

***Frankliniella occidentalis* (Thysanoptera; Thripidae)** **– a new pest in Danish glasshouses** **A review**

Frankliniella occidentalis (Thysanoptera; Thripidae)
– et nyt skadedyr i danske væksthuse
En litteraturgennemgang

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Summary

The western flower thrips (*Frankliniella occidentalis* Pergande 1895) was brought into Denmark from the United States probably via Holland and Western Germany in the autumn of 1985, where it was found in two glasshouses with *Saintpaulia ionantha* (Wendl.). Since then, this flower thrips has spread to a large number of glasshouses all over the country, in spite of comprehensive control measures. The same dispersion has occurred in many other countries in Western Europe,

where it is a serious pest. In 1987, 50–75% of the nurseries in Southern Germany were infested with this thrips species. The reason for the quick and continued spreading is that it is very difficult to control with insecticides. This is partly due to its hidden way of life in flowers and buds, partly because it has developed resistance to a number of insecticides.

This article is a literature review of the biology, spread and economic importance of *F. occidentalis*.

Key words: *Frankliniella occidentalis*, thrips, *Thysanoptera*, glasshouse pest, biological control, chemical control, monitoring.

Resumé

Saintpaulia-tripsen (*Frankliniella occidentalis* Pergande 1895) blev indslæbt til Danmark fra USA via Holland og Vesttyskland i efteråret 1985, hvor den blev fundet i to væksthuse med *Saintpaulia ionantha* (Wendl.). Siden har denne blomstertrips spredt sig til et stort antal væksthuse over hele lan-

det på trods af omfattende bekæmpelsesforanstaltninger. Den samme spredning har fundet sted i mange andre lande i Vesteuropa, hvor den er et alvorligt skadedyr. I 1987 var 50–75% af gartnerierne i Sydtyskland angrebet af denne tripsart. Årsagen til den hurtige og fortsatte spredning lig-

ger dels i dens skjulte levevis i blomster og knopper, dels i at den har udviklet resistens over for en række pesticider.

Denne beretning er en litteraturgennemgang af *F. occidentalis*'s biologi, spredning og økonomiske betydning.

Nøgleord: *Frankliniella occidentalis*, trips, *Thysanoptera*, væksthusskadedyr, biologisk bekæmpelse, kemisk bekæmpelse, monitoring.

General information about

Frankliniella occidentalis

Systematic classification

Frankliniella occidentalis (Pergande) belongs to the insect order *Thysanoptera* (46) comprising about 5,000 species (67). The *Thysanoptera* are usually divided into two sub-orders: *Tubulifera* with one family (*Phlaeothripidae*), and *Terebrantia* with four families (*Aeolothripidae*, *Thripidae*, *Merthripidae* and *Heterothripidae*) (49, 65 a.o.).

F. occidentalis belongs to the family *Thripidae* (46). This is the family where most of the economically important thrips are found (16).

List of synonyms

The genus *Frankliniella* was described in 1910 by *H. Karny*. Before then, the species were placed with *Thrips* (L. 1758), *Euthrips* (Targ.-Toz. 1881) or *Physopus* (Uzel 1895) (29).

The species *F. occidentalis* was described in 1895 by *T. Pergande* who placed it in the genus *Euthrips* (46).

As there are great variations within the *F. occidentalis* species, many entomologists have described new species which have later turned out to be only variants of *F. occidentalis*. *Bryan* and *Smith* (9) and to some extent *Oliver* and *Baker* (43) have compiled a list of synonyms for *F. occidentalis*:

- Euthrips occidentalis* Pergande 1895
- Euthrips tritici* Crawford 1909
- Euthrips tritici* var. *californicus* Moulton 1911
- Euthrips helianthi* Moulton 1911
- Frankliniella occidentalis* Karny 1912
- Frankliniella helianthi* Karny 1912
- Frankliniella tritici* var. *moultoni* Hood 1914
- Frankliniella tritici occidentalis* Watson 1919
- Frankliniella tritici californica* Watson 1923
- Frankliniella moultoni* Morgan 1925
- Frankliniella claripennis* Morgan 1925
- Frankliniella canadensis* Morgan 1925
- Frankliniella trehernei* Morgan 1925

