen randomly from the field. Plants were lifted from the soil to enable aphid observance on the base of a plant. When more than 50 % of plants were infested, aphids were counted on 50 plants only.

Migrating aphids were sampled by a modified Rothamstedt suction trap fixed on the flat roof of the department building in Jokioinen, at a height of 12 meters as described by TAYLOR and PALMER (1972). The suction trap was operated from the beginning of May to the end of October (when the daytime temperature was consistently above zero).

Barley yellow dwarf-virus (BYDV) was identified from *R. padi* early in the season of 1988 in order to asses the risk of viral transmission due to the migration of foreign aphids. Winged *R. padi* were collected from fields during the 24th to 28th of May, immediately after the aphids had appeared. A group comprised of 5 to 10 aphids from each site was removed with a brush directly into Eppendorf tubes containing a 50 µl saline solution. Serological identification of BYDV in viruliferous aphids was performed within 2 days of sampling. Two Swedish antisera (27/77 and 39/79, EWEIDA and OXEFELT 1985) and a commercially available antiserum (BYDV »F», BIOREPA, Switzerland) were made available for this purpose. The samples for viral detection by immunosorbent election microscopy (ISEM) (ROBERTS and HARRISON 1979) were prepared by crushing the aphids with a glass rod in saline. After a 3 min low speed centrifugation, the clear supernatant solutions were poured onto antibody-coated grids and the method continued according to ROBERTS and HARRISON (1979).

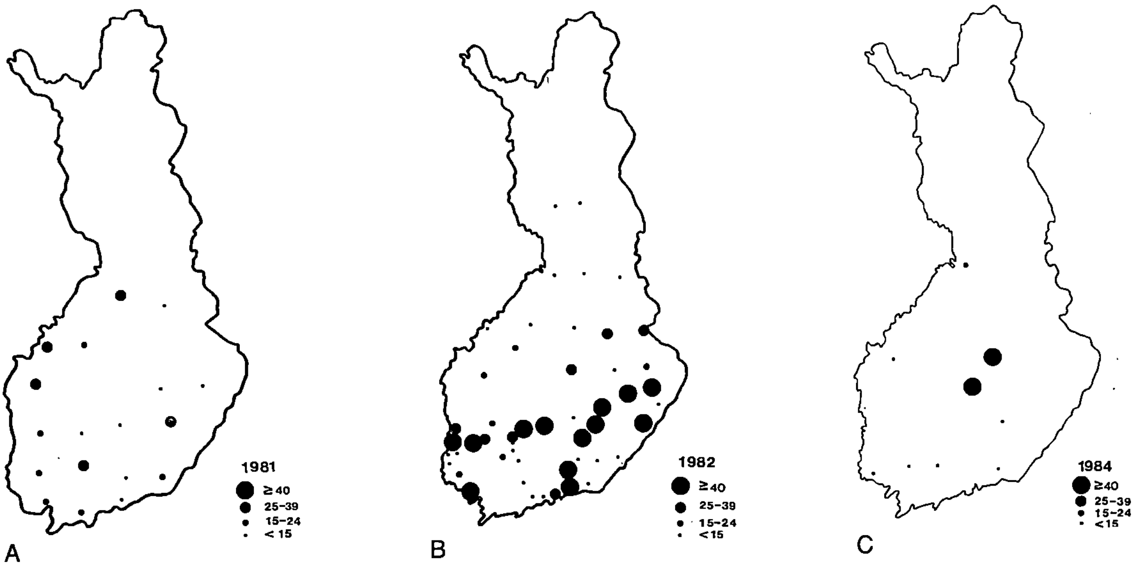
The *R. padi* counts from field experiments performed by the Research Stations, and approximated yield losses due to aphid injuries were compared with the local abundance of the *R. padi* overwintering population.

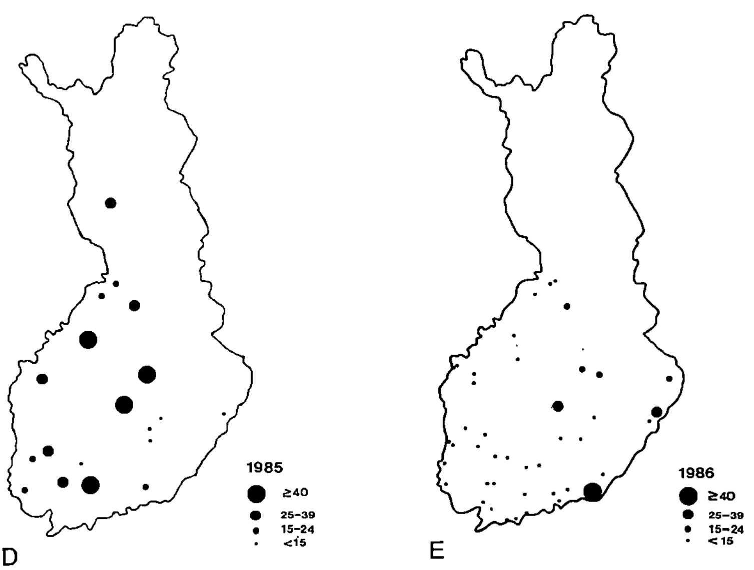
RESULTS

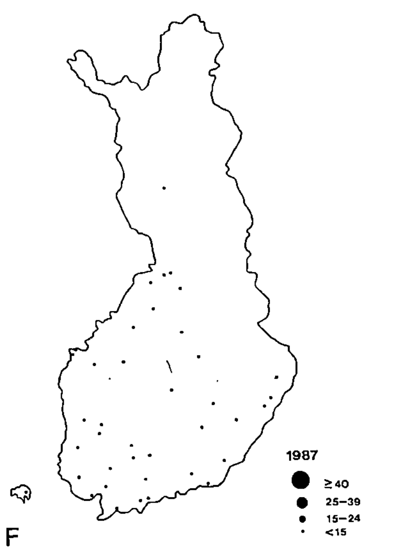
Overwintering population during the 1980s

The number of *R. padi* winter eggs counted from the bird cherry tree peaked during the winter of 1987—88. Egg number was found to be in the highest category, presented by LEATHER (1983), nearly throughout the country (Fig. 1). In many cases, even the cracks of branches were full of eggs and eggs were found on the berries of bird cherry trees (Fig. 7a). During the other years, eggs were layed almost exclusively on micro branches and buds.

The maximum mean number of eggs was as high as 610/100 buds (dead eggs due to an expected mortality of 5 % per week excluded) counted in Jämsä, located in central Finland (Fig. 1), and even the total mean of all samples was 204 eggs/100 buds. The lowest number of winter eggs counted, 35 eggs/100 buds, was reported by the Central Ostrobothnia (To-







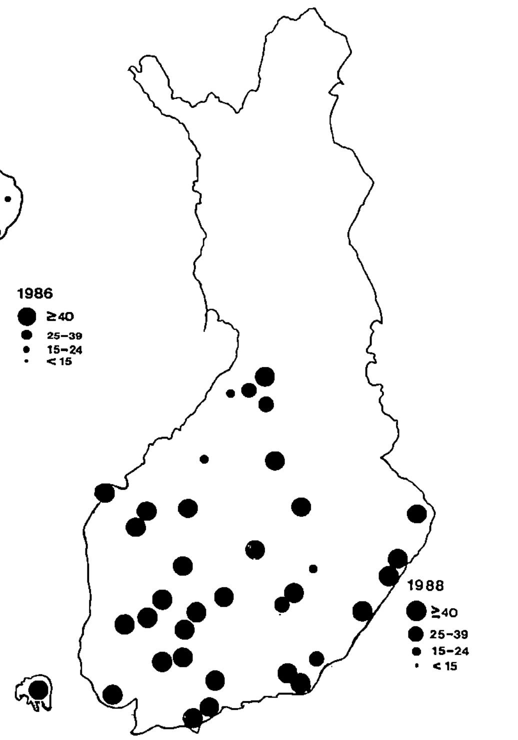


Fig. 1. *R. padi* winter eggs on bird cherry tree buds during 1981—1988. Scales show number of winter eggs per 100 buds of bird cherry tree, according to LEATHER (1983).

holampi) Research Station (Fig. 1), in an area where aphids had been destroyed in the previous autumn during preparation of cereals for silage. However this harvest was an exceptional one and had been performed due to the extremely late season.

Winter egg mortality has been described earlier (KURPPA 1986) based on data from the year 1985. Mortality was found to be slightly higher in the northwestern coastal area than elsewhere. Eggs hatched normally in the first days of May in southern Finland, and up to one week later further north.

Relationship between overwintering population and populations on fields during the previous year

The rise in the overwintering *R. padi* population was preceded by a late increase of the field populations during the previous autumn, for example during 1984—1985 and 1987—1988. This was very obvious from the number of alate exules caught in yellow water trays as well as by the suction trap method (Figs. 2, 3, 4).

During August 1987 the increase in *R. padi* populations was exceptionally intense and late

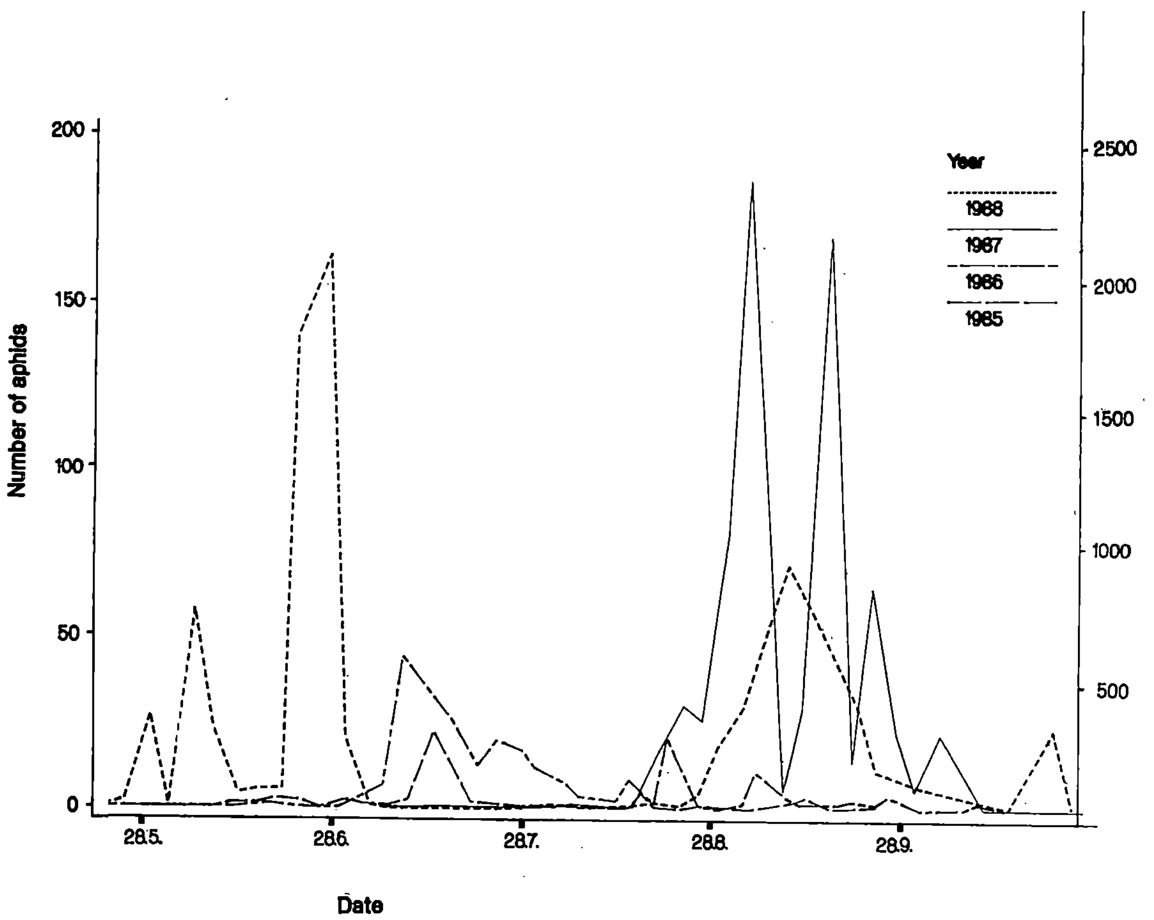


Fig. 2. Number of winged *R. padi* in the catches of a suction trap fixed at the height of 12 m at Jokioinen. The left scale shows the years 1985, 1986 and 1988, and the right scale that for 1987.

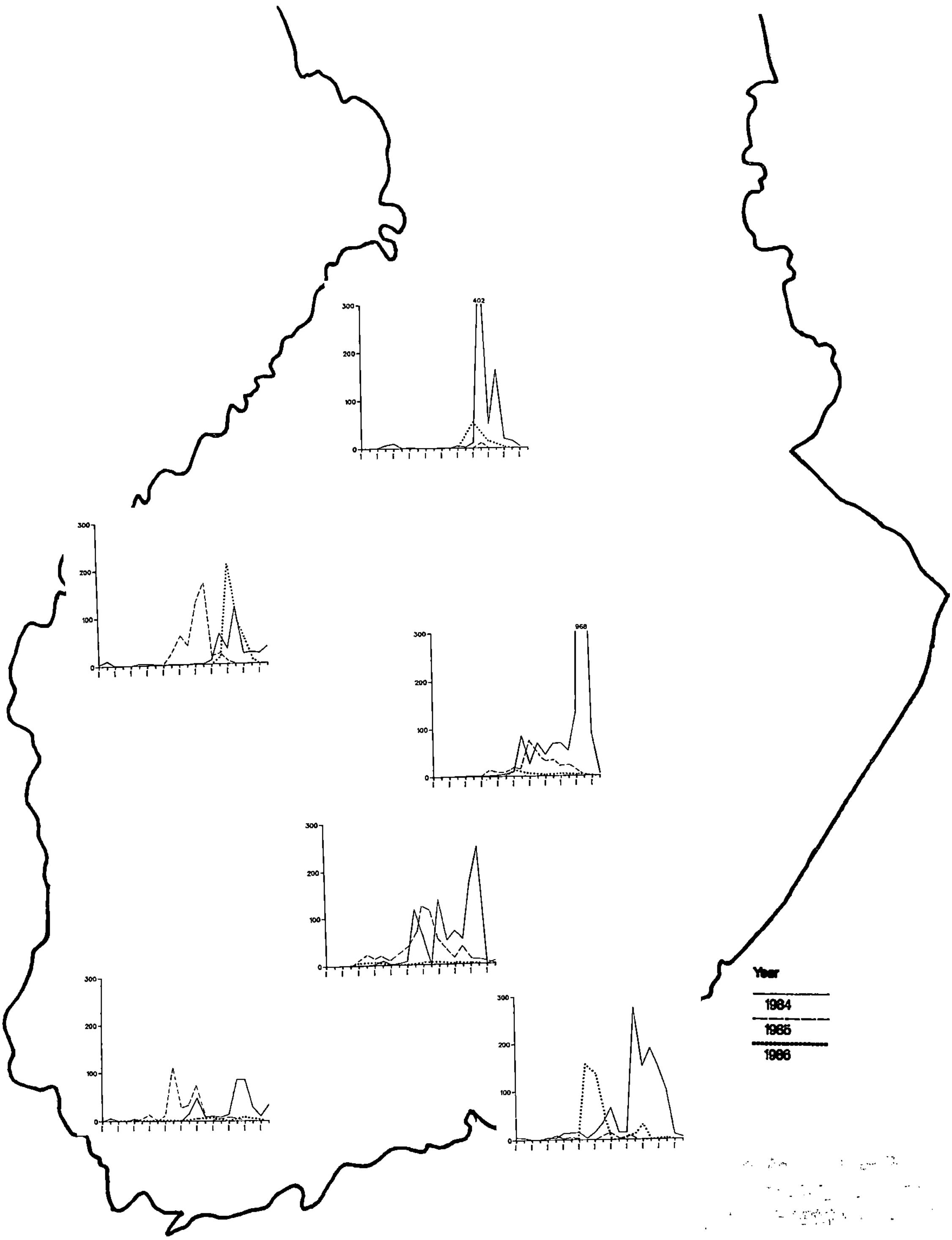


Fig. 3. Number of winged *R. padi* in yellow water trays, in different areas of the country during 1984—1986. Time of monitoring from the first of June to the 15th of August. Time in weeks is indicated by the major scale, dates of counts indicated by the minor scale.

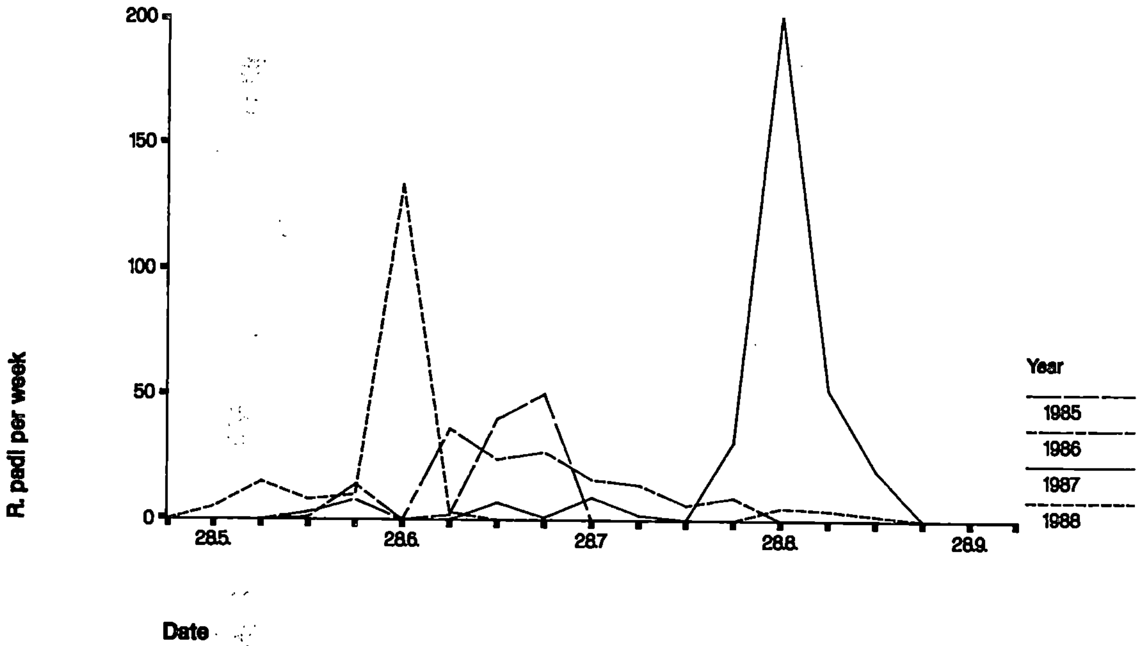


Fig. 4. Numbers of winged *R. padi* in yellow water trays at Jokioinen, during 1985—1988.

(Figs. 2, 4, 5) Late multiplication on cereals was made possible by a prolonged vegetative growth, thus providing suitable hosts for aphids to feed on. The behaviour of the populations was similar at Research Stations all over the country, except for the northwestern areas were cereals are harvested for silage.

Relationship between abundance of the overwintering population and number of emigrants

High overwintering populations were followed by high catches of emigrants in the yellow water trays and in the suction trap during the following spring (Figs. 2—4). Between the outbreaks in 1985—1987 populations were, however, so low that only a few aphids could be obtained by both trapping methods. The first aphids of the spring migration (emigrants) were observed a couple of days earlier when using the suction trap method than by the yellow water trays.

The spring migration, in 1988 began in the first week of June (Fig. 2) and the peaked within a few days. In Jokioinen, the spring migration from bird cherry trees formed a second peak for spring populations, the first being formed by aphids migrating from a long distance. Thus, the arrival of the first aphid emigrants was 10—14 days earlier compared to that of years with lower aphid abundance.

Early appearance of *R. padi* due to long distance migration

The significant effect of long distance migration became evident in 1988 and was also obvious in the South-East of Finland during 1986 (Fig. 2). On the 24th of May, winged *R. padi* was detected in abundance on cereal fields in southern and southeastern coastal areas, and a few

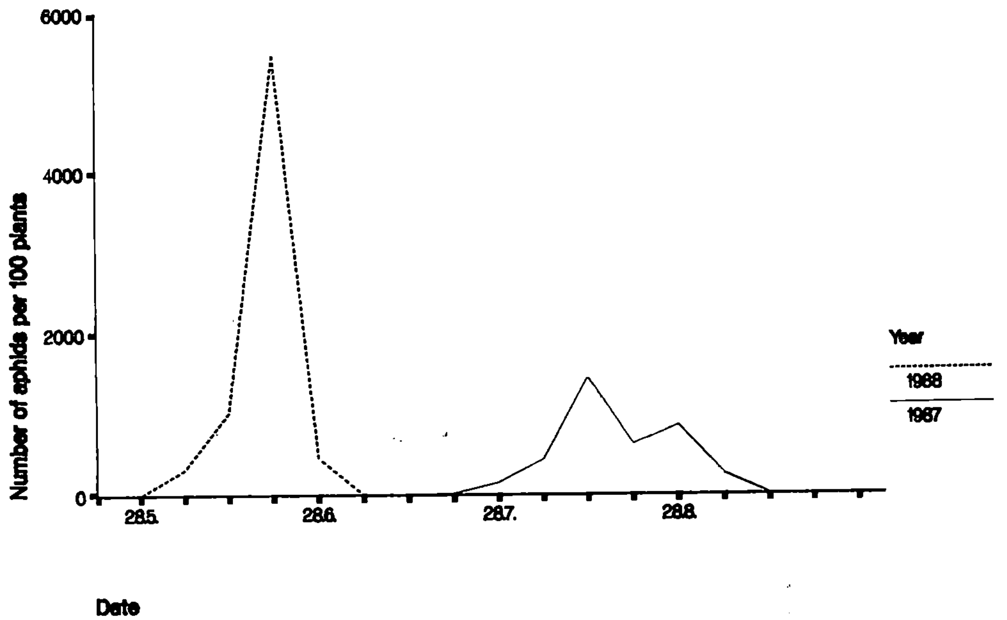


Fig. 5. Number of wingless *R. padi* on oat plants, at Jokioinen during the 1987 and 1988 growing seasons.

aphids were seen even as far as 300 km from the coast to the north (Fig. 6a). Coincidently cereal seedlings had just emerged, wheat being mainly the earliest. At this time the major part of the overwintering populations were destined to remain in bird cherry trees as wingless nymphs.

Winged *R. padi* appeared at a time when the prevailing air flow at the height of 500 m to 2000 m was directed to Finland from the South and South-East. According to air pressure conditions and air flow trajectories, it could be concluded that particles of the size and weight of aphids most likely came from the Belorussia (Fig. 6b) (Finnish Meteorological Institute, Air Quality Department, Official Report, in Finnish).

Many of the aphid samples collected from newly arrived, winged field populations were shown (by ISEM) to be viruliferous by barley yellow dwarf virus (Figs. 6a, 7b). Especially due to this observation a recommendation of aphid control was immediately issued to farmers.

Infestation of cereals by *R. padi* during the outbreak

R. padi infestation on cereals was initiated from the 22nd to the 25th of May in the area affected by the long distance migration. At the beginning of June infestation had already reached 50 %, and by around the middle of June 100 % of cereal plants were infested. Aphid numbers culminated as early as from the 24th to the 26th of June (Fig. 5, Table 1), being slightly earlier in dry areas and later in the areas of higher precipitation. Maximum mean numbers of 40 to 50 aphids per plant were common.