Frankliniella californicus Moulton 1929

Frankliniella californica Moulton 1931

Frankliniella venusta Moulton 1936

Frankliniella obscura Moulton 1936

Frankliniella chrysanthemi Kurosawa 1941 (60)

Frankliniella californica f. *trehernei* Moulton 1948

Frankliniella dahliae Moulton 1948

In the U.S.A., the common names of *F. occidentalis* are 'Western flower thrips' and 'alfalfa thrips' (8 a.o.). In Denmark, *F. occidentalis* is called 'Saintpaulia-trips' (14) because the first plant on which *F. occidentalis* was found in Denmark was *S. ionantha*, and it is a serious pest on this ornamental crop. Danish growers also call it 'den amerikanske blomstertrips' (21).

Morphology

F. occidentalis may be determined by means of the keys developed by *Moulton* (40), *Mound* and *Walker* (42), *zur Strassen* (69) or *Bournier* and *Bournier* (8). Fig. 1 shows the key characters for *F. occidentalis*.

F. occidentalis imagines are macropterous thrips with a total length of 1.2-1.9 mm. The males are usually smaller than the females (8, 66).

Both larvae and imagines of *F. occidentalis* have piercing/sucking mouthparts. These are gathered into a so-called mouthcone. The front consists of clypeus and labrum, the sides of the galeate part of the maxillae with palps, and the back of labium with palps. Inside the mouthcone there are two thin maxillary stylets which may be combined to form a tube, and a strong left mandibular stylet (the right mandible has degenerated) (1, 13, 27, 41, 72).

The female has a serrate ovipositor with which she makes a pocket in the parenchymatous tissue of leaves, flowers or fruits. In this pocket she lays a 0.25 × 0.50 mm opaque reniform egg.

Bryan and *Smith* (9) and *Sakimura* (59) found three genetically determined colour variants of *F. occidentalis* in California: a dark, a light and an

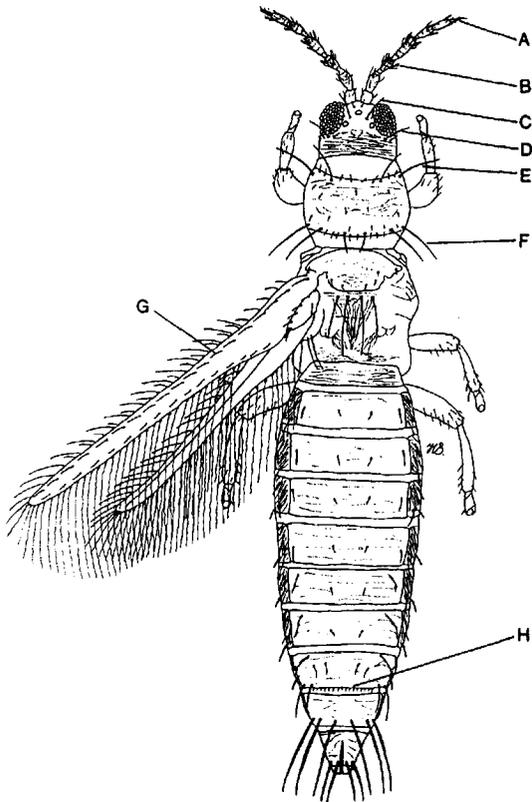


Fig. 1: *F. occidentalis* female. Dorsal aspect. Right wing pair not drawn.

Some key characters.

- A: Antennae 8-segmented
- B: Forked trichomes on antennal segments III and IV
- C: Interocellar setae III long and at the margin of the ocellar triangle
- D: Postocular setae long
- E: Anteroangular and one pair of anteromarginal setae long
- F: Posteroangular and one pair of postermarginal setae long
- G: Forewing with complete row of setae (16-20) on first vein.
- H: Tergit VIII with complete comb on posterior margin (only females).

intermediate form. Only diploid females have phenotypical expressions of the three colour variants. The haploid males always have a pale colour. Moreover, *Bryan and Smith* (9) found that the ratio between the three colour variants bore

no relation to the host plants; but the ratio between the colour variants depends on the time of year in California. Thus, the largest number of dark specimens are found in the spring and most of the pale ones during the summer and autumn. The intermediate form is a constant part of the populations throughout the year. They say that this may be because the dark form is better at surviving cold and wet weather than the pale form.