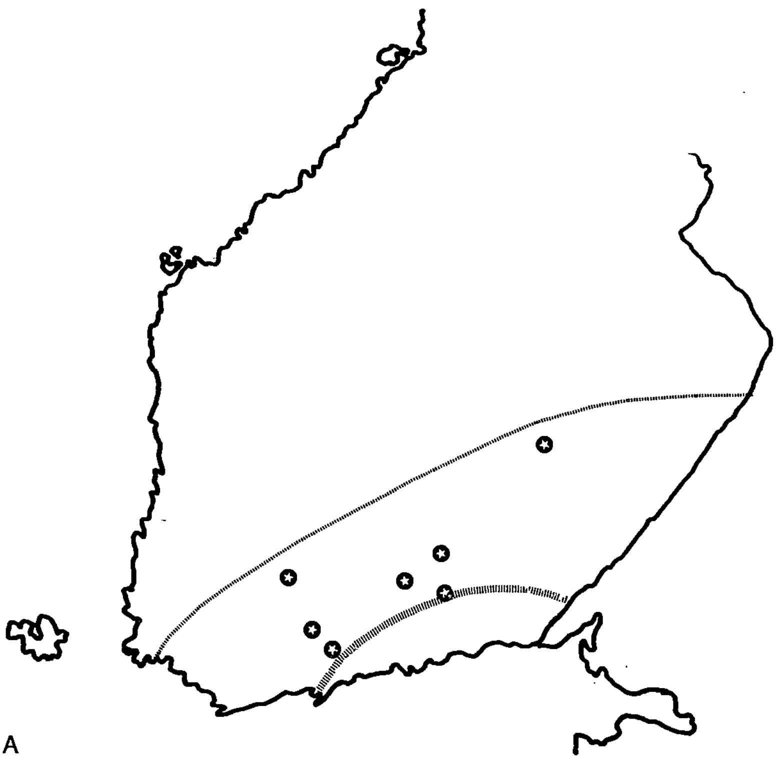
Beyond the reach of the southern invaders, winged *R. padi* arrived on cereals from local bird cherry trees via the normal spring migration, at the beginning of June (Table 1, Mou-

Table 1. Abundance of *R. padi* in oat, at Mouhijärvi (number 6 in Fig. 1), Ylistaro (number 9) and Jokioinen (number 1) and in barley, at Vihti (southern Finland). (Barley was grown in Vihti only)

	Sowing date	Arrival of *R. padi* date	50 % of plants infested date	100 % of plants infested date	Peak date	Population size aphids/ plant
Mouhijärvi	18.5.	1.6.	3.6.	17.6.	25.6.	97
Ylistaro	16.5.	3.6.	13.6.	28.6.	30.6.	35
Jokioinen	16.5.	22.5.	2.6.	9.6.	23.6.	54
Vihti	17.5.	22.5.	6.6.	14.6.	22.6.	55

hijärvi and Ylistaro). In these southwestern and central areas aphid populations on early sown cereals peaked, however, same time as the southern populations. Population peak was slightly delayed further north.

After *R. padi* had left cereals a high, determinate peak for the winged aphid population was detected on potato. This occurred around the 5th of July. Maximum numbers were up to 25 specimens per potato leaf, in Jokioinen.



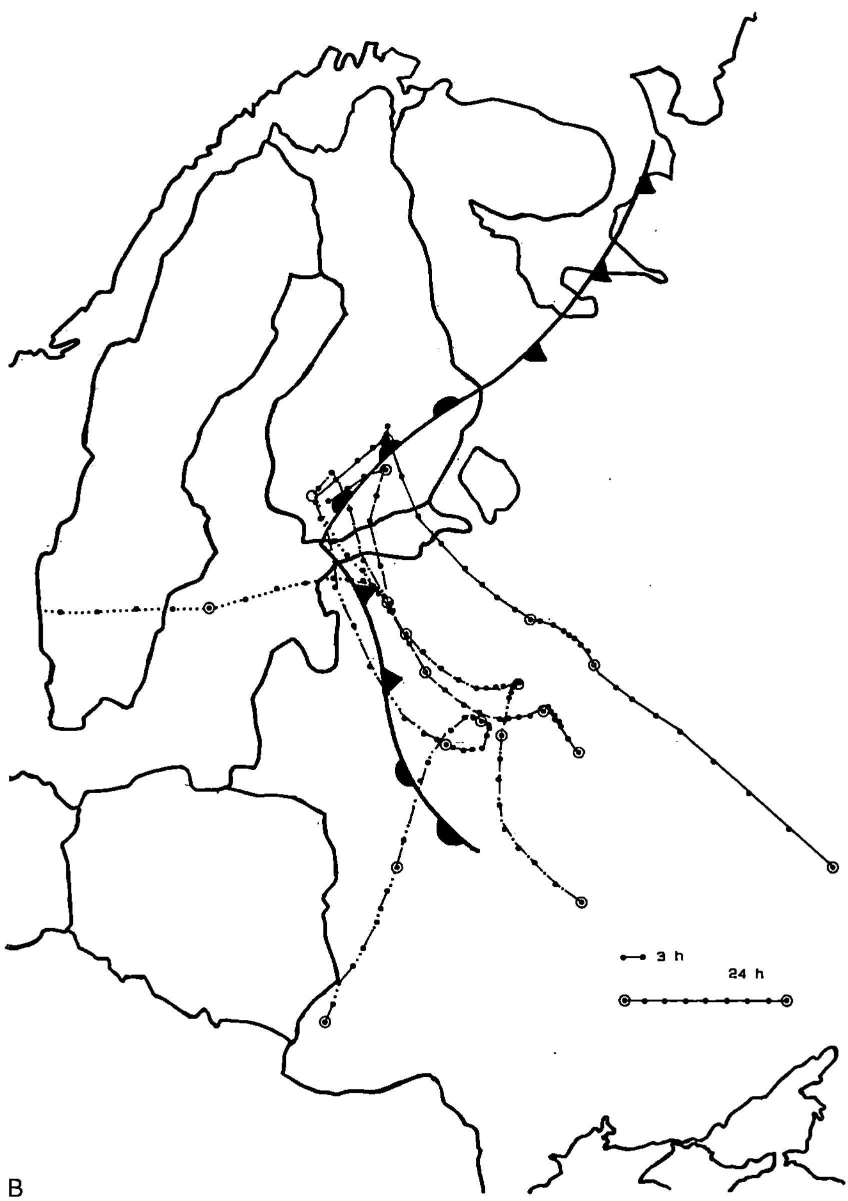
A

Fig. 6a. Dispersal of *R. padi* alates in the fields of southern Finland from the 25th to the 28th of May 1988; up to 100 aphids/m² were found from the south side of the broader line, up to 10 aphids/m² between the broader and thinner line and no aphids north of the thinner line. The original locations of BYDV-positive aphid samples are indicated by stars at the back background.
b. Warm and cold fronts, and trajectories describing air flow at the height of 1 km arrived in Finland during May 21st and 22nd. Timing of trajectories from left to right. (Redrawn from a report by the Finnish Meteorological Institute, Air Quality Department.)

During the outbreak, the rythm of development of the *R. padi* population was about two weeks ahead of normal. Thus outbreaking populations infested cereals at a very early and sensitive stage of development. Aphid populations were initiated a few days after seedling emergence and peaked at ear emergence.

Relationship between abundance of overwintering population and infestation of cereal plants

The number of winter eggs, between 0 and 60 eggs/100 buds, correlated with the peak number of apterous *R. padi* counted from cereal



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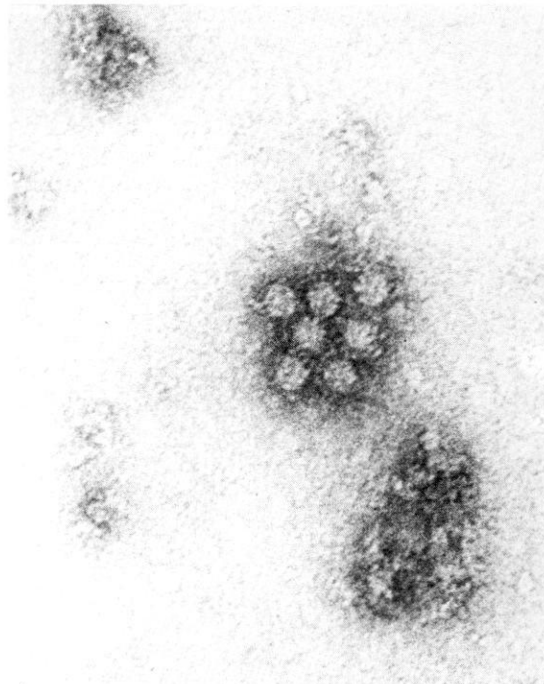

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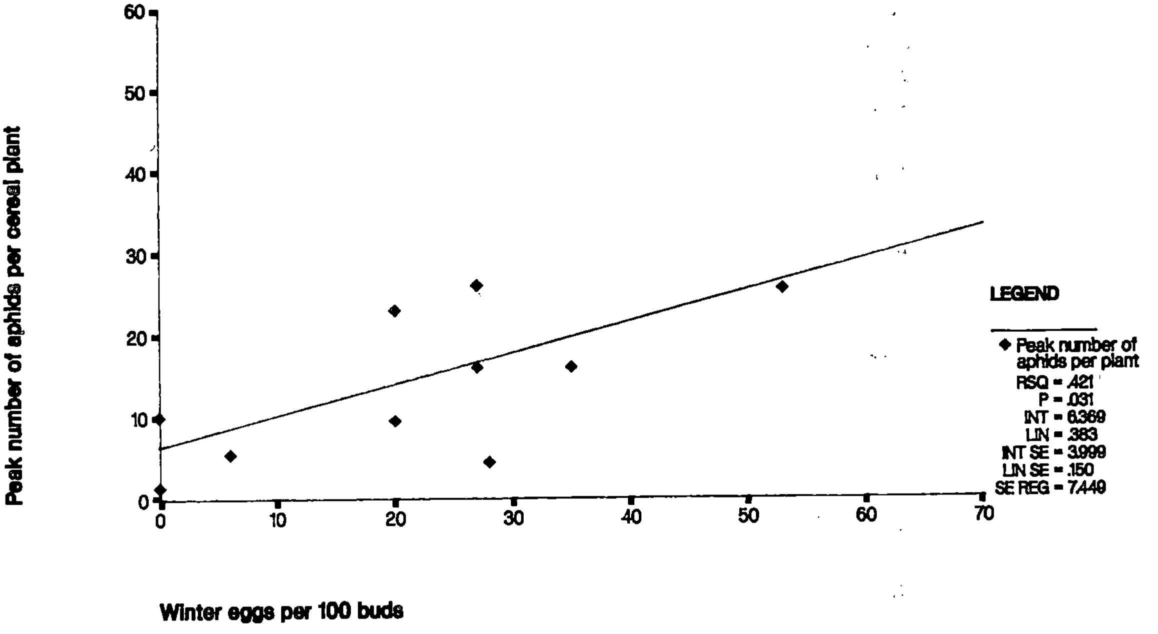
Fig. 7. a) Winter eggs of *R. padi* on cracks of branches in bird cherry tree. b) A micrograph of a group of BYDV particles detected by ISEM. Magnification 240 000. Photos by Aarne Kurppa.

plants (Fig. 8a). Also the number of winter eggs correlated with the yield loss due to aphids, as evaluated from the field experiments (Fig. 8b). The variations were, naturally, high between the numbers of 20 and 35 winter eggs/100 buds. High increases in the numbers of winter eggs meant, however, that the numbers of aphids on plants could not increase excessively. This was obvious in the results from 1988 (Table 1).

DISCUSSION

The *R. padi* outbreak was predictable based on the high abundance of immigrants from the previous year, the abundance of winter egg population on the primary host as well as on the abundance of emigrants. Counting the winter eggs was easy, economical and practical method for evaluating the overwintering population. Even during an outbreak year, only one months' work by one person was sufficient for estimating egg numbers, provided sampling was organised at each site by local staff and the number of samples remained within the scale of this study. During years between outbreaks this work could be accomplished in about two weeks. A great advantage is that egg counting causes none of the identification problems, that commonly occur when counting the material in yellow water trays and suction traps. The problem of variation between the egg numbers of different bird cherry trees (Leather 1986) must be recognised. The same trees were therefore sampled year after year in this study to eliminate such variation.

Monitoring the *R. padi* population through-



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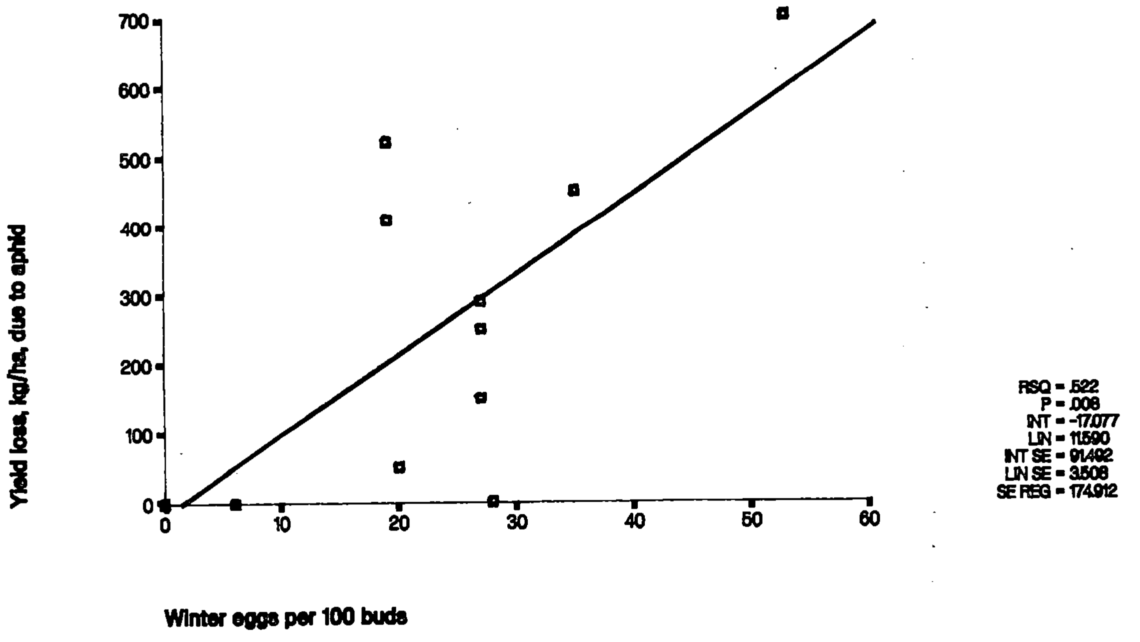

B

Fig. 8. Regressions between the abundance of *R. padi* winter egg population and a) peak numbers of aphids on cereal plants during the following summer, and b) experimental yield losses due to aphids.

out the spring (Fig. 8a) is necessary, however. Finnish weather might be hazardous, especially to emigrants. In 1982, high numbers of emigrants were most probably killed by frost and snow. The number of *R. padi* on cereal remained low all over the country (MARKKULA 1983) even though the overwintering population was found to be fairly abundant.

The observation of the timing of *R. padi* arrival on cereal plants (Fig. 8b) is necessary in order to evaluate population increase (RAUTAPÄÄ 1976), as well as estimate the possible yield loss due to aphids. The identification of emigrants caught by yellow water trays and suction traps requires a trained personel. If this scheme is not possible, then the start of infestation must be determined by counting the first apterae on cereal plants. Accurate observations of plant bases are needed, and therefore plants have to be lifted from soil. Counting has to be repeated to clarify the rate of increase of the aphid population (RAUTAPÄÄ 1976), if the population is not high enough as to automatically indicate control. Injuries have been shown to greatly depend on temporal variability in cereal plant quality due to cereal development stage (LEATHER and DIXON 1981, LEATHER 1981, LEATHER and LEHTI 1982). Early control has been found to be necessary and most economic when aphid infestation has been initiated at a very early stage of development (KURPPA 1989). Thus, for the final prediction of the economics of control information about aphid numbers must be combined with knowledge about the stage of crop development.

The importance of long distance migration, described by WIKTELIUS in Sweden (1981), was intensified by a coincidence with a high overwintered population. In order to eliminate the risk due to invading aphids, a couple of suction traps should be situated on the southern and southwestern coastal area. Moreover, cooperation should also be started with meteorologists. Using radar equipments insect colonies could readily be observed from approaching air masses (PUHAKKA et al. 1986).

The abundance of alate exules (summer migrants), was easily detected by yellow water trays and suction traps. Yellow water trays would be practical for observing the local variations of aphid populations on each field. However, problems will arise regarding aphid identification.

The numbers of apterae exules, and accordingly the numbers of alate exules correlated well with the abundance of overwintering population. Variations were, naturally, high in the case of the medium high egg numbers, in which connection growing conditions were assumed to have great regulative effect (LEATHER 1983). However, the correlation shows that if the peak of 20 aphids/cereal plant is used as the economic threshold of control (RAUTAPÄÄ & UOTI 1976), the lower and the upper limits, 15 and 40 winter eggs/100 buds, of the scale are applicable. By employing these limits an acceptable yield response was also obtained. The division of the numbers between the above limits into two scales, 15—25 and 26—39, was found to be needless and a very difficult in practice.

Acknowledgements — I am grateful to Dr. Aarne Kurppa for identifying BYDV from the aphids and to all of those who took part in sampling of the twigs of bird cherry trees for winter egg counting. The catching of aphids by yellow water trays and the counting of aphids on cereals were performed by the staff of the Research Stations. I would also like to thank my technicians for their patient work in identifying the aphids. An early draft of this paper benefitted considerably from the comments of Dr. Simon Leather, Prof. Martti Markkula and Katri Tiittanen, the senior scientist of our institute.

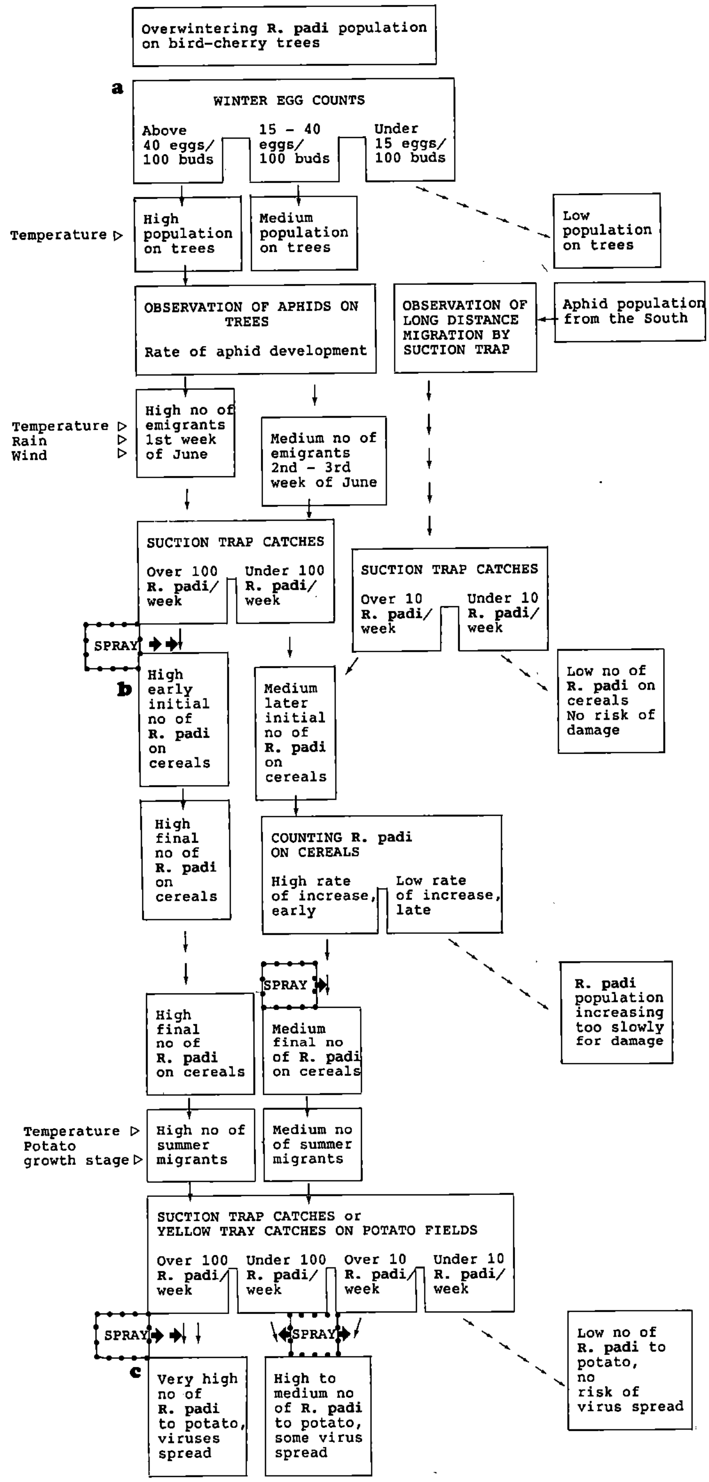

Fig. 9. A scheme for *R. padi* monitoring a) in spring on bird cherry trees, b) in May — June on cereal plants and c) in June — July on potato.

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SELOSTUS

Tuomikirvatuhojen ennustettavuus Suomessa

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Maatalouden tutkimuskeskus

Tuomikirvaennustetta on kehitelty ja menetelmän käyttökelpoisuutta seurattu koko 1980-luvun ajan. Tähän aikaan mahtuu sekä hyvin vähäisiä että hyvin runsaita kirvaesiintymiä.

Talvehtimiskannan laskenta muodosti perustan kirvaennusteelle ja sen avulla jo pystyttiin osoittamaan ne vuodet, joina kirvatuhoriski olisi käytännössä merkityksetön tai ehdottomasti torjuntatoimia vaativa.

Tuomikirvan kevätpopulaation seuranta osoittautui talvimunien laskennan ohella välttämättömäksi. Tällä tavoin havaittaisiin epäedullisten sääolojen vaikutus, erityisesti kirvojen kevätlennon aikana. Myös kirvojen saapumisaika viljakasvustoon oli määritettävä joko lentäviä kirvoja tai kasvuston ensimmäisiä siivettömiä kirvoja havainnoimalla. Tätä tietoa tarvittiin torjuntatarpeen ja torjunta-ajankohdan määrityksessä. Niinä vuosina, jolloin talvimunien määrät vaihtelivat keskivälillä 15—40 munaa/100 silmua, kasvuoloilla oli ratkaiseva merkitys ja kasvustohavaintojen merkitys korostui.

Ennusteen perustana käytetyt kirvojen talvimunien ylin ja alin raja-arvo, 40 elävää munaa/100 silmua ja 15 elävää munaa/100 silmua, osoittautuivat vastaavien viljoista laskettujen kirvamäärien ja satotulosten perusteella sopivasti asetetuiksi. Rajojen väliin jäävien kirvamäärien jakaminen kahteen luokkaan näytti tarpeettomalta ja mahdottomalta soveltaa käytäntöön.

Kaukolevinnän merkitys oli suurin rannikkoalueilla, mutta ulottui lievänä Sisä-Suomeen saakka. Kaukolevinnän merkitys kärjistyi, kun kirvat levittivät viljan virooseja ja myös kotimainen kirvakanta oli runsas. Kaukolevinnän mahdollisimman aikainen havainnointi olisi mahdollista meteorologien käyttämän Doppler-säätutkan avulla. Tämä edellyttää myös parin imupyydyksen sijoittamista eteläiselle ja lounaiselle rannikkoalueelle.

ANNALES AGRICULTURAE FENNIAE, VOL. 28: 349—370 (1989)

Seria ANIMALIA NOCENTIA N. 143 — Sarja TUHOELÄIMET n:o 143

DAMAGE AND CONTROL OF *RHOPALOSIPHUM PADI* IN FINLAND DURING THE OUTBREAK OF 1988

SIRPA KURPPA

KURPPA, S. 1989. **Damage and control of *Rhopalosiphum padi* in Finland during the outbreak of 1988.** Ann. Agric. Fenn. 28: 349—370. (Agric. Res. Centre, Inst. Pl. Protect., SF-31600 Jokioinen, Finland.)

Yield losses and control measures were assessed during the outbreak of *Rhopalosiphum padi,* in Finland, in 1988. Information was obtained via a questionnaire from 3667 fields. For the assessments the material was divided according to the 7 geographical areas of the country defined to represent differences between aphid infestation and growing conditions. The peak number of aphids varied between 20 and 60 per plant. Direct damage caused by *R. padi* was combined with indirect losses due to the aphid-transmitted barley yellow dwarf virus (BYDV). Yield was decreased by the mean of 153 kg/ha per one step in a scale (1—10) of the strength of BYDV symptoms. Yield loss due to aphids was affected the most when *R. padi* arrival to the crop coincided with seedling emergence. As aphid arrival was delayed, yield loss decreased by 41 kg/ha per day of the delay. After infestation had been initiated yield decreased by a mean of 30 kg/ha per day for the duration of infestation.

Over 80 % of the fields were sprayed, dimethoate being the most commonly used compound, and the mean response in yields varied from 300 kg/ha (wheat) to 600 kg/ha (oat). The efficacy of the control was lower in the southern areas and correlated with strength of viral symptoms and yield. The best results of the control were reached by an application inside one week from the first infestation on barley and wheat, and within two weeks on oat. Losses due to delayed spraying were about 8 % per week and, according to the spraying dates used by farmers, losses totalled 6.5 % of barley, 4 % of oat and 9.5 % of the wheat yield.

Index words: *Rhopalosiphum padi,* barley yellow dwarf virus, BYDV, barley, oat, wheat, spring cereals, aphid infestation, migrant, yield loss, damage, control, efficacy, dimethoate, pyrethroids, organophosphoric compounds, pirimicarb.

INTRODUCTION

In Finland, the bird cherry oat aphid (*Rhopalosiphum padi,* L.) has occurred very abundantly and injuriously on spring cereals during 1928, 1947, 1954, 1959 (RAATIKAINEN and TINNILÄ 1961), 1973 (RAUTAPÄÄ and UOTI 1976) and 1978 (MARKKULA 1979). Fairly high populations of *R. padi,* have occurred during the 1980s in 1980 and 1985, respectively (MARKKULA 1981, 1986).

The maximal yield losses of barley and oat due to direct injuries by *R. padi* are known to be nearly 30 % (RAUTAPÄÄ and UOTI 1976) and much higher losses are experienced if *R. padi* transmits the barley yellow dwarf virus (BYDV), which has caused epidemics in Finland, e.g. during 1926, 1947 and 1954 (BREMER 1965) as well as in 1966, 1973, 1978, 1980 and 1985 (Katri Bremer and Aarne Kurppa, oral comm.).

A method for *R. padi* forecast has been developed and was successfully used for predicting the 1988 outbreak (KURPPA 1989). This was the first time when growers could be prepared in advance for the need of extensive control measures. The present paper presents an overview on the outbreak in different cultivation areas of the country as a comparison to the study published about the outbreak of 1959 (RAATIKAINEN and TINNILÄ 1961). Against this background, control measures employed by farmers in 1988 are critically assessed.

MATERIAL AND METHODS

Control measures against *R. padi* and yield losses during the aphid outbreak were investigated by questionnaires distributed among cereal farmers in August 1988. Prior to distribution, the questionnaires were first sent to the advisers of the Agricultural Centres and the Association of Swedish Agricultural Societes in Finland. Each adviser chose, representatively, 1 % of the farmers of his or her area for inquiry.

Replies were received from 955 farms (barley 861, oat 713 and wheat 229), which comprised about 0.5 % of all farms in the country. The information obtained concerned 3667 fields (3591 grew spring cereals) distributed throughout the cultivation area of these crops (Fig. 1). The sets of information obtained from about 1601 barley fields, 1235 oat fields and 307 wheat fields were complete and applicable in all comparisons. Biological and technical data was matched with data on local weather conditions generated by the Finnish Meteorological Institute.

In the questionnaire, the grower's address, details about growing conditions and aphid control, as well as an estimate of viral infection of the crop, amount of yield and approximations of yield loss due to aphids were inquired from each field plot. The details of growing conditions included soil type, fertilization, sowing time and herbicide application. Respondents were requested to provide data on aphid control timing and number of applications, control compound, age of the compound, dose and amount of water used and, in addition, their estimation of the efficacy of the application.

The efficacy of the control application was scaled as follows:

0 = no effect, aphids abundant on base and leaves of plants
1—4 = partial effect; number of aphids on leaves slightly (= 1) to significantly (= 4) decreased
5 = a half effect, no aphids on leaves but base aphid-infested
6—9 = number of aphids on a plant base decreased, aphid-free plants about 50 % (= 6) to about 90 % (= 9) of all plants
10 = practically all aphids killed

Zero on the primary scale of 0—10 was discarded because it became evident that many farmers had marked 0 when they had not monitored aphids after control at all.

The strength of viral infection was scaled as follows:

0 = no symptoms
1—3 = a few single affected plants; proportion of them about 1 % (= 1), 2 % (= 2), 5 % (= 3) of all plants in crop
4—6 = patches of a few affected plants in crop; proportion of infected plants 10 % (= 4), 15 % (= 5), 20 % (= 6)
7—10 = at first, patches of about 1—2 m^2 in crop, which later covered about 30—40 % (= 7), 40—50 % (= 8), 50—60 % (= 9) or over 60 % (= 10) of the field.

Fig. 1 a

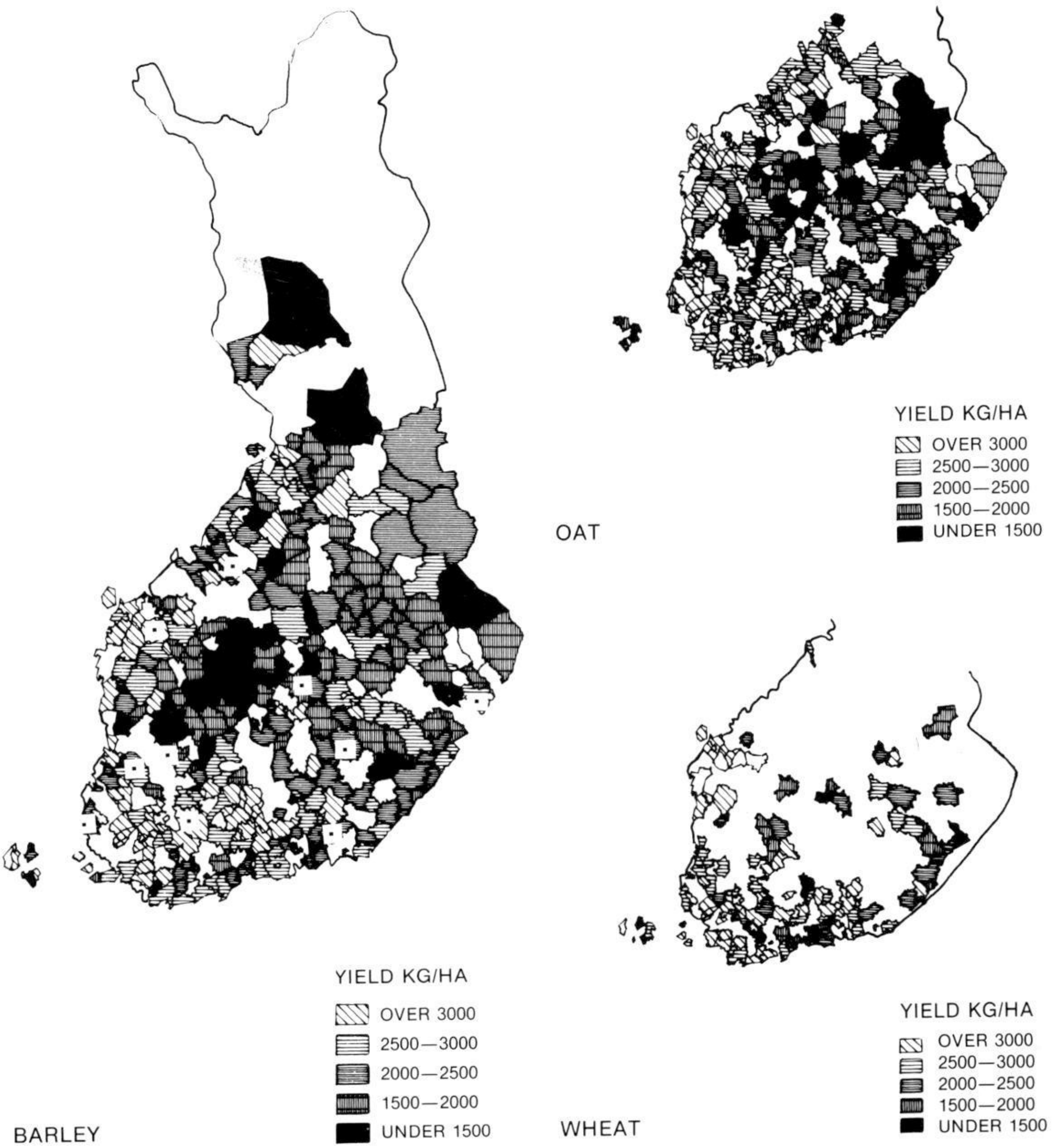
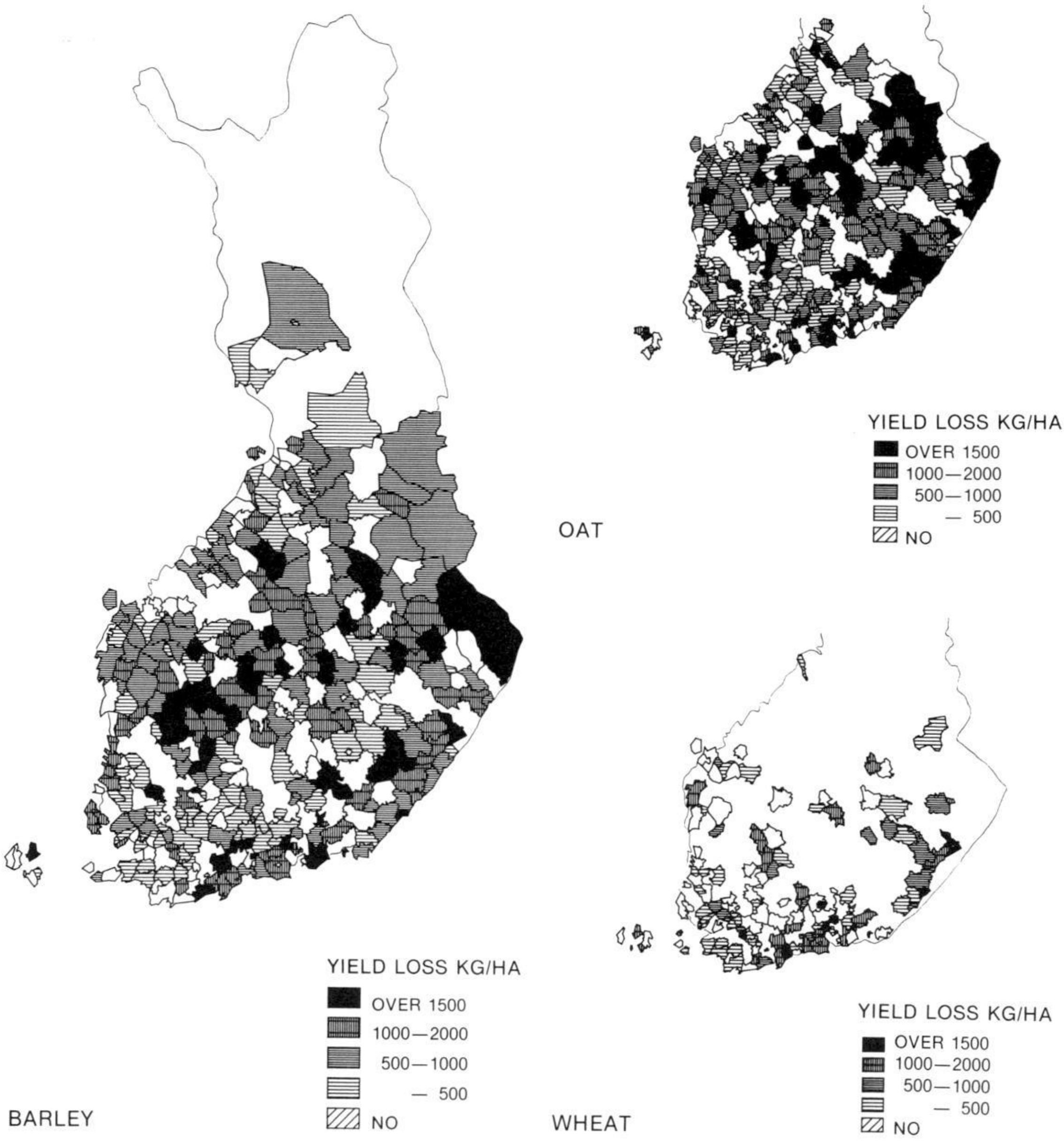


Fig. 1a. Mean communal yields of barley, oat and wheat based on the questionnaire in 1988. The Research Stations of the Agricultural Research Centre that performed the aphid observations area marked by squares.

Fig. 1 b



1b. Mean communal yield losses of barley, oat and wheat estimated by farmers to be due to aphids in 1988.

In order to investigate cereal infestation areally, the country was divided into 7 geographical areas (Fig. 2a). The division of areas was in accordance with general knowledge on growing conditions, information on aphid arrival to the area (Fig. 2b) (KURPPA 1989) and data on sowing times extrapolated from the questionnaire (Fig. 2a). As to growing conditions, special emphasis was given to the abundance of non cereal gramineous plants, because these are facultative hosts for *R. padi* and sources of BYDV-infection.

Fig. 2 a

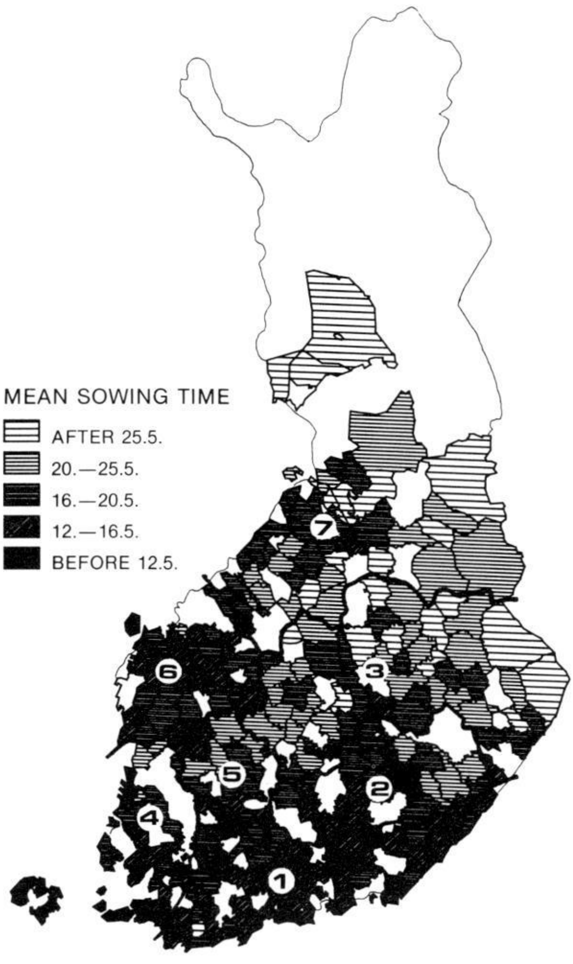


Fig. 2 b

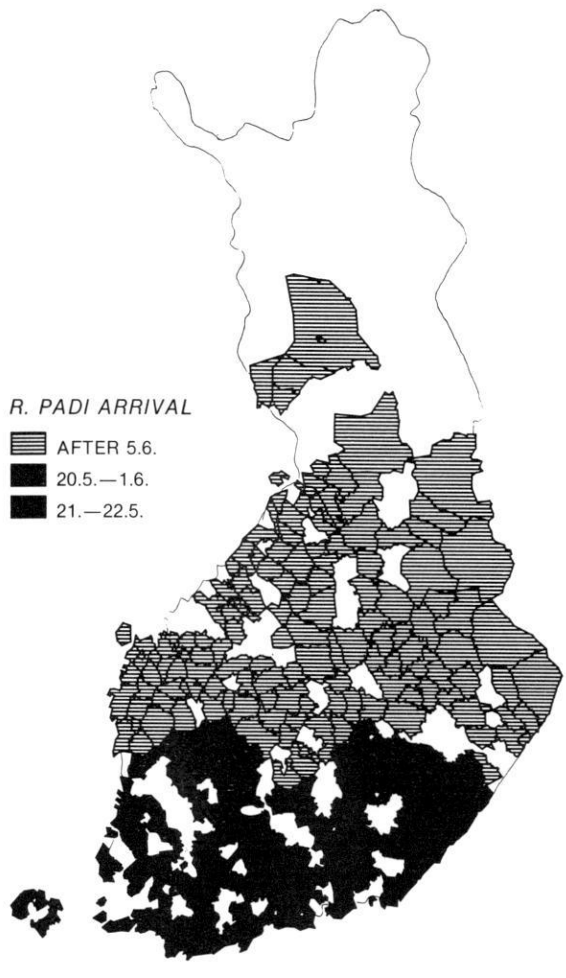


Fig. 2. Time differences between *R. padi* primary infestation and seedling emergence, and between infestation periods of *R. padi*. on cereals in different areas of Finland. a) Mean sowing time of cereals. (With wheat 8 days and with barley and oats 9 days were added to sowing time in order to count seedling emergence time.) b) Approximated time for *R. padi* arrival. c) Mean time difference between mean seedling emergence and primary infestation. d) Mean approximated length of infestation period.

In order to obtain areal information about aphid arrival and duration of infestation during the outbreak, aphids were counted on cereal plants at the Research Stations of the Agricultural Research Centre (Fig. 1a), later referred as the Research Stations. The time of the first infestation (FI) was counted as the number of days between seedling emergence and *R. padi* arrival. The duration of infestation (DI) was calculated for each area beginning from the date when seedlings had emerged and the first aphids had arrived, and ending at the time of summer migration. On fields where a control application had been performed, the duration of infestation was decreased according to the estimated effect of control (i.e., multiplication of the period of duration of infestation after application by the coefficient = 1— efficacy of control on a scale of 10/10).

RESULTS

Areal aphid infestation in the country

The following areas of *R. padi* infestation were identified (Fig. 2a):

1. **Southeastern area**; an important cereal growing area, with a fair amount of grass (ratio of cereals: grass 4.9 in the southern part and 1.9 in the eastern part, 1988), where the majority of migrant aphids arrived from overseas on the 21st and 22nd of May. Growing conditions were extremely dry and yield losses were estimated to be high in the southern and southeastern parts of the area.

2. **Southern central area**; a more forested area with, in addition to cereals, much more grass than area 1 (ratio of cereals: grass 1.3). Here, a low number of the migrant aphids were distributed, however, infestation was chiefly initiated by overwintered aphids at the change of the May and June months. Yield losses were high in the southeastern part, also a fairly dry area.

3. **Northern central area**; a major ley area, (ratio of cereals: grass 0.8), typical for small field plots surrounded by forests, where *R. padi* infestation was initiated exclusively by overwintered population, in early June. Growing conditions varied from wet to dry. Fairly high yield losses were experienced.

4. **Southwestern area**; a major cereal growing area (ratio of cereals: grass 10.4—6.8 in the southern part and 3.7 in the northern part), typified by large, open fields, which received no major emigrant aphids, thus, the infestation was initiated during the last days of May by the overwintered population. Conditions were moderate at first and later dry. Yield losses were the lowest in the country.

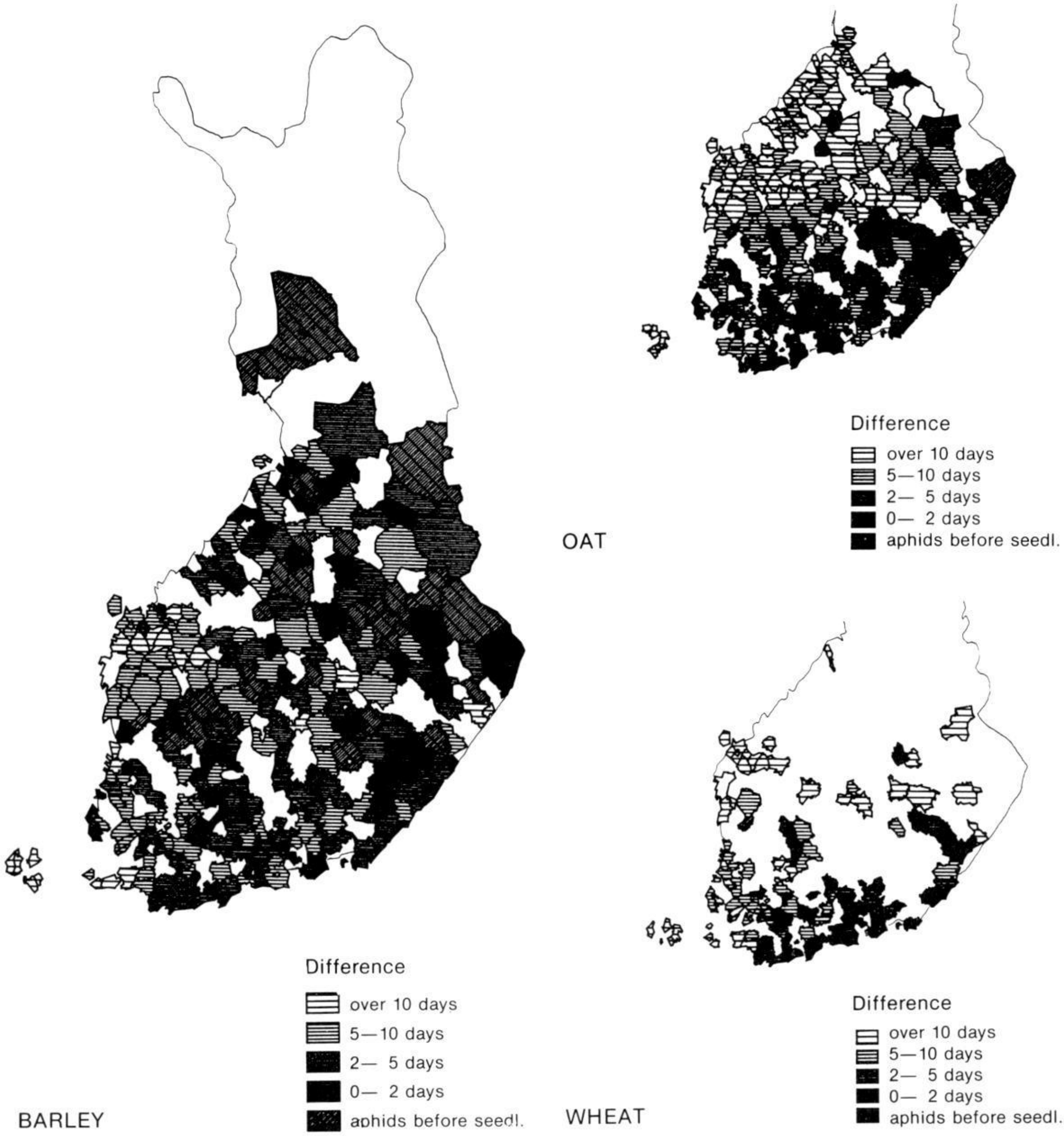
5. **Western central area**, a cereal and grass growing area (ratio of cereals: grass 1.6), a more forested area, where overwintered aphids started infestation during the first days of June. Conditions varied greatly between wet and dry. Yield losses were estimated to be high.

6. **Western area**; a flat, sparsely forested area growing mostly grass (ratio of cereals: grass 2.3), where overwintered *R. padi* initiated the infestation during the period from the third to the fifth of June. Conditions were at first moderate and later variably dry. Yield losses were estimated to be moderate.

7. **Northwestern area**; the northernmost area growing barley and wheat of the spring cereals, but principally a grass growing area (ratio of cereals: grass 0.75), overwintered *R. padi* arrival to fields was after the fifth of June. A fair amount of water was obtained throughout the season. Yield losses were moderate.

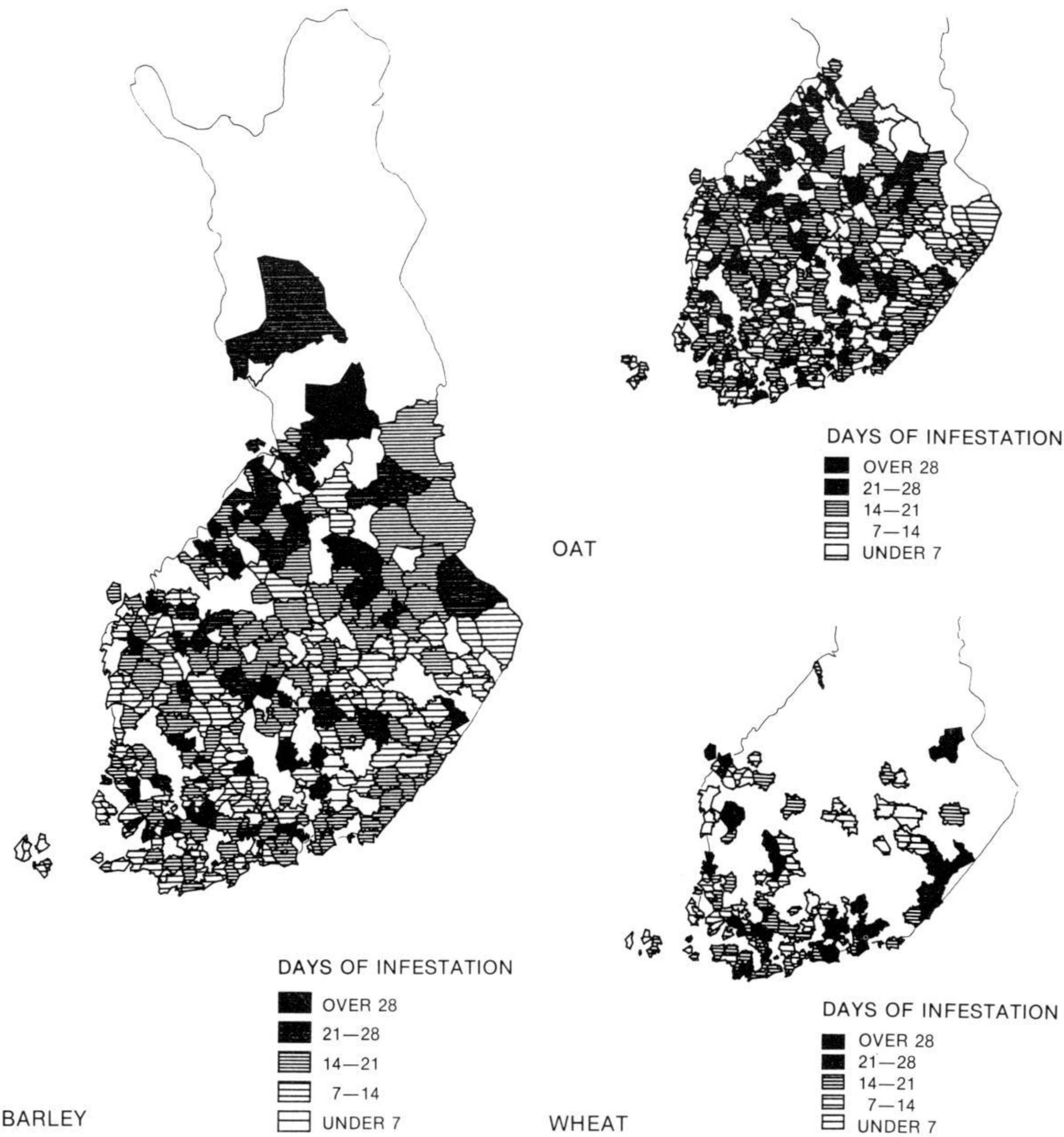
R. padi primary infestation coincided with the early growth of cereals differently in various areas of the country (Fig. 2c), with a cer-

Fig. 2 c



tain variation being due to differences in sowing dates within each area. The duration of aphid infestation (Fig. 2d) varied more within each area due to the timing of first infestation relative to the development stage of the crop and control measures performed. The mean

Fig. 2 d



peak of *R. padi* infestation ranged between 20 and 60 aphids per plant. The yields notified by farmers (Fig. 1a) correlated negatively with the mean estimated yield losses (Fig. 1b); barley $r = 0.44$, oat $r = 0.50$ and wheat $r = 0.405$, $P < 0.001$.