In Germany (66) and in the Netherlands (*W. P. Mantel*, pers. comm. 1987), only the pale and the intermediate forms have been found. The dark form has only been found at one occasion (Dec. 1988) in Denmark (*H. F. Brødsgaard*, unpublished).

Life cycle

As the metamorphosis of *Thysanoptera* has elements of both a hemi- and a holometabolic development, *Thysanoptera* is placed by some authors (9, 30, 56 a.o.) in the hemimetabolic group, and by others (32, 48, 65 a.o.) in the holometabolic group depending on the elements considered to be most important by the scientist in question. Other entomologists place *Thysanoptera* in an intermediate group. Thus, *Schliephake and Klint* (62) speaks of a remetabolic metamorphosis.

Since most European entomologists have placed *Thysanoptera* in the holometabolic group and a greater uniformity in the nomenclature is desirable, the present article uses the holometabolic nomenclature to describe the life stages of *F. occidentalis*.

There are six stages in the life cycle of *F. occidentalis*: Egg, first and second stage larvae, first and second stage pupae and imago.

After hatching, the first stage larvae move to the surface of the plant, where they at once start feeding. They are quite mobile, but usually stay on the part of the plant where the egg was laid. The second stage larvae move faster and cover greater distances than the first stage larvae. They consume about three times as much food as the first stage larvae. At the end of the second larval stage, the thrips move to protected parts of the plants or to the ground where pupation takes place. At the first pupal stage they are almost immobile and do not feed. Pupae in the second stage only move when they are disturbed, and they do not feed either. At the imago stage they are quiescent for about 24 hours after the final molt. Just after the molt, the colour is white or a pale yellow,

and the final colouring does not appear until 48 hours later (8, 9, 66).

It has been established that the time of development and the fecundity of *F. occidentalis* are to a large degree related to temperature and host plant. Three investigations of the time of development and fecundity of *F. occidentalis* are summarized in Table 1. It should be noted that the experimental lay outs of the three investigations differ considerably, and, for instance, air humidity and photoperiod are not specified.

It will be seen from Table 1 that the time of development depends very much on temperature and less on the host plant. On the other hand, the quality of the food seems to have a great influence on the fecundity, which is much greater when the thrips are given whole chrysanthemum flowers rather than radish leaves or bean pods. The reason for this may be that the egg formation of *F. occidentalis* improves when pollen is available (cf. Table 1). Another difference in the experimental lay outs is the fact that males and females were together in the chrysanthemum experiment, but not in the two others, and *Robb and Parrella* (57) think that the greater fecundity may be because the females mated. However, *Watts* (73) showed that for *F. tritici* there was no difference between the fecundity of mated and unmated females.

Bailey (4) examined the rate of development of *F. occidentalis* outdoors in California and found a total life cycle of 15–20 days. This is in agreement with the three laboratory examinations mentioned above.

Trichilo and Leigh (71) have examined some life table parameters for *F. occidentalis* at 27°C and a day length of 14 hours for mated females on cotton leaves without pollen and on cotton leaves with pollen, respectively (Table 2). It appears from this that the net reproductive rate (R_0) is about 4 times higher with pollen than without. Besides, it can be seen that the longevity is not very much influenced by access to pollen. This is in agreement with the results shown in Table 1.

The way of reproduction of *F. occidentalis* has not been examined, but that of other species of *Frankliniella*. These examinations show that the reproduction of *Frankliniella* is partly sexual, partly parthenogenetic, i.e. facultative parthenogenesis. The parthenogenetic reproduction is always arrhenotoky, i.e. unfertilized females lay eggs that all develop into males, and most of the eggs laid by fertilized females are female. Much

Table 1. Duration of life stages and fecundity of *F. occidentalis* at different temperatures and with different host plants (— = no data).
Varigheden af livsstadier og fecunditet hos F. occidentalis ved forskellige temperaturer og værtsplanter (— = ingen data).