Barley yellow dwarf virus (BYDV) infestations in the field

The primary symptoms of BYDV were observed in the fields around the tenth of June in southern areas, and as early as about 10 days later, virotic patches of a few square meters in size could be seen. Strong symptoms were found, especially, around the occasional couch grass (*Elymus repens*) growing among the cereal plants.

According to the symptoms, barley yellow dwarf virus was concentrated in the eastern and central areas, and infections were most abundant and virulent in oat (Fig. 3, Table 1).

A significant regression was found between the strength of viral symptoms and the duration of *R. padi* infestation in the field, in many cases combined with the effect of sowing time and nitrogen fertilization. This result was obtained with oat in all areas except for area 7, with barley in all areas except for 5 and 7, and with wheat in area 4. The equations were, e.g. for barley (area 4) $y = 0.207 + 0.07 \times DI + 0.11 \times ST + 0.0008 \times N$, d.f. = 161, $r^2 = 0.21$ (DI = duration of infestation, ST = sowing time, N = amount of nitrogen fertilization); oat (area 3) $y = 3.58 + 0.11 \times DI$, d.f. = 208, $r^2 = 0.12$; and wheat (area 4) $y = 2.74 + 0.14 \times DI—0.02 \times N$, d.f. = 50, $r^2 = 0.42$.

R. padi and BYDV as yield determinants

Regression equations and coefficients between the amount of yield and the strength of viral infection (V), time of the first aphid infestation days (FI) and the duration of aphid infestation (DI) were significant in many areas. The effect of these variables has been quantified in Fig. 4 with the sectors based on the regression coefficients and the mean values of the variables in the area. The area inside the circle is related to the mean yield of the particular area of the country.

The importance of the various determinants varied from south to north and from east to west in different areas, however, viral infection caused the major decrease in yield. The regressions between virus estimates and yield calculated from data throughout the whole country were as follows: barley $y = 2788—111(\pm 10) \times V$ (N = 1529, $P < 0.001$, $r^2 = 0.27$), oat $y = 2912—140(\pm 9) \times V$ (N = 1094, $P < 0.001$, $r^2 = 0.41$), wheat $y = 2930—75(\pm 25) \times V$ (N = 272, $P < 0.01$, $r^2 = 0.18$). According to the areal regressions the effect of the virus on oat was strongest in the western (6) area, on barley in the southwestern (4) and southern central areas (2), and on wheat in the southwestern area (Figs. 4 a, b, c). The decrease in yield was on the average 153 ± 55 kg per one step on the scale of virus

Table 1. The frequency of fields, mean yield and mean estimated yield loss counted for the scale of the strength of BYDV symptoms. All pairs of yield results except for those combined with a vertical line differed from each other significantly ($P < 0.05$).

Scale of BYDV symptoms	Barley			Oat			Wheat		
	%	Yield kg/ha	Yield loss kg/ha	%	Yield kg/ha	Yield loss kg/ha	%	Yield kg/ha	Yield loss kg/ha
0	29	2756		15	2706		32	2774	
1	13	2783 |	654 |	8	3054	448 |	21	3083 |	523 |
2—3	26	2622 |	695 |	24	2660	608 |	25	2838 |	742 |
4—6	22	2141	930	30	2288	843	17	2413	852 |
7—9	8	1995	1281	17	1756	1423	4	2100	1800 |
10	2	1439	1918	6	1369	2066	1	1433	1800

Fig. 3

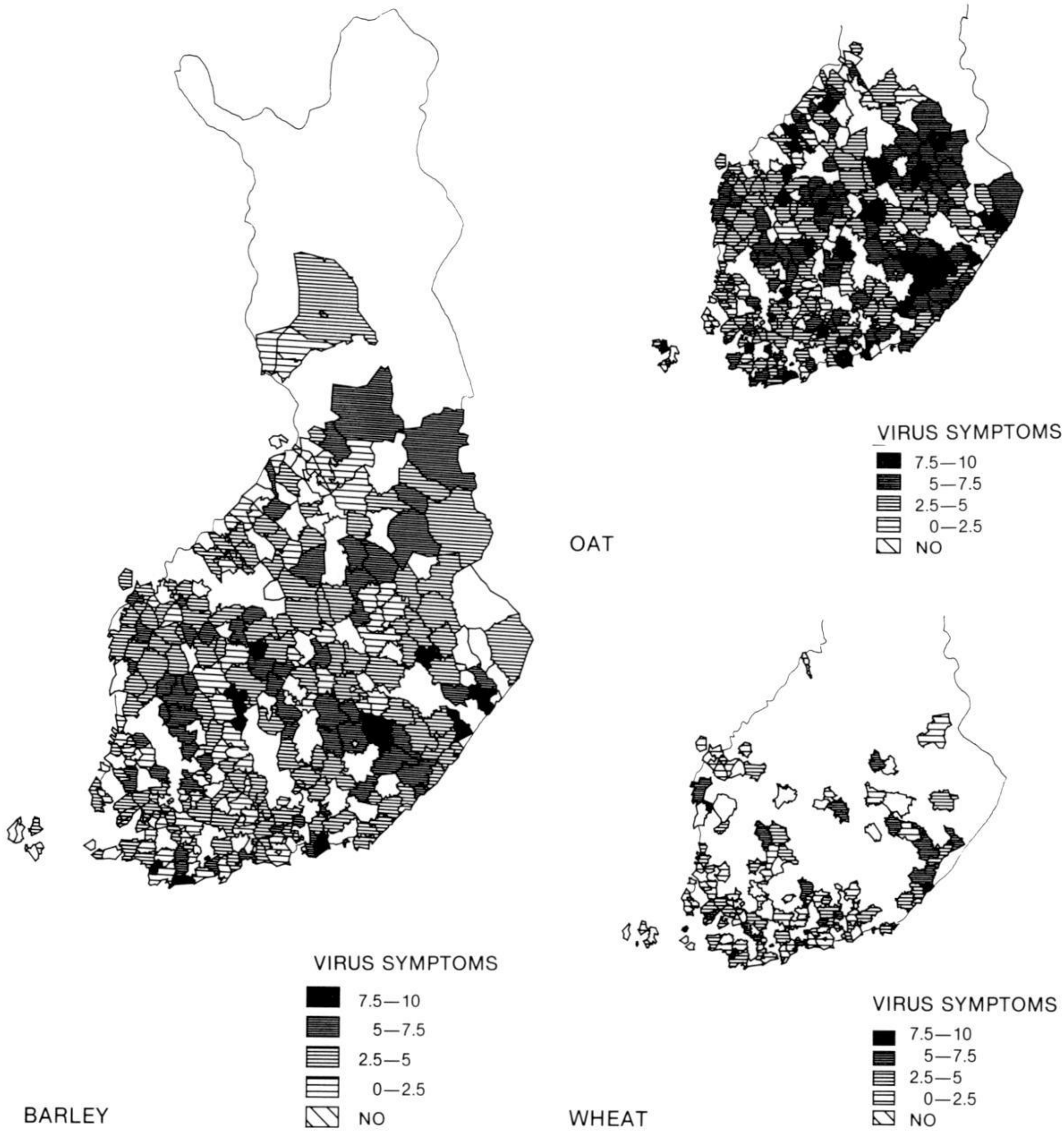
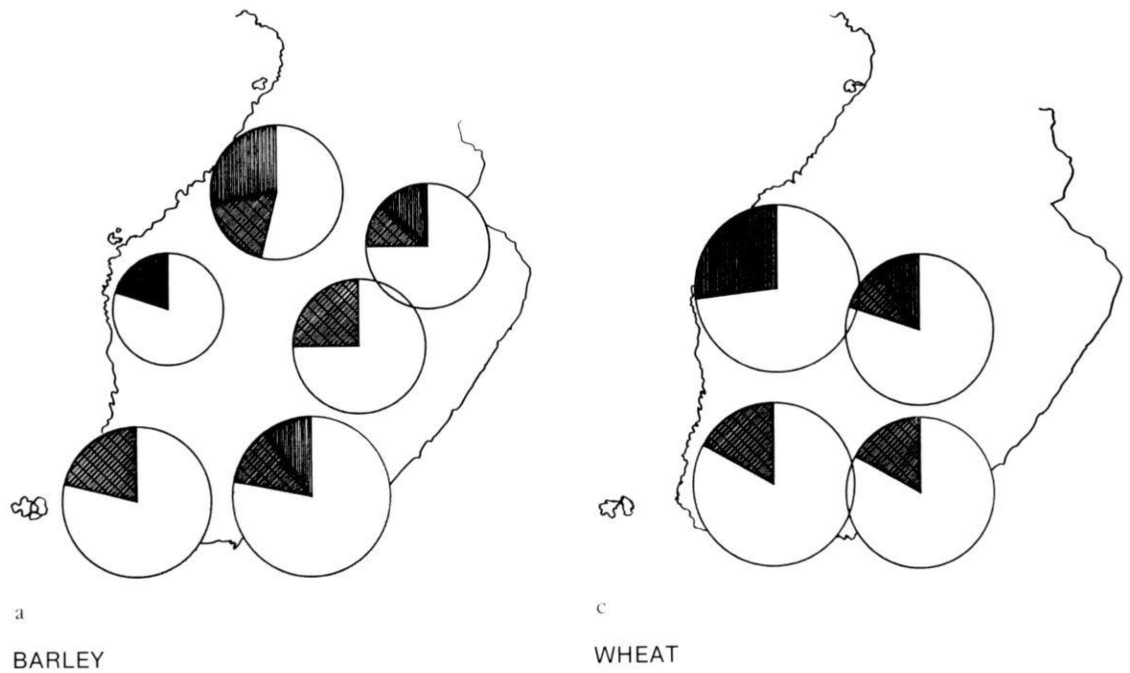
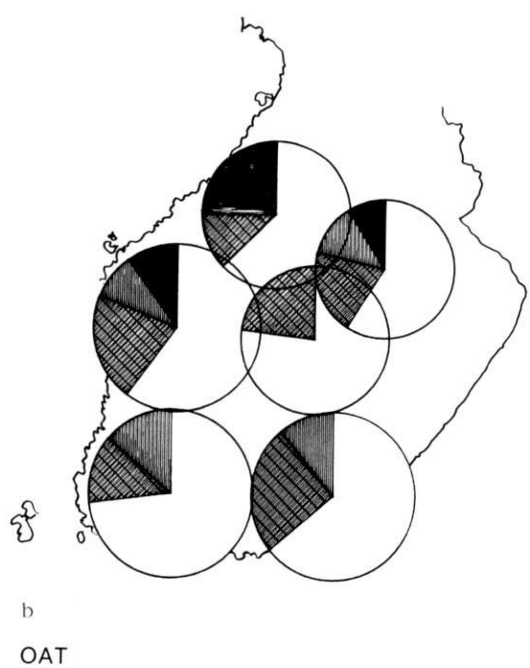


Fig. 3. BYDV-infection (scale 0—10) in different areas of Finland. a) barley, b) oat, c) spring wheat.

Fig. 4





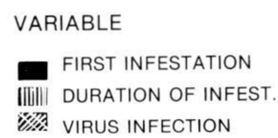


Fig. 4. Mean effect of viral infection, duration of *R. padi* infestation and time of aphid arrival to the yield of a) barley, b) oat and c) wheat. Counted according to regression equations.

symptoms (calculated as a mean from all significant regressions of different cereals in different areas).

The effect of the duration of aphid infestation was equal in size but opposite to the effect of the time of first infestation. Yield was decreased by longer duration (DI) and earlier infestation (FI). The mean effect of DI was 30 ± 16 kg/day as DI varied from a few days to 5 weeks, and the effect of FI was 41 ± 17 kg/day as FI ranged from 0 days to 2 weeks. In the comparisons between the periods of duration in weeks from 1 to over 5, most of the differences in the strength of viral symptoms in the yields and yield losses were significant (Figs. 5 a, b, c). Yield decrease was highest as sowing time was delayed. The mean negative effect of sowing time was 47 ± 20 kg/day (these were also counted similarly as that for virus effect).

Abundance of control applications and control substances

Most of the fields in the questionnaire were treated to control *R. padi:* barley 82.4 %, oat 86.3 % and spring wheat 89.6 %. The numbers and proportions of fields treated in the different areas were as follows:

Areas	Appl. once		Appl. repeated	
	%	no	%	no
Southeastern (1)	93	963	11	108
Southern central (2)	96	186	18	34
Northern central (3)	81	497	1	4
Southwestern (4)	87	508	8	42
Western central (5)	89	189	2	4
Western (6)	79	482	2	10
Northwestern (7)	65	318	0	0

Most of the areas receiving two applications grew barley (47 %) or oat (38 %). Only 14 % of wheat fields had two applications.

Altogether 5 major substances of organophosphorous compounds, pyrethroids and a carbamate, pirimicarb, were used for aphid control on cereals (Table 2). The pyrethroids were cypermethrin, deltamethrin, fenvalerate and permethrin. In addition, mevinphos, parathion and even bromophos and lindane were used, each in less than 1 % of fields. Toluene was sprayed in two fields. Of the farmers that responded, 10.3 % (296) did not reveal the product used in their response. Most of the products used for control, 83.8 %, had been newly purchased, in 1988, only 8.3 % in 1987, 2.4 % in 1986 and 1.6 % in 1985, and less than 1 % were bought in previous years.

The lower recommended dose, 0.5 l/ha, was by far that most frequently used in the case of dimethoate (Table 2). Variability of the doses of pyrethroids was very high with the products for which range of doses was presented in the recommendation. Products for which one single dose was recommended that was used by most of the farmers (Table 2. pyrethroids, medium recommended = 66 %).

There were no differences between the proportion of various active ingredients or compounds used for the different species of cereals. Comparison of the different areas showed that dimethoate was the compound of just choice in all areas except for the northwestern area (7). There, pyrethroids had been used the most (in 38 % of fields), dimethoate being the second (35 %) and organophosphorous compounds were, also, used in exceptionally high amounts (30 %).

Applications were usually performed by a tank mixture containing a herbicide. Mixtures were 73 %, 75 % and 79 % of applications on barley, oat and wheat, respectively. The most common herbicides present in the mixtures were: MCPA + dichlorprop 33.4 %; MCPA 28 %; MCPA + dichlorprop + ioxynil + bromoxynil 10 %; MCPA + mecoprop + dichloropicolinic acid 2 % and chlorsulfuron 14 % of the fields.

The typical amount of water used per hectar was 200 liters (Table 3). Approximately equal amounts of water were employed in applications for an insecticide alone or in mixture (Table 3). The amount of water did not differ between various control substances.

a
b
c

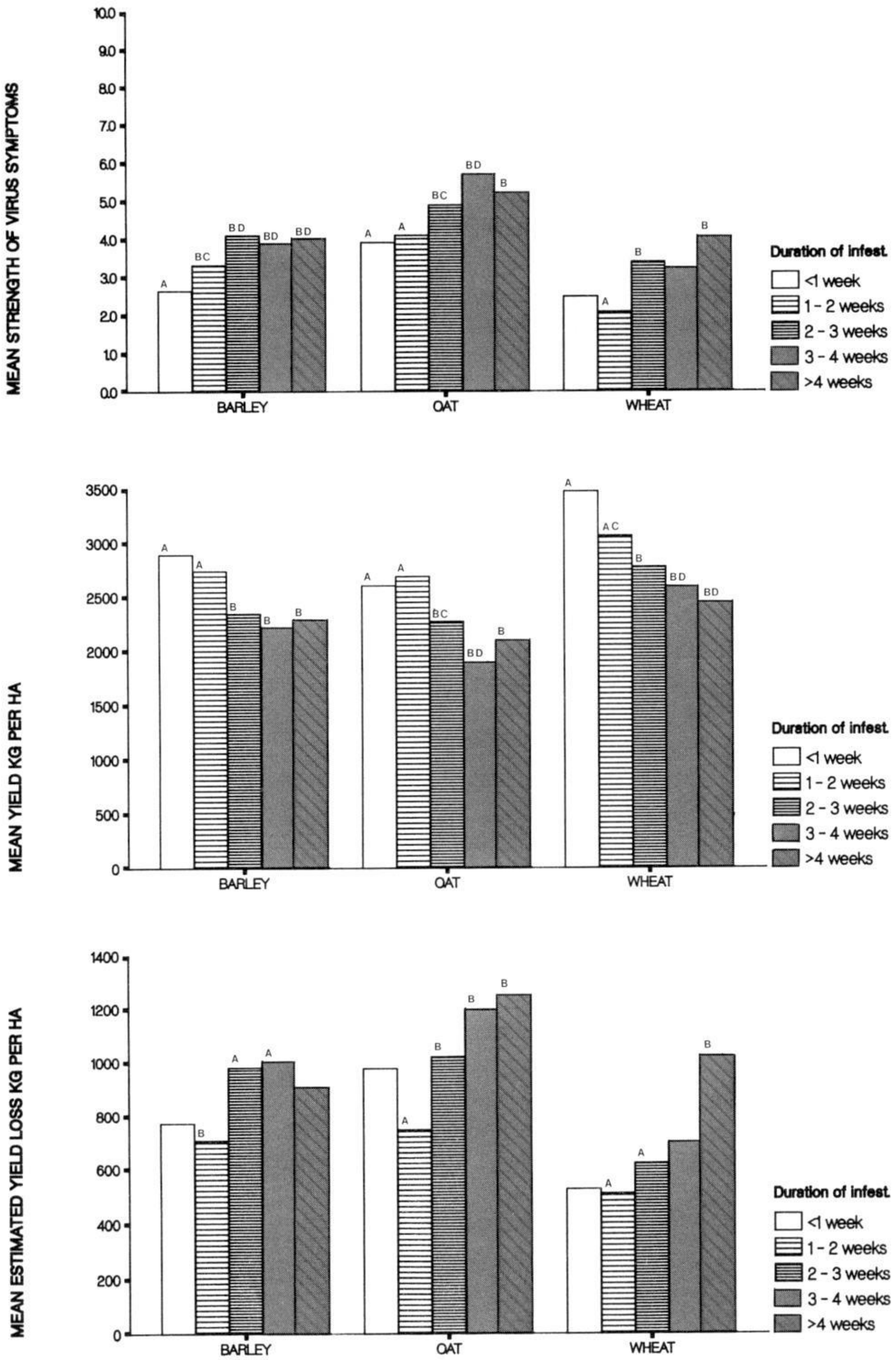


Fig. 5. Effect of the period of duration of *R. padi* infestation on a) strength of viral symptoms, b) mean yield and c) mean yield loss.

Table 2. Frequency of substances and doses of each substance used to control *R. padi,* in 1988.

Substance	% of fields appl.	Doses used in % of fields sprayed				
		Subdose	Recommended doses			Overdose
			Lower	Medium	Higher	
Dimethoate	62	3	72		24	1
Pirimicarb	4	17		73		10
Pyrethroids	20	35	19	(66)	26	16
Fenitrothion	5	31		61		8
Malation	1	0	44		50	6

Pyrethroid with a single recommended dose in brackets.

Efficacy of applications

The control of *R. padi* resulted in a significant increase in the yield of all spring cereals (barley and oat $P<0.001$, spring wheat $P<0.01$) (Fig. 6a). The mean yield increase for barley was 401 kg/ha, for oat 596 kg/ha and that for wheat 303 kg/ha. The highest increase in the mean yield of an area growing barley was 931 kg/ha in the southern area (1), that for oat 1294 kg/ha in the western central area (5) and for spring wheat 1230 kg/ha in the western area (6). The estimated yield losses decreased, correspondingly (Fig. 6b).

Estimates of the efficacy of the applications did not vary significantly among the three cereal species (Table 4). Efficacy was evaluated to be lowest in the southern area (1) particularly on the southern coast. The only difference between the various control compounds was detected in the case of oat, where significantly the worst efficacy was obtained with toluene.

Table 3. The amount of water used in aphid control by applications with insecticide alone or applications with tank mixtures.

Water amount l/ha	Proportion of treated fields			
	Insecticide		Mixture	
	no	%	no	%
100—180	17	4	44	2
200	246	58	1448	56
210—300	123	29	912	36
over 300	37	9	153	6

No indications of the effect of compound age, dose, tank mixture or amount of water on the efficacy of control or on yield response due to control was found.

The amount of yield correlated with the evaluated values of control efficacy (barley: $r=0.51$, $P<0.001$, oat: $r=0.56$, $P<0.001$, wheat: $r=0.59$, $P<0.01$). On barley, the mean yield increase over all areas was 330 kg/ha as estimated efficacy increased from 1 to 10. The highest mean increase of an area 875 kg/ha (between the efficacy 3 to 10) was obtained in the western area (5). On barley, the mean yield increase was 1182 kg/ha and the highest mean of an area 1438 kg/ha was obtained in the western central area (5). On spring wheat, the mean yield increase was 981 kg/ha.

BYDV symptoms were decreased with the help of *R. padi* control. On oat, the difference in the mean strength of viral symptoms between controlled and uncontrolled fields for all areas was 4.5 against 3.5 ($P<0.001$), and the highest change, 2.6, was obtained in the southern area (1). On barley the mean change of the symptoms due to control was for all areas, from 5.8 to 4.8, and the highest change was 1.9, in the southwestern area (4). On wheat, the difference of symptoms was 1.1 (4.0 against 2.9) and the highest difference 3.7, was in the southwestern area (4).

The values of the strength of BYDV symptoms correlated significantly with the efficacy of *R. padi* control on barley, $r=—0.202$,

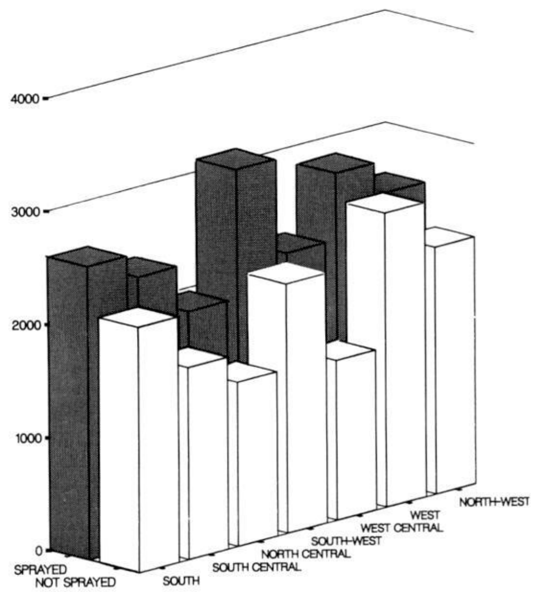
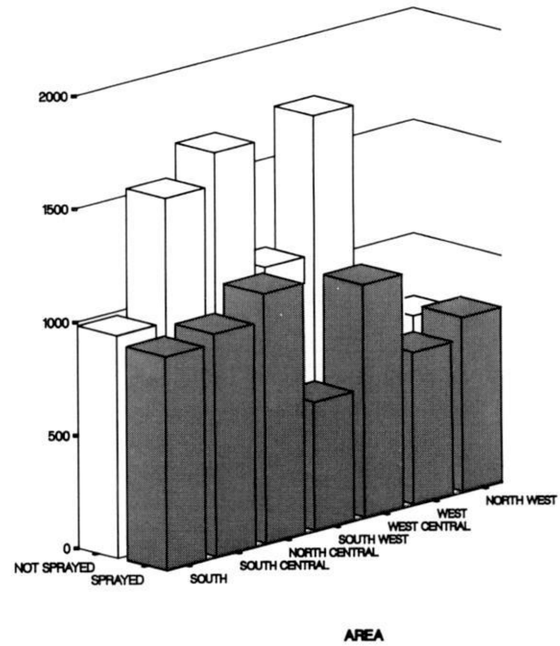


Fig. 6. Mean effect of control of *R. padi* a) on yield and b) on estimated yield loss in all spring cereals: barley, oat and spring wheat.



b

$P<0.001$, and on oat, $r=-0.297$, $P<0.001$ and spring wheat, $r=-0.204$, $P<0.05$. On oat, the mean value on the BYDV scale decreased from 6.4 to 2.6 and on barley from 3.0 to 1.4 as the value for efficacy improved from 1 to 10.