Temperature (°C)	Host plant	Eggs (days)	1st larval stage (days)	2nd larval stage (days)	1st pupal stage (days)	2nd pupal stage (days)	Youth stages total no. (days)	Imago (days)	Preoviposition (days)	Postoviposition (days)	Fecundity (eggs/female)	Source
15	Radish	13	7	12	4	8	44	90	3	30	40	(9)
15	Bean	11	5	9	3	6	34	71	10	—	24	(35)
16.7	Chrysanthemum	3	2	4	2	3	14	45	—	—	300	(57)
20	Radish	6	3	6	2	5	22	40	3	0	65	(9)
20	Bean	6	2	5	2	3	18	57	2	—	100	(35)
26.7	Radish	4	2	4	1	3	14	40	—	—	—	(9)
30	Bean	4	1	4	1	1	11	28	2	—	44	(35)
36.7	Chrysanthemum	3	1	2	1	1	8	30	—	—	150	(57)

Table 2. Life table parameters for *F. occidentalis* on cotton leaves at 27°C and 14 h light (71).

Lifetable-parametre for F. occidentalis på bomuldsblade ved 27°C og 14 timers fotoperiode.

Parameters	Without pollen	With pollen
Net reproductive rate (R_0)	30.1	111.8
Doubling time (DT) (days)	4.4	3.1
Mean generation time (T) (days)	21.6	23.4
Intrinsic rate of increase (r_m)	0.157	0.220

seems to indicate that *Frankliniella* spp. males are haploid and the females are diploid, but this has not been cytologically demonstrated. Arrhenotoky has been demonstrated in *F. schultzei* (syn. *F. insularis*) (15), *F. fusca* (18) and *F. tritici* (73).

Experiments carried out at this laboratory show that female *F. occidentalis* may start reproduction without the presence of males, and the sex ratio was in all our experiments about 1 male: 6 females (*H. F. Brødsgaard*, unpublished). This seems to indicate that arrhenotoky also occurs in *F. occidentalis* (32).

The importance of *Frankliniella occidentalis* as a pest

Distribution

F. occidentalis was originally found in the USA in an area west of Rocky Mountains (39), reaching north to Alaska (9) and south to Mexico (59), both in the field and in glasshouses. In the 1970'es and '80'es it rather suddenly became widespread. It now occurs in the whole of the USA, in large parts of Canada (43), and on Hawaii (60), in New Zealand (68), in Southern Korea (74), in Peru (44) and in most of Western Europe in glasshouses (69).

F. occidentalis is mainly spread in connection with import and export of plant material, but there is no obvious commercial explanation why *F. occidentalis* should become so widespread in the 1970'es and '80'es. Therefore, a change might have taken place in the biology of the species, and this change may have given it greater insecticide tolerance (43); but this has not yet been demonstrated (see also later section).

Host plants

F. occidentalis is polyphagous. *Oliver and Baker* (43) have registered a total of 219 species from 59 genera as host plants, i.e., plants on which the thrips has been found. Usually, the qualifications of the individual plants as host plants have not been examined. Although *F. occidentalis* prefer flowers, they also thrive on the leaves and stems of many plants (43).

Plant damage caused by *F. occidentalis*

The damage to plants caused by *F. occidentalis* is first of all mechanical. During feeding the epidermis and the mesophyll cells are penetrated by means of the stylets in the mouthcone, and the cell sap is sucked out. Depending on the host plant in question, yellow, brown or silver necroses occur as a consequence of air entering the empty cells (1, 13, 72). Mechanical damage also occurs when the females saw pockets in the epidermis or mesophyll cells in connection with the oviposition (32).

Apart from the purely mechanical damage, pathogenic fungi and bacteria may gain access through these wounds. The pathogens propagate in excrements left by *F. occidentalis* on the plant surface (32). Among the financially important bacteria *Bailey* (3) mentions *Erwinia amylovora* and *Bacillus dianthi*.

Moreover, *F. occidentalis* is one of the main vectors of tomato spotted wilt virus, which is the only thrips-transmitted virus (32, 59 a.o.).