Effect of spraying time

Significantly the best results in the form of estimated efficacy, decreased strength of BYDV symptoms, yield response and decreased yield loss were obtained by early control applications during the first or at least during the second week after aphid arrival (first infestation) (Figs. 7 a, b, c, d). Actually, these results were demonstrated only in the southwestern and western areas (Fig. 8 a, b, c), where *R. padi* arrival occurred within a restricted, easily defined period of time.

A total of 64 % of barley growers were late in spraying, 39 % by less than a week and 25 % by more. Yield losses were 5.5 % and 13 %, respectively. Of oat growers, 27 % sprayed later than inside two weeks after the first infestation and experienced on average a 14 % yield loss. Of wheat growers 41 % were late

Table 4. The proportion (%) of fields in the scale of estimated control efficacy.

	Scale									
	1	2	3	4	5	6	7	8	9	10
Barley	1	2	2	4	14	8	9	20	24	16
Oat	1	1	4	6	14	10	11	18	20	14
Wheat	2	2	3	5	19	11	7	15	22	12

Fig. 7 a

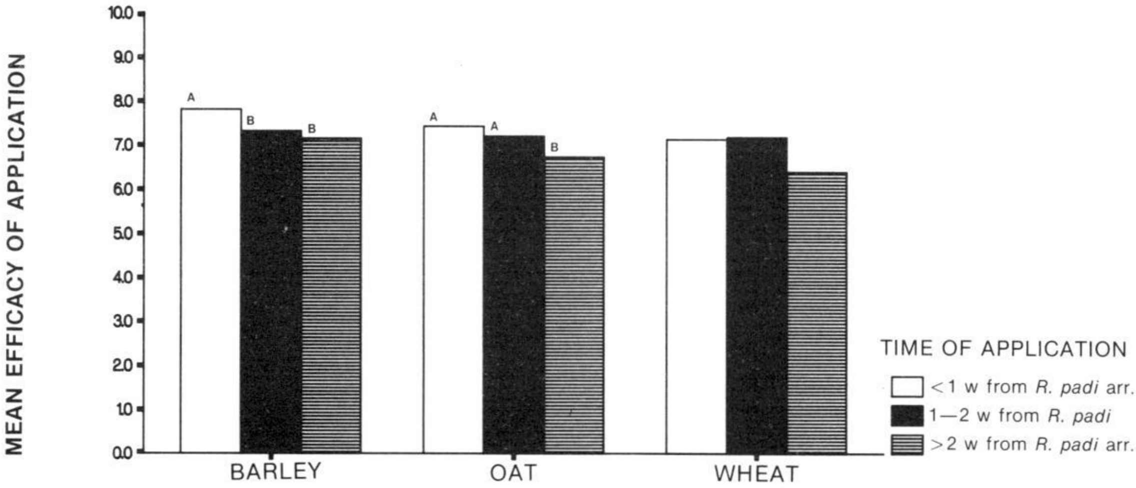


Fig. 7 b

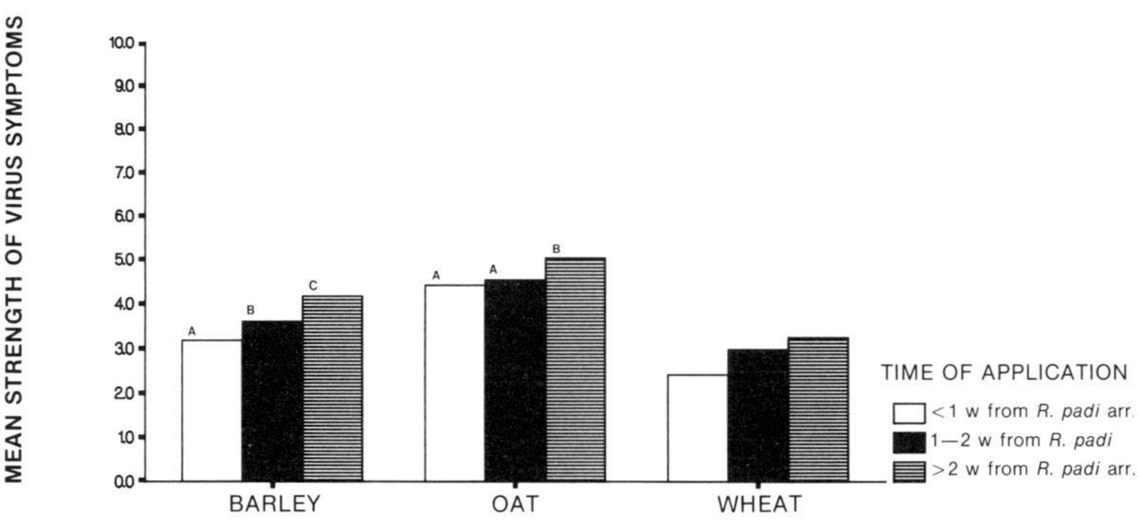


Fig. 7. Effect of spraying time on a) efficacy of spraying, b) strength of viral symptoms, c) mean yield, d) mean estimated yield loss.

Fig. 7 c

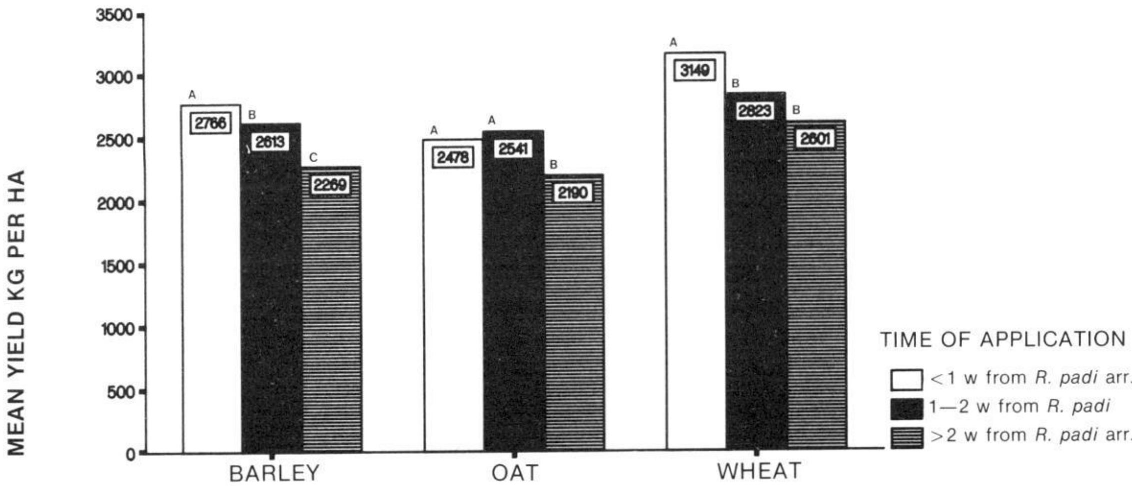
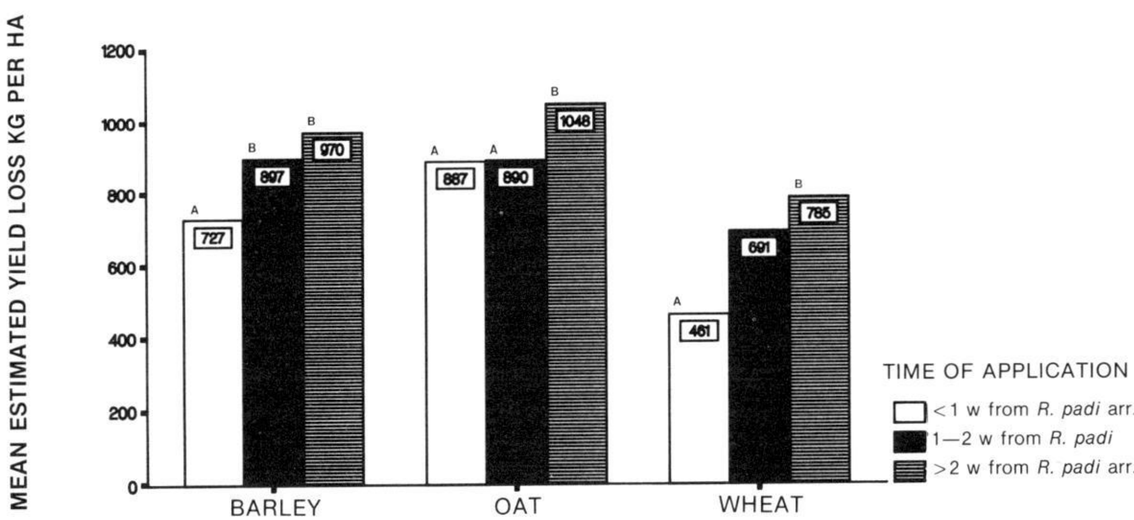

MEAN YIELD KG PER HA
3500
3000
2500
2000
1500
1000
500
0
A
2766
B
2613
C
2269
A
2478
A
2541
B
2190
A
3149
B
2823
B
2601
BARLEY
OAT
WHEAT
TIME OF APPLICATION
<1 w from R. padi arr.
1—2 w from R. padi
>2 w from R. padi arr.

Fig. 7 d


MEAN ESTIMATED YIELD LOSS KG PER HA
1200
1000
800
600
400
200
0
A
727
B
897
B
970
A
887
A
890
B
1048
A
461
691
B
785
BARLEY
OAT
WHEAT
TIME OF APPLICATION
<1 w from R. padi arr.
1—2 w from R. padi
>2 w from R. padi arr.

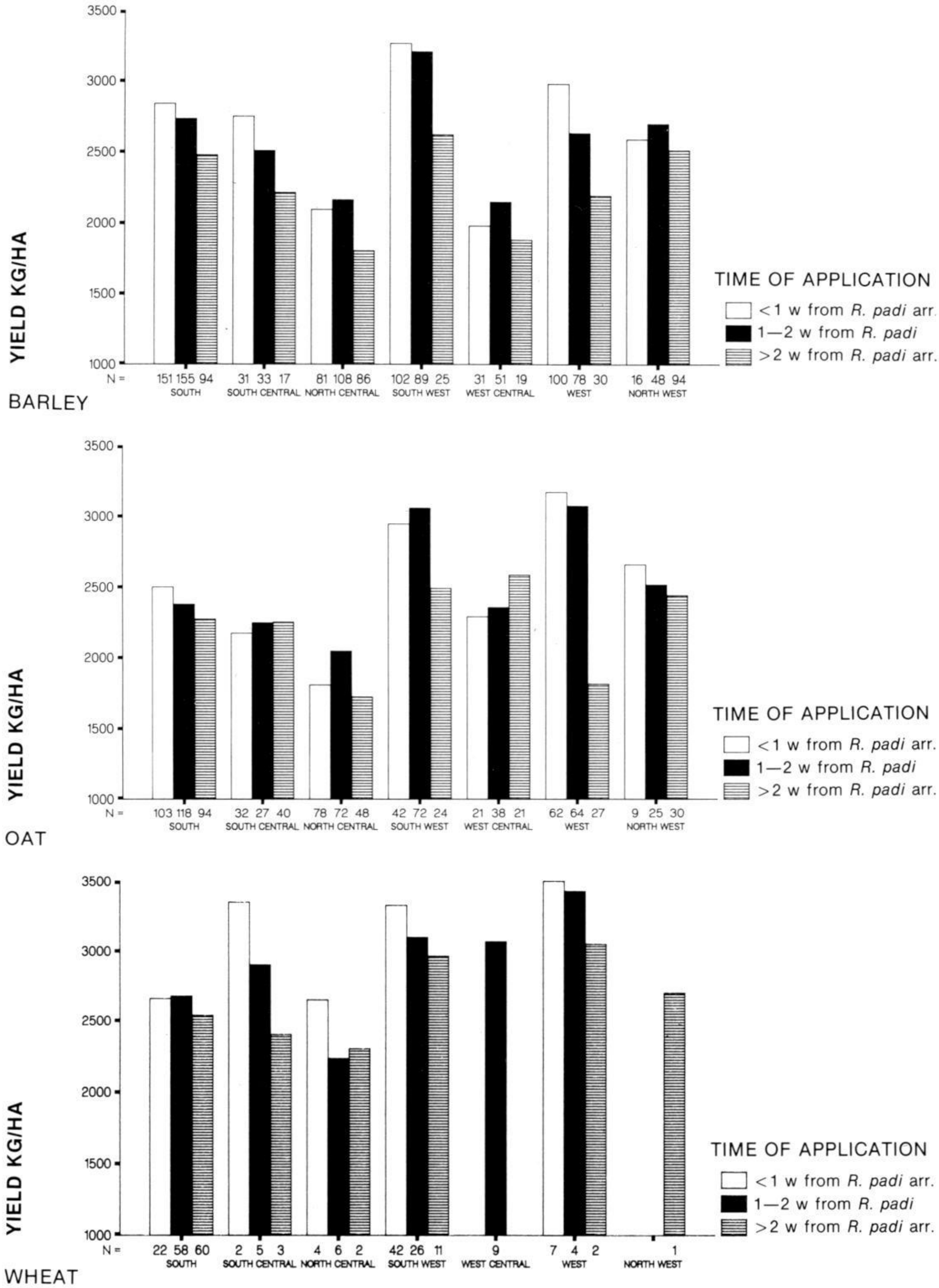


Fig. 8. Yield increases obtained by control for different time periods, in different areas of the country. N = number of fields sprayed.

Table 5. Mean yields in fields where *R. padi* was controlled by two applications, variably at the correct time or delayed. Significant differences indicated by a different letter.

	Yield kg/ha			
		Success in timing of 1st and 2nd aphid spray		
	1st and 2nd on time	1st on time 2nd delayed	1st delayed 2nd immediate	1st and 2nd delayed
Barley	3229 a	3157	2400 b	2611
Oat	2927 a	2400	2226 b	2389
Wheat	3280	3150	2486	—

by less than a week and 30 % by over a week, suffering on average 10 % and 18 % yield losses. Total yield losses were thus 6.5 % (2 + 4.5 %) of barley, 4 % of oat and 9.5 % (4 + 5.4 %) of wheat yields. If this is related to the growing area of these cereals in Finland during 1988 (ANON. 1988), the yield losses due to the incorrect timing of *R. padi* control were 105 million kg of barley, 34 million kg of oat and 26 million kg of wheat yield.

In fields that were sprayed twice, yield loss due to the delay in the first spraying was not compensated by an immediate repeat spray (Table 5).

DISCUSSION

The distribution of fields in the questionnaire corresponded to the actual distribution of fields for different cereals in Finland, (ANON. 1988), with the exception of some parts in southwestern Finland that were represented by about a 35 % lower number of fields than expected. The effect of the outbreak on this area was minor compared to that on the other areas. The parameters describing the total effect of the outbreak throughout the country might be therefore slightly biassed toward higher values. On the other hand, mean areal yields in the inquiry were 11 % higher than the actual mean yields of each area (ANON. 1988), indicating the better skills of the growers who replied to the inquiry, which in turn might lessen the effects of the outbreak estimated from this material.

The numbers of *R. padi* were above the damage threshold throughout the country and therefore were not scaled areally as in 1959 (RAATIKAINEN and TINNILÄ 1961). Overwintered *R. padi* migrated at the end of May as also in 1959 (RAATIKAINEN and TINNILÄ 1961). Long distance migration was reported during both of the outbreak years 1959 and 1988. During both years, *R. padi* was accompanied by the same other species, *Euceraphis punctipennis* L.

BYDV infection followed the normal epidemiology of the virus in Finland (BREMER 1965). The great importance of the virus in southern areas refers to the fact that the virus inoculum was brought by aphids arriving from long distances. The virus was actually identified from the aphids directly after their arrival (KURPPA 1989). Long distance migration has been demonstrated to be the major source of virus in Canada (PALIWAL 1982). Further north, local sources of BYDV in the form of wild gramineous plants must be important. Symptoms on wheat were stronger than expected, which most likely resulted from the very early infection, a phenomenon that has been described by SMITH and SWARD (1982). In 1988, wheat fields sown mostly with foreign seed received the first aphids, the emergence of most barley and wheat fields having been delayed due to poor seed from 1987. The effect on the yield became, however, not as obvious as expected, because the very dry and warm conditions caused early maturation of cereals, lowering of yield level and thus being unfavourable conditions for virus multiplication.

The importance of early infestation in the formation of yield losses due to *R. padi* has been demonstrated by KIECKHEFER and KANTACK (1980, 1986) in experimental fields. In the areas of long distance migration studied in 1988, the variation in the timing of the first infestation was, however, diminished because migrant aphids were available to infest new seedlings almost any time. The effect of the timing of the first infestation became obvious in the western and northern areas, where sowing times and times of aphid arrival were during restricted periods. Sowing time forms the background for the effect of the timing of the first infestation. The effect of sowing time in 1988 was not as strong a determinant of the strength of viral infestation as normally either, because of the above described reason.

The effect of the duration of *R. padi* infestation is comparable to the aphid index as defined by RAUTAPÄÄ and UOTI (1976). Also the level of the effect is the same. Whereas Rautapää estimated the increase of aphid index by 100 to cause a yield loss of 144 kg/ha, in the present material the aphids stayed on plants for about 25 days, and the peak number was about 40 aphids/plant. This resulted in an aphid index of 400 with yield loss being about 30 kg/ha/day and 600 kg/ha for oat.

The frequency of *R. padi* control was much higher in 1988 than in 1959 (RAATIKAINEN and TINNILÄ 1961) being even higher than that in England during 1988 (WRATTEN and MANN 1988). The number of repeat applications was abnormally high, but easily justified in the southern areas by the extended migration covering over 2 weeks' time at the beginning of cereal growth.

Control substances have changed completely since the earlier outbreak of 1959. The substances used were also different from those reported from England (WRATTEN and MANN 1988) and Sweden (Sigwald oral inf.), especially, with regard to the low use of pirimicarb (4 % of applications), the major substance used elsewhere. However, 1988 was the first year when pirimicarb became available for cereal application and it came on the market at a time when aphid control had already started. In the future, pirimicarb will most likely substantially displace the use of dimethoate, also in Finland.

A slight shortage of control substances, or at least difficulty in their delivery, was experienced in 1988 as also in 1959. This was most probably the reason why pyrethroids and organophosphorous compounds were so commonly used, especially in the northern areas. The various doses and ranges of doses with pyrethroids seems to have caused confusion among farmers. This might be reason for some of the variability in the efficacy.

Spraying against *R. padi* was slightly delayed from the optimal time by the majority of the growers, but timing has been shown to be difficult elsewhere, too (WATT et al. 1984, WRATTEN and MANN 1988). A significant improvement has taken place since 1959 when control was mostly performed near the peak of the *R. padi* population, being far too late to result in a real economic response. For the correct timing, the monitoring of aphids at the beginning of the season is necessary, as presented in KURPPA (1989). Correct timing presents the advisory service with a great challenge, as the critical time varies by changes in aphid behavior as well a by changes in growing conditions and cultivars. A computer simulation of this should be worked on.

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SELOSTUS

Tuomikirvan tuhot ja torjunta Suomessa kirvojen massaesiintymävuonna 1988

SIRPA KURPPA

Maatalouden tutkimuskeskus

Tuomikirvatuhojen ja toteutettujen torjuntatoimien arviointi tehtiin viljelijöihin kohdistettuna kyselytutkimuksena. Tiedot saatiin yhteensä 955 tilalta ja ne koskivat 3591 ohra-, kaura- tai kevätvehnäpeltoa.

Tiedot käsiteltiin alueellisesti. Sitä varten maamme jaettiin 7 alueeseen tuomikirvojen esiintymistavan ja yleisten viljelyolojen perusteella. Eteläiset ja kaakkoiset alueet kärsivät tuomikirvan etäislevinnästä, joka ajoittui jo toukokuun lopulle. Kauempana Sisä-Suomessa ja läntisillä alueilla tuomikirvat olivat peräisin paikallisista talvehtimiskannoista ja tulivat viljaan odotetusti kesäkuun alkupäivinä. Kirvojen saapumisajan ja viljan vioitusalttiin vaiheen keskinäinen ajoitus vaihteli siten jossain määrin alueittain. Kirvojen viipymäaika viljoissa vaihteli kunkin alueen sisällä varsin voimakkaasti erityisesti ruiskutusajoista ja ruiskutusten onnistumisesta riippuen.

Tuomikirvan suoranaiset tuhot ja tuomikirvalevintäisen kääpiökasvuviroosin tuhot yhdistyivät. Viroosi oli lähes kaikkialla tärkein satoa rajoittava tekijä. Kun viruksen oireet pahenivat yhden asteen asteikolla 1—10, sato aleni keskimäärin 153 kg/ha. Vaikutus oli voimakkain kaurassa, mutta se oli yllättävän vahva myös vehnässä, mikä johtunee hyvin aikaisesta saastunta-ajankohdasta. Etelä-Suomeen etäislevinnän mukana tulleet tuomikirvat hakeutuivat erityisesti vehnäpeltoihin, koska ne orastuivat yleensä ensimmäisinä. Ohran ja kauran myöhästyminen johtui edelliseltä kesältä alkuperää olleesta huonosta siemenestä.

Kirvojen tuloajan ja viljojen orastumisen keskinäisen ajoit-

tumisen merkitys sadonmuodostuksessa oli merkitsevä läntisillä ja pohjoisilla alueilla, joilla kirvojen tulo ajoittui tiettyihin ajanjaksoihin. Eteläisillä ja kaakkoisilla alueilla kirvoja tuli pelloille jopa yli kahden viikon aikana, ja kaikki kasvustot saastuivat hyvin nuorina. Tällaisessa kirvalevintätilanteessa kylvöajan merkitys katosi. Sitä on totuttu pitämään tärkeänä kääpiökasvuviroosin levinnässä. Kirvojen viljassa viettämän ajan vaikutus satoon oli merkitsevä, mikäli viruksen merkitys ei ollut täysin hallitseva. Kun kirvojen huipumäärä oli karkeana keskiarvona 40 kasvia kohden, kunkin viipymäpäivän vaikutus satoon oli noin 30 kg/ha.

Yli 80 % viljapelloista ruiskutettiin tuomikirvaa vastaan vuonna 1988. Etelä- ja Kaakkois-Suomessa jouduttiin suorittamaan myös uusintakäsittelyjä (yhteensä noin 6 %:ssa pelloista). Ehdottomasti käytetyin torjunta-aine oli dimetoaatti. Ainoastaan Pohjanmaan keski- ja pohjoisosissa pyretroidien yleisyys ohitti dimetoaatin, mikä lienee seuraus markkinoilla ilmenneestä dimetoaatin vajauksesta etenkin ruiskutuskauden lopulla.

Dimetoaattia levitettiin pääasiassa virallisen suosituksen alimpana käyttömääränä. Pyretroidien käyttömäärät sen sijaan vaihtelivat voimakkaasti, mikä viittasi siihen, että monet eri valmisteet useina eri suosituksina olivat aiheuttaneet viljelijöille sekaannuksia. Uutena valmisteena kauppaan tullutta pirimikarbia ehdittiin käyttää noin 4 %:lla pelloista. Esimerkiksi Ruotsissa ja Englannissa pirimikarbista on jo aikaisemmin tullut viljan kirvojen tärkein torjunta-aine.

Kirvaruiskutus tehtiin kolmessa tapauksessa neljästä rikkakasviruiskutusten yhteydessä. Yleisimmät vesimäärät olivat 200 ja 300 l/ha.

Kirvaruiskutusten avulla saatiin ohrasta keskimäärin 400 kg/ha sadonlisä ruiskuttamattomaan verrattuna. Kauran vastaava sadonlisä oli 600 kg/ha ja vehnän 300 kg/ha. Suurin keskimääräinen alueittainen sadonlisä ohralla oli 930 kg/ha ja se saatiin ruiskutusten avulla Etelä- ja Kaakkois-Suomessa. Suurin keskimääräinen kaurasadon lisäys oli jopa 1300 kg/ha, Länsi-Suomessa, ja suurin keskimääräinen vehnäsadon lisäys 1230 kg/ha, myös Länsi-Suomessa. Ruiskutusten tehosta saadut arviot korreloivat sadonmenetysten ja viroottisuusarvioiden kanssa. Epäonnistuneiden ja onnistuneiden ruiskutusten väliset satoerot olivat samaa luokkaa kuin erot kokonaan ruiskuttamatta jätettyjen ja onnistuneesti ruiskutettujen lohkojen välillä.

Oikean torjunta-ajan valinta osoittautui tärkeäksi. Vuonna 1988, torjunta-ajan vaikutus tuli esiin selvästi Länsi- ja Sisä-Suomen alueella, joissa kirvojen tuloaika oli helposti määriteltävissä. Mahdollisimman edullisen torjuntatuloksen saamiseksi torjunta olisi suoritettava mieluimmin viikon tai ainakin 2 viikon aikana kirvojen saapumisesta. Myöhästyminen aiheutti noin 8 %:n sadonmenetyksen viikossa, ja myöhästymisistä aiheutuneet sadonmenetykset olivat vuoden 1988 ohrasadosta noin 6.5 %, kaurasadosta noin 4 % ja vehnäsadosta noin 9.5 %.

ANNALES AGRICULTURAE FENNIAE, VOL. 28: 371—383 (1989)

Seria ANIMALIA NOCENTIA N. 144 — Sarja TUHOELÄIMET n:o 144

SUSCEPTIBILITY AND REACTION OF WHEAT AND BARLEY VARIETIES GROWN IN FINLAND TO DAMAGE BY THE ORANGE WHEAT BLOSSOM MIDGE *SITODIPLOSIS MOSELLANA* (GEHIN).

SIRPA KURPPA

KURPPA, S. 1989. **Susceptibility and reaction of wheat and barley varieties grown in Finland to damage by the orange wheat blossom midge *Sitodiplosis mosellana*** (Gehin). Ann. Agric. Fenn. 28: 371—383 (Agric. Res. Centre, Inst. Pl. Protect., SF-31600 Jokioinen, Finland.)

Good coincidence was found between orange wheat blossom midge flight and ear emergence of late winter wheat varieties and early spring wheat and barley varieties in Finland. A breeding line of spring wheat showing significantly less infestation than all other varieties and lines was chosen for further screening. The appearance of injured grains in the combine harvested yield of different varieties varied greatly. In some varieties most of the injured grains were strongly shrivelled and easily sifted out from the yield during harvest. On the contrary, the injured grains of some other varieties reached almost normal size and were harvested into the yield. Differences in the reactions of various varieties were demonstrated with single grains injured by one, two or three larvae. Reactions to damage were greatly modified by variable growing conditions, but differences between varieties remained significant. Reactions were not affected by nitrogen surplus and fungicide applications.

Index words: *Sitodiplosis mosellana,* orange wheat blossom midge, grain injury, grain weight, susceptibility, varieties.

INTRODUCTION

A few studies have been carried out on the susceptibility of wheat varieties to the orange wheat blossom midge (MÜHLOW 1935, BARNES et. al 1959, BARNES and ARNOLD 1960, BASEDOW and SCHÜTTE 1974 and BASEDOW 1977). Some differences have been found, but have proved inconsistent over time. Many of these differences have appeared as a pseudoresistance, based purely on the coincidence between midge flight and ear emergence of the host. Against the sorghum midge, related to wheat midge, resistance is being, in any case, intensively screened for the use in integrated pest management, especially (TEETES 1985).

In Finland, damage due to wheat blossom midge became common at the beginning of the 1980s (HELENIUS et. al 1984) and later these midges have distributed throughout the wheat growing area of the country on winter and spring wheat, and even on barley (KURPPA 1989). In practice, observations, questions and expectations have been presented as to the differences in infestations and damage among various varieties. In plant breeding experiments it has, also, been found necessary to screen the susceptibility of new lines to the wheat midge. Therefore screening was begun in 1985 and also some older data was re-examined for this purpose.

Comparison of abundance of midge injuries among varieties and lines

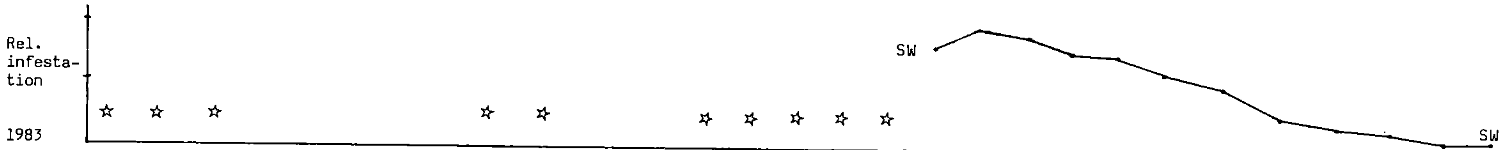
For comparing the abundance and intensity of *S. mosellana* injuries on different varieties, ear samples were taken from plant breeding experiments at the Agricultural Research Centre, Kymenlaakso Research Station at Anjalankoski, southeastern Finland, in 1983, 1985, and 1987. In 1984, injured grains were counted from the combine-harvested raw yield, because ear samples were not available. The relationships of varieties in this material, however, were in agreement with counts of larvae numbers from the same material presented by HELENIUS et al. (1984). The year 1986 was omitted, because the abundance of midges in that year was practically zero. In addition, winter wheat samples were also collected from another research station at Kokemäki, 300 km west from the first mentioned station. The number of varieties and lines of each year is presented in Table 1.

Experimental plots were 10—12 m² in size and situated in random order in three replicates. Sampling was timed to the later part of midge larval development, which occurs at the late milk to soft dough development stage (on the decimal scale GS 77—85, ZADOKS et al. 1974) of cereal grains. In 1985 and 1987, samples were formed of 25 ears taken from two replicates of the field experiments. During the first year only 10 ears were incorporated into one sample. Each grain from all of the ears was observed from fresh or deep-frozen samples under a microscope. The size of midge larvae was observed and weight measured if a variation in size was obvious.

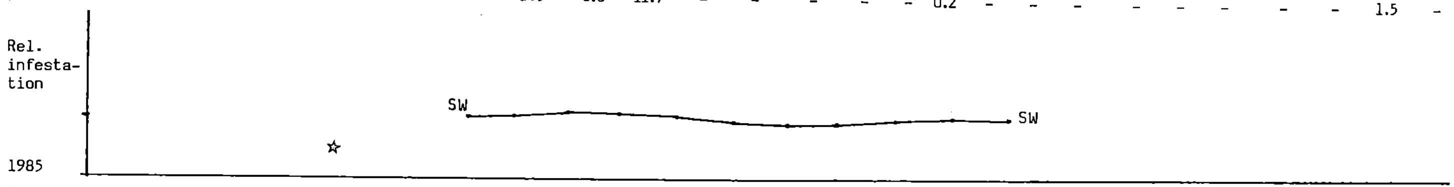
The observed abundance of injured grains on different cultivars was first compared to the total mean abundance of injuries on all varities and lines for each cereal species in every year (relative infestation). In order to ensure precision, infestation between varieties and lines was compared each day of a variety's specific period of ear emergence (relative infestation per day). The variation of the mean intensity of infestation during the total period of ear emergence of various varieties was thought to describe the variation of infestation pressure during this time. This was taken into account by assigning a daily weight; 1 for the day of the mean of infestation for all varieties and lines over the total period of ear emergence, and higher or lower values directly related to the mean intensity of infestation of a particular day (daily weight of infestation pressure). Relative infestation per day of each variety was then divided by this daily weight of infestation pressure and, finally, the mean of these values was calculated over the ear emergence period of the particular variety (mean relative daily weighted infestation). Relative infestation intensity over the years was determined for each variety as a mean of annual values or by weighting the annual values according to the relative strength of infestation between years, giving the values from years of high midge abundance more importance in the mean.

Measuring effect of injuries on yield

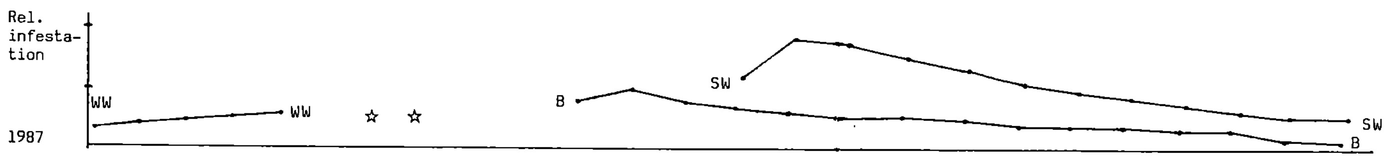
The effect of midge larvae injuries on wheat yield was studied from samples of commercial varieties and one breeding line, in 1985 and 1987. The breeding line was WW19052, and was chosen for this study because in previous studies, it had been found to suffer significantly less injury than other lines and varieties. Injured grains were separated from 2 samples of 0.1 l in volume taken from a combine-harvested and sifted (1 mm crevice sieve) yield lot of each variety and a line. The yields were earlier combined from subsamples of three replicates in the field. The abundance of injuries in the grains of the yield was compared with that on the field (ear samples explained above). The



Date	18.6.	19.6.	20.6.	21.6.	22.6.	23.6.	24.6.	25.6.	26.6.	27.6.	28.6.	29.6.	30.6.	1.7.	2.7.	3.7.	4.7.	5.7.	6.7.	7.7.	8.7.	9.7.	10.7.	11.7.	12.7.	13.7.	14.7.	15.7.
dd °C	400		430					467					512					568					637					718
max/min	18/13	22/7	20/13	15/7	16/2	19/3	20/5	17/9	20/8	18/10	17/10	18/12	19/9	23/12	24/12	20/13	18/9	20/8	22/10	25/12	28/11	30/12	31/14	30/13	29/13	28/13	21/13	22/7
prec.mm	-	0.2	-	0.1	-	-	-	-	0.5	8.0	11.7	-	-	-	-	-	0.2	-	-	-	-	-	-	-	-	1.5	-	1.9



Date	30.6.	1.7.	2.7.	3.7.	4.7.	5.7.	6.7.	7.7.	8.7.	9.7.	10.7.	11.7.	12.7.	13.7.	14.7.	15.7.	16.7.	17.7.	18.7.	19.7.	20.7.	21.7.	22.7.	23.7.	24.7.	25.7.
dd °C	393					429					477					544					600					656
max/min	17/4	16/7	13/7	18/9	21/4	23/8	22/11	20/8	19/9	21/12	22/14	26/8	26/9	26/10	21/16	24/13	21/16	20/10	17/13	22/9	20/14	21/12	20/14	21/8	23/9	22/16
prec.mm	-	0.2	0.6	-	-	-	18.8	9.3	5.4	0.7	-	-	-	-	1.1	-	-	5.7	1.3	-	0,9	4.7	6.9	-	2.8	-



Date	2.7.	3.7.	4.7.	5.7.	6.7.	7.7.	8.7.	9.7.	10.7.	11.7.	12.7.	13.7.	14.7.	15.7.	16.7.	17.7.	18.7.	19.7.	20.7.	21.7.	22.7.	23.7.	24.7.	25.7.	26.7.
dd °C				418					476					519					560					629	
max/min	20/10	21/10	20/3	21/4	24/12	25/11	25/14	21/13	18/11	15/11	18/9	20/8	19/12	18/12	14/5	20/1	22/4	23/9	24/6	27/7	28/9	28/10	26/12	19/15	19/11
prec.mm	-	-	-	-	11.5	6.6	2.3	-	4.0	5.1	-	-	-	-	-	-	-	-	-	-	-	-	5.2	-	-

Table 1. Mean daily relative infestation of the orange wheat blossom midge on spring wheat (SW), winter wheat (WW) and barley (B). The scales for winter wheat and barley are 1/5 of the scale of spring wheat. Cumulative daydegrees over 5 °C (dd), daily temperatures (min/max) and amounts of daily precipitation (prec. mm) are presented. All results from the Agricultural Research Centre, Kymenlaakso Research Station in Anjalankoski. In 1983 9 varieties and 12 lines (21 plots), in 1985 9 varieties and 16 lines (25 plots), in 1987 barley: 19 varieties and 17 lines, spring wheat: 7 varieties and 13 lines (49 plots), winter wheat: 7 varieties and 5 lines. Stars indicate days of suitable conditions to midges to fly.

grain weight, measured from two samples of 400 grains, was compared between the injured and noninjured fraction, and the rate of weight loss due to injuries was compared among varieties.

The effect of larval number on the extend of injury on a single grain was studied from ears sampled at the early dough stage (GS 83) obtained from plant breeding experiments at the Sata-Häme Research Station at Mouhijärvi in 1988. Grains with one larva, two larvae and three or more larvae were extracted from the ears, and control grains for each larvae infested grain were taken from the same level at the opposite side of each ear. The ears were uniform in length (= total grain number) and the number of infested grains per each ear was one or two. The number of grain pairs at all infestation levels was 50. Losses in grain weight caused by different numbers of larvae were compared among varieties.

Observations on the effect of excessive nitrogen and fungicide application on appearance of injuries in yield

The effect of excessive nitrogen and fungicide application on spring wheat was investigated from experiments conducted by Kemira Co. at their research station, in Stor Sarvlax, Lovisa in 1987 and in Västankvarn, Sibbo in 1988. The experimental years and their growing conditions were opposite to each other. Nineteen eighty-seven was wet and cool, effective daydegrees over 5 °C were 997 °C and amount of precipitation 441 mm at harvest. Nineteen eighty-eight was very warm and dry; effective daydegrees totalled 1323 °C and amount of precipitation 220 mm. Thus, highly variable nitrogen mobility in the soil and pressure for fungal diseases could be expected.

The experimental plots were 12.5 m² in size and situated in random order inside four replicates. Nitrogen was placed in 8 cm at sowing. The lower amount of nitrogen, 120 kg/ha, was that normally used in intensive farming and 160 kg/ha represented an excessive amount. The earlier fungicide application was performed on the first days of the accepted application time for propiconazol, at tillering, and the later during the final days of the application period, at ear emergence. Fungicide was sprayed with a portable azopropane sprayer using a pressure of 0.25—0.3 MPa and an amount of water 200 l/ha. Yield was harvested by an experimental combine harvester.

Samples of 1 kg from the raw yield were used for separating injured grains and weighing grains from the noninjured and injured fraction. The fraction of injured grains was sifted by a 2.4 mm crevice sieve. The grains that passed through weighed less than 80 % of normal noninjured grains. The weight of noninjured grains and the two fractions of injured grains were measured as explained above.

RESULTS

Coincidence of ear emergence of various varieties with flight of the wheat orange midge

At the Kymenlaakso Research Station, the first emergence of spring wheat ears occurred at the daydegrees 555 °C, 510 °C, 460 °C and 520 °C in 1983, 1984, 1985 and 1987, respectively. As orange wheat blossom midges emerged at 400 °C daydegrees, the waiting period before emergent ears were available varied from two and a half weeks (1983) to about a week (1985) (Table 1). During 1985, the year of the highest wheat blossom midge damage, the intensity of infestation began after a short waiting period, and remained high throughout ear emergence of all varieties. In the years characterized by a long waiting period the intensity of infestation peaked shortly after the ears of the earliest varieties appeared.

The first winter wheat ears emerged as early as at daydegrees 310—350 °C and ears of later varieties were emergent at the time of wheat blossom midge appearance. Thus the intensity of infestation increased up to the end of the emergence of the latest variety (Table 1). The intensity of winter wheat infestation was, e.g. in 1987 at Anjalankoski, only 1/10 of the intensity of infestation of spring wheat. This relation, however, varied between years and growing habitats. In 1984, major infestations were found on winter wheat, but overall numbers of damage were very low. Barley ears emerged a few days before those of wheat. Similarly as on spring wheat the intensity of infestation peaked upon ear emergence of the earliest varieties (Table 1). The maximum intensity was 1/4 and at the mean 1/10 of the intensity of infestation of spring wheat. This relation was confirmed at Sata-Häme Research Station (Mouhijärvi) in 1988. The intensity of infestation there was a sixth of the infestation of spring wheat in the same area.

The flight of the orange wheat midge was initiated by the end of normal ear emergence of winter wheat varieties. The flight period of the midge extended to the emergence of the earliest barley and spring wheat varieties, at least (Table 1). The theoretical description of the mean coincidence of flying midge population and ear emergence of winter and spring wheat showed why injuries in winter wheat are often concentrated on the top grains of ears, and on spring wheat on the grains in the middle section of the ear (Fig. 1).

Susceptibility of wheat and barley varieties to orange wheat blossom midge infestation

When the mean daily relative intensities of infestations and mean annual relative intensities of infestations were taken into account, the spring wheat line WW19052 was found to be the least infested. Of the commercial varieties, Luja was slightly less infestated than the others. This difference as well differences among other varieties, were obscured by high annual variation. Tähti, for instance, was only slightly infested when overall infestations were reasonable, but with increase in overall infestation the intensity of infestations on Tähti increased abruptly (Table 2).

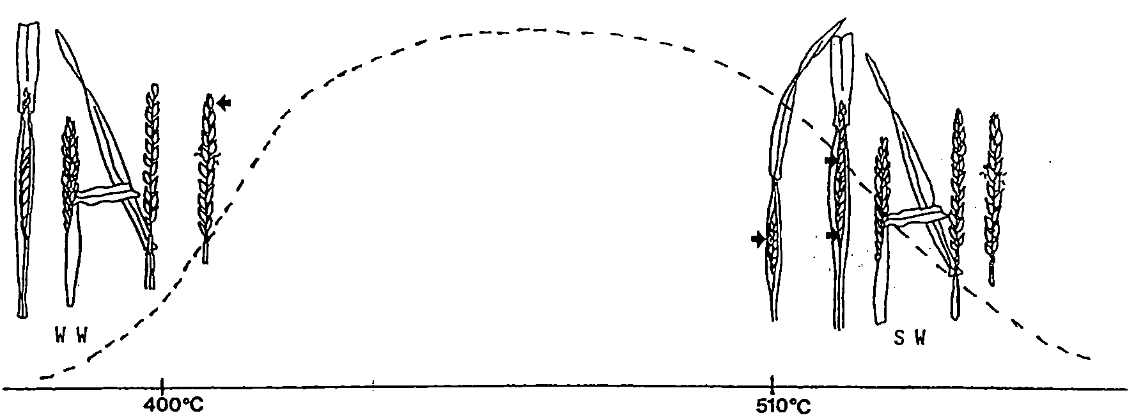
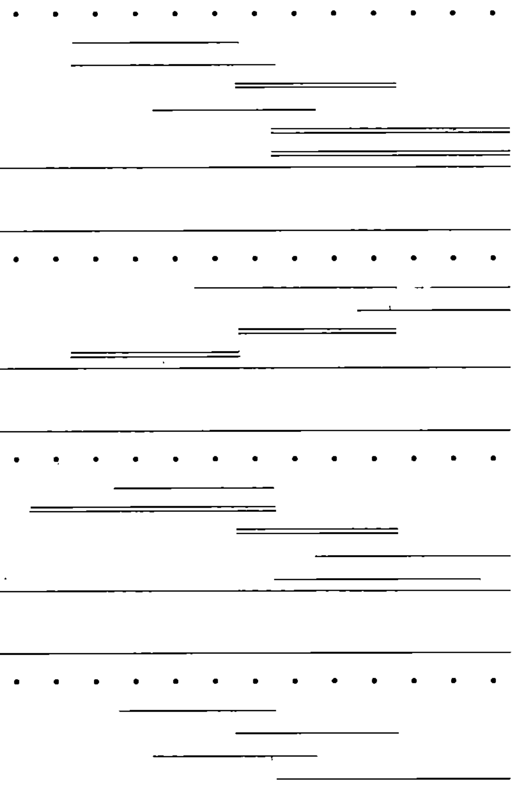


Fig. 1. Theoretical description of the mean coincidence of the flying and egg laying population of the orange wheat blossom midge, *S. mosellana*, and the emergence of winter (WW) and spring wheat (SW), in Finland. Daydegrees are counted on the basal temperature of 5 °C. The areas of ears with concentrated midge infestation are indicated by arrows.

Table 2. Observed, relative, relative daily weighted infestation intensity of orange wheat blossom midge, *S. mosellana*, on different spring wheat varieties and a line, in 1983—1987, at the Agricultural Research Centre, Kymenlaakso Research Station. Daily coincidence of ear emergence and midge flight is indicated by line. Douple line indicate relatively high infestation.

Variety -year (m = org. s = clay soil)	Obs. infest. % of grains	Relative infest. between varieties each year	Relative daily weighted infest. intensity	Period of ear emergence (——) during period of midge flight Days from first coincidental ear emergence and wheat midge flight
Jo8187				
-83	90.2	240	143	
-84	7.0	410	594	
-85m	72.1	132	131	
Mean			376 ± 235	
-year weighted			162	
Ulla				
-83	42.2	115	67	
-84	2.4	140	243	
-85m	57.9	106	98	
-87m	68.4	364	268	
-87s	23.8	225	296	
Mean			194 ± 104	
-year weighted			126	
Tapio				
-83	18.8	50	33	
-84	1.9	110	159	
-85m	56.8	104	101	
-87m	42.3	225	293	
-87s	24.7	233	306	
Mean			179 ± 120	
-year weighted			121	
Reno				
-83	50.8	135	90	
-84	3.6	216	308	
-85m	50.8	93	97	
-87m	20.1	107	159	
-87s	9.7	92	137	
Mean			158 ± 88	
-year weighted			101	
Runar				
-83	44.0	117	70	
-84	1.5	85	123	
-85m	49.1	90	92	
-85s	57.8	122	111	
-87m	19.2	102	106	
-87s	19.8	187	246	
Mean			125 ± 62	
-year weighted			117	
Ruso				
-83	30.1	80	53	
-84	1.7	100	147	
-85m	44.8	82	84	
-87m	15.2	62	91	
-87s	8.4	94	138	

Mean			102±39	
-year weighted			76	
Kadett				
-83	43.6	116	77	
-84	1.1	65	92	
-85m	56.2	101	109	
-85s	32.2	68	70	
-87m	11.6	62	102	
-87s	9.9	94	155	
Mean			101±30	
-year weighted			101	
Tähti				
-83	34.6	24	32	
-84	1.4	100	76	
-85m	61.1	112	120	
-85s	62.1	131	122	
Mean			87±43	
-year weighted			127	
Luja				
-83	8.3	22	16	
-84	1.4	80	116	
-85m	56.8	104	112	
-87m	7.5	40	71	
-87s	3.1	29	46	
Mean			73±38	
-year weighted			63	
WW19052				
-83	16.2	43	31	
-85m	30.8	68	73	
-85s	37.1	65	67	
-87m	3.2	17	28	
-87s	3.1	29	48	
Mean			49±20	
-year weighted			71	
Annual mean	37.6	1.4	Daily weight of inf. intens. -83	1.1 1.9 1.8 1.5 1.5 1.3 1.2 .5 .3 .3 .3 .3 .3
	1.7	0.06	-84	.7 .6 .6 .6 .7 .8 .8 1.5 1.3 1.3 1.3 1.3 1.3
	51.0	1.9	-85	1.1 1.1 1.2 1.1 1.0 1.0 .9 .9 .9 .9 .9 .9 .9
	15.9	0.6	-87	1.2 1.7 1.6 1.5 1.3 1.0 .9 .9 .7 .6 .5 .5 .5



In the case of winter wheat, the ears of infested varieties emerged after 350 °C. No significant differences in varieties or lines with simultaneous ear emergence could be found (Table 3).

The barley varieties Arra, Niina, Pokko, Pomo and Kymppi could be designated as more infested. Eero and Kalle were clearly less infested than the others (Table 4).

Weight loss of the damaged grains of different varieties

In the ears, the decrease in the grain weight of spring wheat depended on the number of larvae per grain and varied among varieties. With one larva per grain, the minimum decrease in grain weight was 16.7 % and maximum 61.7 % (Table 5). With two or three lar-

Table 3. Observed and relative infestation intensity of *S. mosellana* on different winter wheat varieties and a few lines, in 1987, at the Agricultural Research Centre, Kymenlaakso Research Station, in Anjalankoski and the Satakunta Research Station, in Kokemäki. Daily coincidence of ear emergence and midge flight is indicated by a line.

Variety	Obs. infest. % of grains	Relative infest. between varieties	Period of ear emergence (____) during period of midge flight Dates from first wheat midge flight 27.6. 1.7. 6.7.
Kymenlaakso			
Miranowsk.	1.8	98	
Pitko	1.5	81	
Vakka	1.5	81	
Aura	0.8	43	
Ilves	1.9	103	
Hja21614	1.9	103	
Hja21682	2.0	109	
Kosack	2.4	130	
Folke	2.3	125	
Mean	1.84		
Daydegrees			340 410
Peipohja			
Miranowsk.	0.4	19	
Vakka	0.4	19	
Pitko	0.9	43	
Ilves	0.6	28	
Aura	4.4	209	
Hja21614	2.8	133	
Hja21682	0.8	38	
Folke	2.4	114	
Nisu	2.4	114	
Linna	4.0	190	
Mean	2.1		
Daydegrees			305 350

vae per ear the decrease were 44.5—77.6 % and 51.2—95.5 %, respectively. The intensity of the decrease in grain weight at the level of one larva per ear was lowest in early varieties and highest in late emerging varieties (Table 5). The relative grain size compared to Ruso noninjured grain (fresh g.w. 37 mg) was, at the level of one larva per grain, lowest in Kadett and highest in Ruso, itself. The grains of Ruso remained the biggest at the level of 2 larvae per grain, but the differences among varieties were more obscure.

There were great variations in grain weight among the cultivars Reno, Runar and Kadett, at one larva per ear. A few single, one-larva-infested grains had nearly grown to the weight of noninfested grains, but many other specimens infested grain were strongly shrivelled. In the case of Reno, especially, the size of second and third larvae were often abnormally small. Similar small larvae were found in other varieties also but at the level of infestation of over three larvae per ear. Variations in larval size in all of the varieties were clearly highest in 1987. Then, the mean weight of the smallest larvae was only about 35 % of the mean weight of the biggest larvae. In 1988, the weight of the smallest larvae was about 75 % of the largest.

In the combine-harvested yield, the grain weight decreased by 29 %, on average (Table 6). Of the original number of injured grains in ears, 87—93 % was included into the yield of the varieties Luja and Ruso. On the contrary, with the varieties Tapio, Runar, Kadett and the

Table 4. Observed, relative and relative daily weighted infestation intensity of *S. mosellana* on barley varieties at the Agricultural Research Centre, Kymenlaakso Research Station, in Anjalankoski, in 1987. Daily coincidence of ear emergence and midge flight is indicated by a line.

Variety	Mean % of grains	Relative infest. between varieties	Relative daily weighted infest. intensity	Period of ear emergence (____) during period of midge flight Dates from first coincidental ear year emergence and wheat midge flight
				12.7 … 22.7
Hja Potra	1.8	131	78	
Arra	3.4	245	157	
Hja Eero	0.8	60	46	
Kilta*	1.4	101	84	
Kalle	1.8	48	36	
Niina	1.9	137	134	
Pohto	1.1	80	77	
Agneta	1.0	74	88	
Pokko*	1.8	131	170	
Kustaa (2)*	0.9	61	88	
Pomo	2.0	146	219	
Apex (2)	0.5	34	51	
Kymppi (2)*	1.5	105	171	
Mette (2)	0.2	17	28	
Spirit (2)	1.3	91	156	
Ida (2)	0.7	51	87	
Trine	3.2	231	395	
Havila (2)	0.5	34	58	
Nafy (2)	0.1	9	52	
Mean		Daily weight of infestation		1.7 2.0 1.6 1.4 1.2 1.0 1.0 .9 .8 .8 .8 .7 .8

Two row varieties indicated by (2)
Four samples from varieties indicated by *, two from the others.

Table 5. Relative decrease of preharvested grain dry weight due to midge injury, in early, middle early and late varieties of spring wheat. Number of the pairs of injured grains and noninjured control grains, opposite side of the particular ear, was 50.

Variety	Mean g.w. at samling mg (fresh)	Relative decrease of g.w. (% ±s.e.) and relative size (fresh weight of grains compared to Ruso noninjured = 100) in brackets		
		1 larva/grain	2 larvae/grain	3 or more larvae/grain
Early:				
Luja	34	16.7±2.7 (76)	49.9±6.3 (52)	62.8±11.0 (39)
Ulla	37	26.9±5.5 (73)	55.3±0.5 (46)	80.5±0.7 (20)
Midle early:				
Reno	33	34.6±10.3 (52)	47.4±2.6 (42)	51.2±1.1 (39)
Ruso	37	22.3±1.0 (78)	44.5±5.1 (56)	81.7±2.8 (18)
Tapio	38	44.5±9.2 (48)	68.1±2.7 (28)	87.1±3.0 (11)
Late:				
Runar	39	34.7±10.5 (65)	60.4±6.9 (40)	88.9±5.0 (11)
Kadett	39	61.7±11.6 (31)	77.6±2.9 (18)	95.5±5.0 (4)

line WW19052 only a third or less of the originally injured grains were found in the harvested yield. The decrease in grain weight was slightly stronger in 1987 than in other years, but the relation between varieties remained unaffected.

Effect of growing conditions with nitrogen and fungicide applications on appearance of damage in different varieties

The proportion of injured grains present in the yield at harvest was more than twice as high in Luja than Kadett (Table 7) in both years. Grain weight in the injured fraction was strongly affected by growing conditions, being around 60 % of the grain weight in the noninjured fraction, in 1987, but under 40 % in 1988. The proportion of small grains sifted out of a 2.4 mm crevice sieve (grain weight less than 80 % of weight of noninjured grains) formed 76—100 % of the injured grains in Kadett but 50—79 % of the injured grains in Luja. In 1987, Kadett constituted a special case as it did not include any bigger injured grains at all. In the case of Luja, on the contrary, even 50 % of injured grains were left in the yield after sifting. In 1988, this difference was greatly diminished.

Excessive nitrogen or fungicide application had no major effect on the appearance of damage in the yield. In 1987, the weight of noninjured grains was slightly higher with a nitrogen surplus, and thus in Luja the proportion of small injured grains increased. Similar changes were not found in 1988. At that time, fungicide application caused a slight increase in the grain weight of Kadett, without any further effects.

Table 6. Number percentage of *S. mosellana* injured grains of ears found in the yield after combine harvesting and cleaning through 1 mm sieve, and relative difference between the weight of noninjured grains and injured grains in the yield. Material from the years 1985 and 1987 at the Kymenlaakso Research Station (Anjalankoski).

Variety	No % of injured grains included to yield	Rel. decrease of g.w. in injured grains
Luja	93 ± 7	30.4 ± 4.8
Ulla	47 ± 9	25.3 (only in 1987)
Reno	37 ± 18	25.3 ± 6.0
Ruso	87 ± 13	26.9 ± 8.3
Tapio	21 ± 10	31.8 ± 3.2
Runar	24 ± 2	30.4 ± 6.3
Kadett	28 ± 6	27.4 ± 4.8
WW19052	24 ± 6	37.8 (only in 198)
	Mean	29.4

DISCUSSION

When the observations on wheat ear emergence were compared with the data on wheat blossom midge emergence (KURPPA 1989), a coincidence was present but not optimal, in Finland. The appearance of midges in the fields is in most years slightly too late to infest winter wheats, or slightly too early to infest spring wheats. Barley is, according to this study and additional observation from farmers' fields, a host of secondary value to the midge. The differences between midge larvae abundance on winter wheat are most obviously due to the coincidence between a sensitive period of plant development and midge flight. In 1986, for instance, when midge abundance at Anjalankoski was extremely low, fairly high populations of midges, especially in later varieties were found, in western areas of the country (KURPPA 1989).

The quality of line WW19052, which showed significantly less infestation, is the object of further detailed studies. Poor coincidence between the sensitive period of this variety and midge flight, so called pseudoresistance, is not the explanation. However the structure of its ear arouses speculation. Before flowering the florets of WW19052 are very compact in the ear. This quality has been suggested to be a resistance factor in old Swedish varieties (MÜHLOW 1935) and has been widely studied with the sorghum midge *C. sorghicola* (Coquillet) (TEETES 1985). Other candidate mechanisms of midge resistance would be nonpreference and antibiosis as explained by ROSSETTO (1985), for instance.

Damage caused by the same number of midges varies clearly among varieties. It seems

Table 7. Effect of growing conditions (years 1987, 1988) with nitrogen fertilization (from 120 kg N/ha = 1N to 160 kg N/ha = 2N) and fungicide application (propiconazol 125 g/ha, 1P = at tillering, 2P = at ear emergence) to proportion of injured grains and rate of grain weight decrease due to *S. mosellana* injuries. Significant differences are indicated by different letters: A, B, C between varieties and a, b, c between treatments of each variety. Grains sifted out with 2.4 mm crevice sieve (weight less than 80 % of the weight of uninjured grains) are referred by 'small grains.

Treatment	% injured grain weight of raw yield	G.w. of non-injured grains	Loss of g.w. due to injury %	% small grains in no of injured	Rel. yield kg/ha	% injured as small grains sifted out from yield
1987						
Luja 1N	10.1	35	37	62	100	5.4
Luja 2N	12.2	38	40	70c	116	5.5a
Luja 1N1P	12.3	35	34	50b	102	8.4c
Luja 2N1P	10.5	39	41	65a	115	5.6a
Luja 1N2P	10.0	38	38	66a	96	5.0a
Luja 2N2P	9.3	36	42	79c	107	3.0b
	10.7A	37	39	65A		5.5A
Inj. grain no in ears	17.7 %					
Inj. grain no in yield	17.5 %					
Kadett 1N	1.6	34	35a	100	100	0.0
Kadett 2N	1.5	34	41a	100	103	0.0
Kadett 1N1P	1.8	34	41a	100	110	0.0
Kadett 2N1P	1.8	35	34a	100	111	0.0
Kadett 1N2P	1.6	36	50b	100	120	0.0
Kadett 2N2P	1.5	37	51b	100	112	0.0
	1.6B	35	42	100B		0.0B
Inj. grain no in ears	9.1 %					
Inj. grain no in yield	2.9 %					
1988						
Luja 1N	3.7	31	64	77	100	2.0
Luja 2N	3.1	31	67	78b	104	1.8
Luja 1N1P	2.8	32	67	72	102	1.9
Luja 2N1P	2.4	32	67	71	102	1.9
Luja 1N2P	2.7	32	68	70a	99	2.2
Luja 2N2P	3.0	31	66	74	107	2.0
	2.9A	31A	67A	73A		2.0A
Inj. grain no in ears	9.5 %					
Inj. grain no in yield	8.8 %					
Kadett 1N	1.5	36a	63a	83	100	0.6
Kadett 2N	2.2	33b	58b	86b	100	0.7
Kadett 1N1P	1.5	37a	65c	78a	102	0.8
Kadett 2N1P	1.1	35a	65c	78a	102	0.6
Kadett 1N2P	1.6	37a	65c	76a	99	1.0a
Kadett 2N2P	1.4	36a	63ac	85	102	0,5b
	1.5B	36B	63B	81B		0.7B
Inj. grain no in ears	9.1 %					
Inj. grain no in yield	4.2 %					

that the varieties with a higher potential for grain number per ear, as Kadett for instance, produce a kind of hypersensitive reaction to injury than varieties with a lower potential for grain number and higher potential to sustain grain formation. The variety Luja is known to be a good representative of the later group. It is, for instance, the best of the Finnish varieties in mobilizing the nitrogenous components in the leaves for grain (Kontturi oral inf.). Decreased weight of the many larvae feeding on strongly shrivelled grain refers to overpopulation.

In practice, the hypersensitive reaction of a single grain is positive, because the grains would then not be present to cause the critical loss of baking quality of the wheat yield (HELENIUS and KURPPA 1989). In addition, it is possible that uninjured grains surrounding the injured, sensitively reactive ones, are able to compensate the injury by a slightly higher weight. This phenomenon was found to be true in 1985 (HELENIUS and KURPPA 1989), and was referred by BASEDOW and SCHÜTTE (1973) with the yellow wheat midge (*Contarinia tritici*, Kirby) and has been also well documented for the sorghum midge (ROSSETTO 1985). A wage indication of compensation was found when measuring the weights of grains of injured and uninjured ears in this study, but the number of additional uninjured ears was not high enough. Compensation ability theoretically depends on the section of the ear in which the grains are injured. Grains in the middle of the ear have the greatest potential for growth while those at the base and top most possibly shrivel if growing conditions turn critical. This refers to a reactional difference between winter and spring wheat (compare Fig. 1). It is moreover difficult to know if plant strategy in compensating injuries would be to increase grain size or to continue producing more grains from the top of the ear. In any case, this is a fact that should be taken to account when modifying the control threshold for each particular instance. This also partly explains the difference between control thresholds in Gentral Europe (BASEDOW and SCHÜTTE 1973) and Finland (KURPPA 1989).

The tendency of injured grains to disappear from the yields of Kadett and Tapio might be the reason why midge damage at the beginning of 1980s was noticed fairly late when infestation had already reached very high proportions. Specifically, Kadett and Tapio were mostly grown in the primary center of the infested area.

Growing conditions seem to modify the reactions of grains to injury. In 1987, many farmers growing Kadett as well as Tapio never noticed midge injuries in the yield, but with Luja, for instance, injuries were present as usual. Intensive growing may cause only slight changes in primary midge infestation and appearance of infestation in the yield. However, differences among varieties in their reactions to damage cannot be eliminated by nitrogen or fungicide applications.

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SELOSTUS

Suomalaisten vehnä- ja ohralajikkeiden herkkyys tähkäsääsken vioituksille ja vioitusten ilmeneminen sadossa

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Maatalouden tutkimuskeskus

Tämän tutkimuksen sääskihavainnot tehtiin ja näytemateriaali kerättiin vuosina 1983—1988, pääosin Maatalouden tutkimuskeskuksen Kymenlaakson tutkimusasemalta, kasvinjalostuslaitoksen ja kasvintuotannon tutkimuslaitoksen järjestämistä lajikekokeista.

Tähkäsääsken lento ja muninta osui parhaiten samaan aikaan myöhäisten syysvehnälajikkeiden ja aikaisten kevätvehnä- ja ohralajikkeiden tähkälletulon kanssa. Ohra osoittautui toissijaiseksi isäntäkasviksi. Siinä esiintyneet sääskitoukkamäärät olivat vain 1/4—1/10 kevätvehnässä tavatuista määristä. Syysvehnän saastuvuus näytti riippuvan tähkälletuloajasta, myöhäiset lajikkeet vioittuivat pahiten.

Kevätvehnän jalostuslinjasta (WW19052, Weibull) löytyi säännöllisesti muita lajikkeita ja linjoja selvästi alhaisempia toukkamääriä. Kyseisen lajikkeen tähkä on rakenteeltaan hyvin tiivis, mikä ominaisuus on aikaisemminkin liitetty tähkäsääskisaastunnan estoon.

Tähkäsääsken vioitukset ilmenivät eri tavoin eri lajikkeiden sadoissa. Esimerkiksi lajikkeiden Kadett, Tapio ja Runar vioittuneet jyvät jäivät surkastuneiksi ja erottuivat sadosta helposti jo puinnin yhteydessä, kun taas lajikkeiden Luja ja Ruso vioittuneetkin jyvät kasvoivat lähes normaalikokoisiksi ja joutuivat satoon. Vioittuneiden jyvien aiheuttama laatuvaurio on jälkimmäisessä ryhmässä huomattava. Nämä lajike-erot osoitettiin myös punnitsemalla yksittäisiä 1—3 toukan vioittamia jyviä. Sääolot muuntelivat sääskitoukkien aiheuttamien jyvävioitusten voimakkuutta ja säätelivät siten vioituksista aiheutuvien sadon laatuvaurioiden merkitystä eri vuosina. Lajike-erot kuitenkin säilyivät vaikka kasvukauden sääolot vaihtelivat tai typpilannoitusta ja fungisidien käyttöä lisättiin.

ANNALES AGRICULTURAE FENNIAE, VOL. 28: 385—396 (1989)

Seria ANIMALIA DOMESTICA N. 87 — Sarja KOTIELÄIMET n:o 87

EFFECT OF LONG-TERM USE OF RAPESEED MEAL ON EGG PRODUCTION

TUOMO KIISKINEN

KIISKINEN, T. 1989. **Effect of long-term use of rapeseed meal on egg production.** Ann. Agric. Fenn. 28: 385—396. (Agric. Res. Centre, Inst. Anim. Prod. SF-31600 Jokioinen, Finland.)

In a long-term study with two generations of White Leghorn hens the use of RSM did not have any consistent effect on the performance of chicks during the rearing period. Egg production and feed intake of the first generation were not significantly affected by the RSM feeding but signs of decreased egg weight could be found especially at the level of 10 % LG-RSM. Decrease of egg weight in the RSM groups was more prominent during the second generation with groups 5 and 6 (10 % LG-RSM) differing significantly ($P<0.05$) from group 1 (control). In laying intensity no significant differences were ascertained but daily egg mass production of the RSM groups was on average 1.7 g lower than in the control group and significant differences were found.

Albumen or eggshell quality were not significantly affected by RSM feeding excluding group 6 which seemed to have the lowest Haugh-unit, particularly in the second generation. The use of RSM did not affect fertility or hatchability of eggs. Day old chicks of the RSM groups were smaller than those of the control group and the first mentioned had a tendency towards enlargement of thyroid glands.

Mortality among hens fed RSM increased during the laying periods and the most important cause of death was damaged liver (fatty, fragile, haemorrhagic broken). RSM caused on average doubled the weight of the thyroid glands.

The results suggest that although the type of LG-RSM used is limited to the level of 5—10 % in the layer's diet, it nevertheless increases mortality during the relatively long life cycle of the hen. LG-RSM in the rearing diets does not seem to affect the results. Used at a dietary level of 5 % HG-RSM and LG-RSM do not seem to differ in their effect on bird performance. The results also suggest that RSM should not be included in the diets of breeding hens because the hatched chicks may have a weaker starting point due to enlarged thyroid glands.

Index words: rapeseed meal, chicken, hen, growth, egg production, reproduction, mortality, thyroid weight, liver lesions.

INTRODUCTION

The results of some studies suggest that negative effects such as increased mortality and impaired performance of hens due to the use of rapeseed meal (RSM) could be reduced by already feeding RSM during the growing period (MARCH et al. 1975, HULAN and PROUDFOOT 1980a). This has been presented to be caused by the adverse effects of the abrupt transition from a soybean meal (SBM) grower diet to a RSM layer diet. However, this observation was not confirmed by HULAN and PROUDFOOT (1980b) and furthermore, there are several influential factors such as the quality and level of RSM, the period of time over which RSM is fed and even the genotype of the birds (MARCH et al. 1975, PROUDFOOT et al. 1983). According to MARCH et al. (1975) and KIISKINEN (1983a) mortality, especially as a result of liver haemorrhage, increased during the laying period among birds fed high dietary concentrations of RSM during the growing period as well. Rapeseed meal has not generally affected the fertility or hatchability of poultry. The abundant use of RSM for breeding hens has led to enlarged thyroid gland in hatched chicks (MARCH et al. 1972, CAWECKI et al. 1972, LESLIE and SUMMERS 1975, LIPINSKA 1978, KIISKINEN 1983a). Apparently this is caused by the reduced transfer of iodine to the egg yolk reported to be due to the inclusion of RSM in the layer diet (GOH and CLANDININ 1977).

The purpose of this work was to investigate the effects of long-term feeding of RSM on White Leghorn chickens during both the growing and laying periods of two generations. Moderate dietary concentrations of low glucosinolate (LG-RSM) and high glucosinolate meal (HG-RSM) and different quantity combinations of LG-RSM between the periods were used.

MATERIAL AND METHODS

Birds, housing and management

White Leghorn chickens (Strain SK 51) of each generation were reared in a windowless house equipped with four three-tier batteries of colony cages (1 × 1 m). In each cage 21—22 birds were housed up to the age of 18 weeks when the birds were moved to a layers' house with three-tier batteries. Three hens were placed in each cage (700 cm^2/hen). In both the rearing and laying house the birds had access to feed and water from nipple drinkers at all times. Similar lighting and room temperature programs were maintained as described by this author (KIISKINEN 1983a). A total of 220 cocks of the first generation which were reared among the hen chickens of the corresponding group were housed in individual cages of three-tier batteries in a different room. The laying period of the first generation lasted around 11 months or 12 periods of 28 days and that of the second generation 7.5 months (8 × 28 days). Hens of the first generation were artificially inseminated with sperm of the cocks of the corresponding group.

Experimental design, rapeseed meals and diets

The study comprised six treatments in which rapeseed meal (RSM) was included in the rearing and laying diets according to the following plan: Group 1 (control) 0 and 0 % RSM; Group 2, 5 and 5 % HG-RSM; Group 3, 5 and 5 % LG-RSM; Group 4, 0 and 10 % LG-RSM; Group 5, 5 and 10 % LG-RSM and Group 6, 10 and 10 % LG-RSM. Each RSM was obtained from the Finnish vegetable oil industry with HG-RSM representing the average commercial meal and LG-RSM originating from the Canadian cultivar Sigga (*Brassica campestris* summer type). Chemical analyses indicated an approximately equal crude protein content in each meal but oil content was higher and crude fibre lower in the LG-RSM than in the HG-RSM (Table 1). The amino acid composition of protein was very similar in each RSM type. The content of total glucosinolates was 51.5 μmol/g in the HG-RSM and 18.8 μmol/g in the LG-RSM. The first mentioned value represents a typical content in commercial meal.

RSM replaced soybean meal (SBM) in the

Table 1. Chemical composition of rapeseed meals used.

	HG-RSM	LG-RSM
Dry matter %	89.1	88.1
Proximate composition % of DM		
Crude protein	36.1	35.5
Ether extract	7.0	10.5
Crude fibre	13.1	11.2
Ash	7.6	7.6
Amino acids g/16 g N		
Methionine	1.9	1.9
Lysine	5.6	5.5
Arginine	5.3	5.6
Histidine	2.6	2.7
Threonine	4.3	4.5
Leucine	6.6	6.9
Isoleucine	3.8	4.1
Phenylalanine	4.1	4.2
Tyrosine	3.2	3.4
Valine	4.9	5.0
Glucosinolates µmol/g		
gluconapine	14.5	5.2
glucobrassicanapine	12.8	4.0
progoitrine	20.1	7.4
napoleiferine	4.0	1.2
Total	51.4	18.8
Tannines % of DM	1.76	1.89

diets which were made isonitrogenous (Table 2 and 3). The calculated protein content in the starter diets was 19, in the grower diets 15 and in the layer diets 15.5 %.

During the rearing period 12 replicate cages for each treatment were allotted and in the layers' house each treatment comprised seven replicate rows with 30 hens, each. The cages and rows in the houses were divided, as far as possible, so that a uniform environment was ensured for all treatments.

Measurements and statistical analyses

In each generation, the total weight in birds of each cage was determined at 6, 12 and 18 weeks of age. Feed consumption between the weighings was measured for a replicate of three cages (4 replicates/group). Egg production (number and total weight) in each replicate group was recorded daily. Feed consumption was measured at 28-day intervals. In the 2nd, 6th and 12th (8th in the 2nd generation) period 10 first eggs from each replicate row were used for the determination of specific gravity by the flotation method, shell strength with a Wazan compression force meter, albumen quality (Haugh unit) by an Ames HU micrometer and yolk colour using the Hoffman-La Roche Colour Fan scale (in the 6th and 12th period of the first generation). All hens were weighed individually at 40 weeks of age and at the end of the laying period. The thyroid glands and livers of 21 hens per treatment (three per replicate) were removed and weighed at the end of the laying period of each generation. Also the thyroid glands of one week old chicks of the second generation were removed and weighed. As far as possible all dead hens were subjected to a post-mortem examination at the National Veterinary Institute.

Proximate analyses were performed for the rapeseed meals and every lot of the experimental diets. Amino acid composition and mineral contents (Ca, P) were determined for the rapeseed meals and a pooled sample of each diet by atomic absorption. Calcium was analysed with an atomic absorption spectrophotometer (Perkin-Elmer 2380) and phosphorus with a photometer after colour reaction with ammonium vanadate. Amino acids were determined with a gas chromatograph (Hewlett Packard 5710) after hydrolysis in 6 N HCl saturated with nitrogen gas (110 °C for 20 hours). The ME-values (AME_N) of the layer diets of the first generation were determined using total excreta collection and six hens per group.

The experimental data were processed and statistically evaluated with oneway analysis of variance using a SPSS-program (Statistical Package for Social Sciences) and a VAX-8200 computer.

Table 2. Composition of the starter and grower diets.

Group nr	Starters (0—6 weeks)			Growers (7—18 weeks)		
	1 and 4	2/3 and 5	6	1 and 4	2/3 and 5	6
Ingredient (%)						
Rapeseed meal[1]	—	5HGM/5LGM	10LGM	—	5HGM/5LGM	10LGM
Fish meal	4	4	4	2	2	2
Soybean meal	18	15	12	10	7	4
Wheat	15	15	15	—	—	—
Barley	33	31	29	57	56	55
Oats	25	25	25	26.8	25.8	24.8
Rapeseed oil	1	1	1	0.5	0.5	0.5
Limestone	0.9	0.9	0.9	0.8	0.8	0.8
Dicalc. phosphate	1.7	1.7	1.7	1.5	1.5	1.5
Salt	0:35	0.35	0.35	0.35	0.35	0.35
Micronutrients[2]	1.0	1.0	1.0	1.0	1.0	1.0
DL-methionine	0.05	0.05	0.05	0.05	0.05	0.05
Composition calculated (analysed)						
ME MJ/kg	11.1	11.0/11.1	11.1	11.0	10.9/11.0	11.0
Crude protein %	19.0 (18.4)	19.0 (18.9)	19.0 (19.1)	15.0 (14.1)	15.0 (14.3)	15.0 (14.5)
Methionine %	0.40 (0.33)	0.41 (0.34)	0.42 (0.36)	0.33 (0.25)	0.33 (0.26)	0.34 (0.27)
Lysine %	1.04 (0.99)	1.04 (1.02)	1.05 (0.99)	0.76 (0.63)	0.77 (0.68)	0.78 (0.72)
Calcium %	1.02 (0.90)	1.04 (0.89)	1.05 (0.88)	0.84 (0.77)	0.86 (0.77)	0.87 (0.75)
Phosphorus available %	0.52	0.53	0.54	0.44	0.44	0.45
Phosphorus total anal.	0.75	0.77	0.81	0.66	0.68	0.70

[1] HGM = high-glucosinolate meal, LGM = low-glucosinolate meal.
[2] Supplies per kilogram of diet: 15000 IU vitamin A, 1700 IU vitamin D, 20 mg vitamin E, 1 mg vitamin K, 3 mg riboglavin, 1,5 mg pyridoxine, 18 mg niacin, 10 µg B_{12}, 0.3 mg folic acid, 500 mg choline chloride, 5 mg Carophyll Orange, 20 mg Fe, 45 mg Zn, 50 mg Mn, 4 mg Cu, 0.5 mg I, 0.1 mg Se.

Table 3. Composition of layer (cock) diets.

Group nr.	1	2/3	4, 5 and 6
Ingredient (%):			
Rapeseed meal[1]	—	5HGM/5LGM	10LGM
Fish meal	2	2	2
Soybean meal	14	11	8
Barley	52 (58)	51 (57)	50 (56)
Oats	21.1	20.1	19.1
Rapeseed oil	1	1	1
Limestone	7.2 (1.2)	7.2 (1.2)	7.2 (1.2)
Dicalc. phosphate	1.3	1.3	1.3
Salt	0.35	0.35	0.35
Micronutrients[2]	1.0	1.0	1.0
DL-methionine	0.05	0.05	0.05
Composition calculated (analysed):			
ME MJ/kg	10.4 (10.64±0.24)	10.3/10.4 (11.47±0.12) (10.39±0.20)	10:4 (10.16±0.25)
Crude protein %	15.5 (15.1)	15.5 (15.4)	15.5 (15.5)
Methionine %	0.33 (0.27)	0.34 (0.28)	0.35 (0.29)
Lysine	0.82 (0.73)	0.83 (0.77)	0.83 (0.81)
Calcium	3.26 (2.90)	3.28 (2.94)	3.29 (2.92)
Phosphorus available %	0.40	0.41	0.42
Phosphorus total % anal.	0.64	0.66	0.70

[1—2] See Table 1.

RESULTS AND DISCUSSION

Rearing period

On the whole, growth of the groups during rearing to 18 weeks was uniform and the differences ascertained were not due to the use of RSM (Tables 4 and 5). Although the final body weight of the pullets in group 6 (10 % HG-RSM) was significantly ($P<0.05$) lower than that of groups 1 and 4 (0 % RSM) in the first generation, this did not persist in the second generation. Feed intake of the birds was not affected by the inclusion of RSM in the diet. Due to the relatively high oil content of rapeseed meal, the RSM diets were apparently nearly isocaloric with the 0-diets. The inclusion of 5—10 % RSM in the rearing diet did not affect mortality.

The significant differences between the groups in the first six weeks' mortality during the first generation cannot be attributed to RSM because in the other 0-group (4) mortality was also high. Besides no differences existed during the corresponding period of the second generation. These results are in agreement with the results of HULAN and PROUDFOOT (1980a and b) who presented that a major portion of SBM of starter and grower diets can be replaced by LG-RSM without adversely affecting mortality or feed intake.

Laying period

Egg production traits were not significantly influenced by feeding RSM during the first generation (Table 4). However, a clear tendency towards decreased egg weight can be seen when the dietary level of RSM increases. Similarly in the second generation, RSM did not have any significant effect on rate of lay but egg weight was reduced prominently and groups 5 and 6 (10 % LG-RSM) differed significantly ($P<0.05$) from the control (Table 5). Compared with the 0-group daily egg mass was decreased on average by 1.7 g in the RSM groups. As a result of decreased egg weight and increased mortality the hen housed production of the RSM groups was clearly lower than that of the control and impairment was significant ($P<0.05$) in group 5.

The reduction of egg weight due to the presence of RSM in the diet observed in this study is in agreement with numerous reports (SUMMERS et al. 1971, MARCH et al. 1972, 1975 and 1978, HULAN and PROUDFOOT 1980a and 1980b, PROUDFOOT et al. 1982 and 1983, KIISKINEN 1983a, ELWINGER 1986). This phenomen has been found also when whole rapeseed has been fed to layers (LESLIE et al. 1973, LEESON et al. 1978). In the present study the lower egg weight in the RSM groups cannot be explained by the differences in body weight of the pullets.

Hens fed RSM consumed less feed than hens fed the control diet but significant differences could be found only in the second generation (Table 5). Obviously, this can be attributed to impaired palatability due to the presence of RSM in the diets because, according to the ME determination, the addition of RSM decreased the ME content of the diet (Table 3) and thus the feed intake of the birds should have increased. However, significant differences were not found in the feed conversion ratio and therefore the birds apparently consumed feed according to their needs for egg production, a conclusion which is supported by similar changes in the body weight of the birds (Table 6).

Mortality among the hens fed RSM seemed to already increase during the first generation although significantly ($P<0.05$) only in group 4 (Table 4). In the second generation differences in mortality were greater with groups 2, 4 and 5 differing significantly ($P<0.05$) from the control (Table 5). Distribution of the deaths during the laying periods does not support the observations of HULAN and PROUDFOOT (1981) that mortality of hens fed RSM accumulates towards the end of the laying period.

Table 4. Performance of birds of the first generation fed RSM.

Group nr.	1	2	3	4	5	6	SE[1]	Significance
RSM % (rearing)	0	HG 5	LG 5	0	LG 5	LG 10		
RSM % (laying)	0	HG 5	LG 5	LG 10	LG 10	LG 10		
Body weight of chick g								
6 weeks	434	422	426	436	425	429	1.5	*
12 weeks	1075^{ab}	1053^{ab}	1063^{ab}	1078^{ab}	1089^{b}	1050^{a}	3.6	**
18 weeks	1435^{b}	1401^{ab}	1404^{b}	1436^{b}	1444^{b}	1355^{a}	7.1	**
Feed intake kg/chick g								
0—6	0.96	0.93	0.95	0.90	0.95	0.93	0.006	NS
6—12 weeks	3.47	3.25	3.41	3.40	3.45	3.22	0.033	NS
12—18 weeks	3.10	3.18	3.06	3.07	3.13	3.12	0.029	NS
Total	7.53	7.36	7.42	7.37	7.53	7.27	0.071	NS
Mortality %								
0—6 weeks	2.9^{a}	7.2^{abc}	9.0^{b}	10.3^{abc}	11.5^{c}	9.0^{abc}	0.71	*
6—18	0.73	1.61	1.51	0.38	0.38	0.0	0.234	NS
Sexual maturity age days[2]	158	158	158	159	159	160	0.61	NS
Egg output								
kg/housed hen	14.65	14.44	14.32	14.27	14.28	14.18	0.078	NS
g/hen/day	46.6	46.6	46.3	46.3	46.1	46.4	0.18	NS
Rate of lay %	79.5	80.2	79.8	80.5	80.3	80.6	0.27	NS
Egg weight g	58.9	58.3	58.2	57.7	57.7	57.8	0.13	NS
Feed intake								
g/hen/day	122	118	118	119	119	118	0.4	NS
kg/kg eggs	2.63	2.53	2.56	2.57	2.58	2.55	0.010	NS
Mortality %[3]	2.9^{a} (58)	5.7^{ab} (42)	6.7^{ab} (43)	10.5^{b} (33)	4.3^{a} (77)	6.7^{ab} (72)	0.74	*
Liver lesions[4]	0/6	3/9	4/8	10/14	5/5	7/10		

a—c Means with a different superscript letter within a row are significantly different ($P<0.05$). If no letters are used, differences are non-significant.
1 SE = standard error of mean.
2 At 50 % production level.
3 Portion (%) of the hens dead during the first half of the laying period.
4 Number of damaged livers (fatty, fragile, haemorrhagic, broken) per dead and obducted hens.

Table 5. Performance of birds of the second generation.

Group nr.	1	2	3	4	5	6	SE[1]	Significance
RSM % (rearing)	0	HG 5	LG 5	0	LG 5	LG 10		
RSM % (laying)	0	HG 5	LG 5	LG 10	LG 10	LG 10		
Body weight of chick g								
6 weeks	500	486	481	477	494	494	2.2	*
12 weeks	1056^{a}	1026^{ab}	1025^{ab}	1005^{b}	1043^{ab}	1046^{ab}	4.1	**
18 weeks	1376	1340	1326	1338	1364	1371	4.9	**
Feed intake kg/chick								
0—6 weeks	1.20	1.14	1.14	1.14	1.16	1.17	0.009	NS
6—12 weeks	2.81	2.79	2.78	2.72	2.79	2.87	0.018	NS
12—18 weeks	2.89	2.92	2.86	2.92	2.90	2.92	0.022	NS
Total	6.90	6.85	6.78	6.78	6.85	6.96	0.048	NS
Mortality %								
0—6 weeks	7.4	2.6	2.7	4.1	3.4	5.0	0.72	NS
6—18 weeks	5.8	1.5	1.6	0.8	2.3	3.2	1.26	NS
Sexual maturity age days[2]	173	172	172	174	173	171	0.68	NS
Egg output								
kg/housed hen	9.09^{a}	8.71^{ab}	8.64^{ab}	8.47^{ab}	8.26^{b}	8.52^{ab}	0.063	**
g/hen/day	46.4^{a}	45.2^{ab}	44.3^{b}	45.1^{ab}	44.4^{b}	44.7^{ab}	0.18	**
Rate of lay %	81.5	81.0	79.5	80.1	80.6	80.8	0.26	NS
Egg weight g	56.8^{a}	55.7^{ab}	55.7^{ab}	56.1^{ab}	54.9^{b}	55.3^{b}	0.13	***
Feed intake								
g/hen/day	124^{a}	120^{b}	119^{b}	120^{b}	120^{b}	122^{ab}	0.4	***
kg/kg eggs	2.71	2.67	2.70	2.69	2.73	2.75	0.010	NS
Mortality %[3]	7.1^{a} (23)	14.3^{b} (29)	10.5^{ab} (18)	14.3^{b} (40)	15.2^{b} (41)	11.0^{ab} (29)	0.86	*
Liver lesions[4]	8/10	15/19	11/14	21/25	15/19	16/16		

[a—c] See Table 3
[1—4] See Table 3.

Table 6. Body weight (b.w.) and weight of thyroid and liver of layers.

Group nr	1	2	3	4	5	6	SE	Significance
RSM % (rearing)	0	HG 5	LG 5	0	LG 5	LG 10		
RSM % (laying)	0	HG 5	LG 5	LG 10	LG 10	LG 10		
1st generation								
Final b.w.	1.99	1.94	1.94	1.95	1.96	1.93	0.007	NS
Weight gain %	38.1	37.4	37.3	35.7	36.6	38.2	0.93	NS
Thyroid weight mg/100 g b.w.	9.6^{a}	18.3^{bc}	15.2^{abc}	13.5^{ab}	20.6^{c}	18.8^{bc}	0.60	***
Thyroid weight relative	100	191	158	141	215	196		
Liver weight g/1,00 g b.w.	1.92^{a}	2.04^{ab}	2.12^{ab}	1.99^{a}	2.33^{b}	2.00^{a}	0.030	***
2nd generation								
Final b.w. kg	2.09^{a}	2.00^{bc}	1.95^{c}	1.96^{bc}	2.03^{abc}	2.05^{a}	0.008	***
Weight gain %	34.1	35.4	31.9	31.7	34.6	34.6	0.37	*
Thyroid weight mg/100 g b.w.	9.4^{a}	22.7^{bc}	18.6^{bc}	17.7^{b}	16.9^{b}	24.1^{c}	0.69	***
Thyroid weight relative	100	241	198	188	180	256		
Liver weight g/100 g b.w.	2.52	2.56	2.68	2.74	2.59	2.47	0.043	NS
Liver fat %	11.0	10.0	10.1	8.7	9.3	9.4	0.40	NS

a—c See Table 3.

Liver lesions were the most important cause of deaths and their incidence seemed to increase with the dietary RSM content in the first generation (Table 4). In the second generation liver lesions were found also among dead hens of the control group (Table 5), but it must be noted that liver lesions are not unique to birds fed rapeseed meal.

It seems that the moderate levels of 5—10 % LG-RSM also in the rearing diets do not affect the laying performance or mortality of hens. The preconditioning effect by RSM feeding during the growing period, found by MARCH et al. (1975) and partly by HULAN and PROUDFOOT (1980a) was supported by the mortality figures of the first generation but not by those of the second generation.

Thyroid weight of the hens fed RSM was increased 1.4—2.2 times in the first generation and 1.8—2.6 times in the second generation (Table 6). The relatively higher weight of thyroid gland in the second generation is logical because as mentioned above, the presence of RSM in the diet of breeding hens causes hypertrophy of the thyroid gland in their progeny and which was also confirmed in the present study (Table 9). In addition, the laying period of the second generation was shorter than that of the first generation.

It was to be expected that HG-RSM produces larger glands than LG-RSM and this was found in each generation although the differences were not significant. On the whole, the use of LG-RSM during the growing period increased the degree of thyroidal enlargement at the end of the laying period.

There was also a tendency towards increased liver weight and group 5 differed significantly ($P<0.05$) from the control in the first generation. Sometimes increased liver weight has been found in broilers due to the feeding of RSM (OLOMU et al. 1975, ELWINGER and ALDÉN 1977, CAMPBELL and SMITH 1979, KIISKINEN 1983b). Slight enlargement of liver in layers was reported by CAMPBELL et al. (1983) as a result of feeding HG-RSM but OLOMU et al. (1975) and LEESON et al. (1976) did not find this. The failure to show increased fat deposition in the livers of RSM-fed birds is in agreement with the observations of OLOMU et al. (1975) and LEESON

Table 7. Albumen and shell quality of the first generation.

Group nr.	1	2	3	4	5	6	SE	Significance
RSM % (rearing)	0	HG 5	LG 5	0	LG 5	LG 10		
RSM % (laying)	0	HG 5	LG 5	LG 10	LG 10	LG 10		
1st determ. (27 weeks) N = 70								
Haugh-unit	88.6	87.1	88.0	87.7	87.7	85.9	0.29	NS
Spec.weight of egg	1.0909	1.0914	1.0903	1.0919	1.0908	1.0912	0.00023	NS
Shell strength	3.29	3.54	3.39	3.55	3.36	3.42	0.028	NS
2nd determ. (42 weeks) N = 70								
Haugh-unit	80.8	79.7	80.0	80.8	80.6	79.4	0.30	NS
Spec.weight of egg	1.0857	1.0855	1.0843	1.0854	1.0849	1.0857	0.00020	NS
Shell strength	3.42	3.40	3.30	3.49	3.32	3.38	0.027	NS
Yolk colour	11.1	11.0	10.8	11.2	11.1	11.4		NS
3rd determ. (67 weeks) N = 70								
Haugh-unit	73.8	72.7	73.0	72.1	71.6	70.7	0.45	NS
Spec.weight of egg	1.0812	1.0812	1.0794	1.0815	1.0801	1.0812	0.00026	NS
Shell strength	3.05	3.07	2.87	3.05	2.87	2.85	0.035	NS
Yolk colour	12.4	12.1	12.2	12.2	11.9	12.1		NS

Table 8. Albumen and shell quality of the second generation.

Group nr.	1	2	3	4	5	6	SE	Significance
RSM % (rearing)	0	HG 5	LG 5	0	LG 5	LG 10		
RSM % (laying)	0	HG 5	LG 5	LG 10	LG 10	LG 10		
1st determ. (25 weeks) N = 70								
Haugh-unit	91.4[b]	91.4[b]	90.1[b]	89.2[ab]	88.0[ab]	85.7[a]	0.32	***
Spec.weight of egg	1.0925	1.0923	1.0907	1.0901	1.0912	1.0914	0.00029	NS
Shell strength	3.42	3.50	3.61	3.25	3.36	3.53	0.033	*
2nd determ. (40 weeks) N = 70								
Haugh-unit	82.2[b]	82.1[ab]	81.4[ab]	81.6[ab]	80.1[ab]	78.5[a]	0.32	**
Spec.weight of egg	1.0833	1.0835	1.0836	1.0825	1.0826	1.0823	0.00023	NS
Shell strength	3.23	3.27	3.49	3.29	3.20	3.26	0.033	NS
3rd determ. (53 weeks) N = 70								
Haugh-unit	78.0	78.0	77.3	79.0	76.9	74.6	0.40	*
Spec.weight of egg	1.0817	1.0827	1.0804	1.0823	1.0818	1.0817	0.00022	NS
Shell strength	3.13	3.14	3.06	3.03	3.12	3.05	0.035	NS

a—b See table 3.

et al. (1976) who suggested that »hepatic (liver) hemorrhage» or »hemorrhagic liver syndrome» rather than »fatty liver syndrome» are more appropriate terms for these lesions.

No significant differences between the treatments were ascertained in egg quality of the first generation (Table 7). In the second generation albumen quality (Haugh unit) was impaired in group 6 (Table 8).

Rapeseed meal had no deleterious effect on fertility or hatchability (Table 9) which is in agreement with the previous studies (McGregor and Blakely 1964, Robblee and Glandinin 1967, Summers et al. 1971, March et al. 1972, Leslie and Summers 1975, Proudfoot et al. 1982, Kiiskinen 1983a). The average weight of day old chicks was in all RSM groups lower than in the control. Also Gawecki et al. (1972) found a decreased weight of hatched chicks in the groups fed RSM in the diet.

Table 9. Data of hatching for the first generation (number of eggs 810 per group).

Group nr.	1	2	3	4	5	6	SE	Significance
RSM % (rearing)	0	HG 5	LG 5	0	LG 5	LG 10		
RSM % (laying)	0	HG 5	LG 5	LG 10	LG 10	LG 10		
Fertility %	95.9	94.6	94.4	92.3	94.0	95.2	0.44	NS
Hatchability %	86.8	87.9	88.8	84.3	87.8	89.4	0.79	NS
Average weight of day old chicks[1]	40.1	38.3	38.5	38.7	37.5	38.4	—	—
Average thyroid weight (+SD) mg/100 g b.w. of one-week-old chicks (N = 40)	7.53 ± 2.39	7.74 ± 2.70	8.30 ± 2.81		8.97 ± 2.27		0.23	NS

[1] Calculated from the total weight and number of chicks per group.

As a result of hypertrophy of the thyroid gland and decreased body weight of the progeny it is not advisable to include RSM in the diets of breeding hens because the next generation may have a weaker starting point for an efficient and healthy production.

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SELOSTUS

Rypsijauhon pitkäaikaiskäytön vaikutus munantuotannossa

TUOMO KIISKINEN

Maatalouden tutkimuskeskus

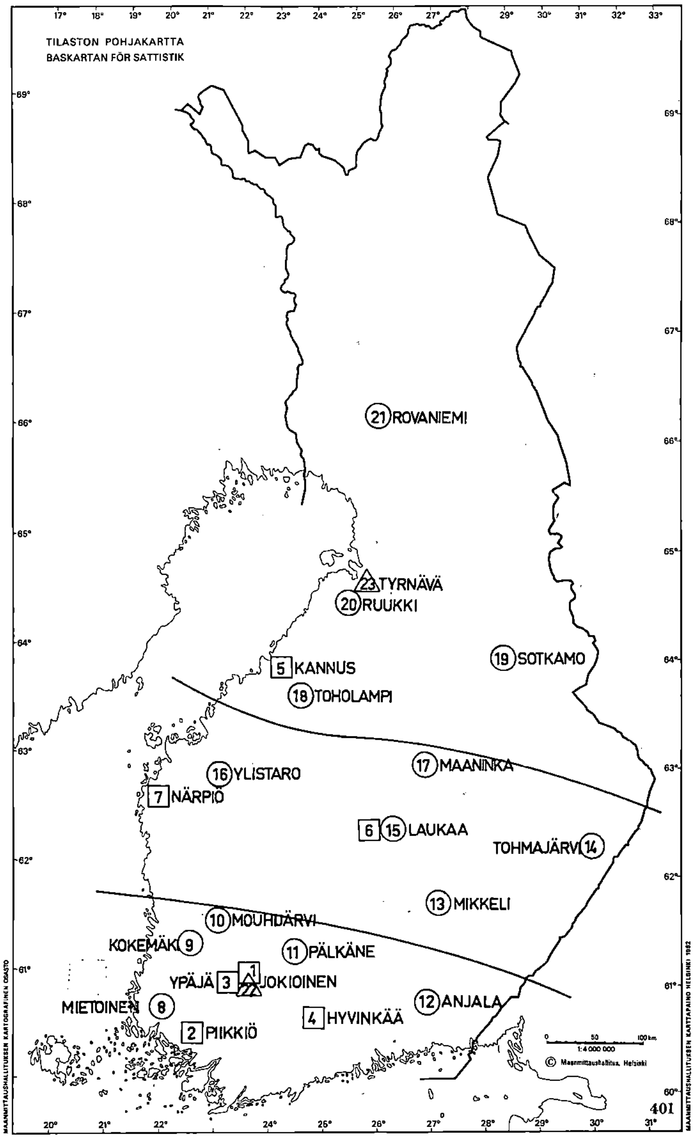
Kanoille (VL, SK-51) syötettiin rypsijauhoa rehussa kahden sukupolven ajan untuvikosta munintakauden loppuun. Kokeessa käytettiin normaalia rypsijauhoa (HG-RSM, kokonaisglukosinolaattipitoisuus 51.4 mikromoolia/g rasvatonta kuiva-ainetta) sekä vähemmän glukosinolaatteja sisältävästä lajikkeesta (Sigga, 18.8 µmol/g) uutettua jauhoa (LG-RSM). Rypsijauhon määrät koeryhmien kasvatus- ja munitusrehussa olivat seuraavat: ryhmä 1 (vertailu) 0 ja 0 %; ryhmä 2, 5 ja 5 % HG-RSM; ryhmä 3, 5 ja 5 % LG-RSM; ryhmä 4, 0 ja 10 % LG-RSM; ryhmä 5, 5 ja 10 % LG-RSM; ryhmä 6, 10 ja 10 % LG-RSM. Munivia kanoja oli joka ryhmässä 210 kpl ja ensimmäisessä sukupolvessa oli myös 30 kukkoa, jotka ruokittiin vastaavilla rehuilla. Munintakauden pituus oli ensimmäisellä sukupolvella 12 ja toisella 8 jaksoa á 28 pv.

Rypsijauhon käytöllä ei ollut yhdenmukaista vaikutusta kasvatuskauden tuloksiin, eikä merkitsevää vaikutusta kummankaan sukupolven muninnan intensiteettiin ja rehuhyötysuhteeseen. Merkkejä munanpainon alenemisesta oli kuitenkin havaittavissa jo ensimmäisessä sukupolvessa rehun rypsijauhopitoisuuden noustessa. Vaikutus tuli selvemmin esille toisessa sukupolvessa, jolloin päivittäinen munantuotos oli rypsiryhmillä keskimäärin 1.7 g vertailuryhmää pienempi.

Munankuoren ja valkuaisen laadussa (HU) ei koeryhmien välillä yleensä todettu merkitseviä eroja lukuunottamatta ryhmää 6 (10—10 % LG-RSM) jonka HU oli muita alhaisempi varsinkin toisessa sukupolvessa. Rypsijauho ei myöskään vaikuttanut hedelmällisyyteen tai haudontatulokseen. Rypsiryhmien untuvikot olivat pienempiä kuin vertailuryhmän ja ensiksimainituilla oli kilpirauhasen suurentuminen todettavissa.

Rypsijauhoryhmissä kuolleisuus oli vertailuryhmää korkeampi munintakaudella ja pääasiallinen kuolinsyy oli maksavaurioissa (verinen, hauras, revennyt, rasvainen). Rypsijauho aiheutti keskimäärin kaksinkertaisen kilpirauhasen painon.

Tulokset osoittavat, että glukosinolaatteja kohtuullisestikin sisältävä rypsijauho saattaa lisätä kanojen kuolleisuutta käyttömäärän ollessa 5—10 % rehussa, mutta sen käyttö tällä tasolla jo kasvatusrehuissa ei näytä vaikuttavan tuloksiin. Glukosinolaattien suhteen erityyppiset rypsijauhot ovat suunnilleen samanarvoisia käyttömäärän ollessa 5 %. Koetulosten perusteella rypsijauhon käyttöä tulisi välttää siitoskanojen rehussa, koska seuraavan sukupolven untuvikkojen suurentunut kilpirauhanen ja mahdollisesti pienempi paino antavat niille huonommat lähtökohdat.



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