In the United States and Canada virus transmission is considered the most damaging property of *F. occidentalis* (28). The above mentioned virus is widespread in temperate and subtropical regions (25), but has never been found in Denmark (*N. Paludan*, pers. comm. 1988), in spite of the fact that another of the main vectors, *Thrips tabaci*, is widespread both outdoors and in greenhouses in this country (36).

Control of *Frankliniella occidentalis*

Chemical control

One of the reasons for the rapid dispersion of *F. occidentalis* in the 1970'es and '80'es is probably its increased tolerance to insecticides. As early as in 1943, insecticide resistance was registered in two *Thysanoptera* species (50), and in 1961 the first report that *F. occidentalis* had developed resistance was published (51). Since then, a large number of

reports have described the reduced insecticide sensitivity of *F. occidentalis*. The insecticides include cyclodiens, organophosphates, carbamates and synthetic pyrethroids (e.g. 45, 57). Dichlorophos applied with fogging equipment is often effective (37), but a Danish screening of insecticides has shown that 100 p.c. mortality of this *F. occidentalis* population could only be obtained by means of chlorfenvinphos (55). However, this compound is toxic for a large number of plant species grown in Danish glasshouses, and thus the applicability is limited. This is the basis for the keen interest in finding alternative control measures shown in Denmark right from the introduction of *F. occidentalis* into the country.

Microbiological control

Shorey and Hall (63, 64) tested *Bacillus thuringiensis* var. *thuringiensis* Berliner on *F. occidentalis* with negative results. Several *Entomophthora* species (7, 12, 52, 53, 61) have been found to infect *T. tabaci*, but there is no information about similar infections of *F. occidentalis*. The practical application of these insect-pathogenic fungi has turned out to be limited, as they require a very high air humidity in order to germinate, and a method of cultivating *Entomophthora* on an artificial medium has only recently been developed (19).

Parasitoids

Only one parasitoid parasitizing *F. occidentalis* is mentioned in the literature: *Thripoctenus americensis* Gir. (*Hymn.: Eulophidae*) (70), and it has not been used for biological control of *F. occidentalis*. That parasitoids might realistically be used for thrips control, however, appears from the fact that *Thripoctenus brui* Vuillet has successfully been introduced into Hawaii from Japan for biological control of *T. tabaci* (58).

Predators

Several arthropods have been described as predators of *F. occidentalis*:

Aeolothrips fasciatus (L.) (*Thysanoptera:*

Aeolothripidae) (24).

Orius insidiosus (Say) (*Hemiptera:*

Anthocoridae) (24).

O. tristicolor (White) (31).

Amblyseius barkeri (Huges) (*Acari:*

Phytoseiidae) (54).

A. cucumeris (Oud.) (20).

So far, only *Amblyseius* spp. has been used for biological control of *F. occidentalis*.

The two *Amblyseius* species have a time of development which is about half that of *F. occidentalis* (6, 17). Bonde (6) indicates an *r* value of *A. barkeri* of 0.22. This means that the predatory mites have approximately the same exponential growth rate as *F. occidentalis*. However, it seems that the population growth rate of the predatory mites is not as high under glasshouse conditions (10, 22, 23).

The adult stages of *A. barkeri* and *A. cucumeris* consume about four thrips larvae per day and the youth stages somewhat less (6). This means that one adult predatory mite may eat the progeny of one thrips. Consequently, the number of predatory mites introduced has to be equal to the number of thrips.

The results of experiments with *A. barkeri* and *A. cucumeris* for control of *F. occidentalis* are few and varying. Successful control has been obtained by Elliott *et al.* (20) and Lindhagen and Nedstam (33) on cucumber; fairly good control was obtained by Jakobsen (26) on Saintpaulia and by Brødsgaard (10) on sweet pepper, and insufficient control was obtained by Lindhagen and Nedstam (33) on melon.

Monitoring

As predatory mites cannot prey on imagines of thrips (5, 6, 20), the predatory mites have to be introduced at the beginning of the thrips attack in order to obtain efficient control. However, the small size of *F. occidentalis* and its secluded way of life in flowers and buds make detection of initial attacks very difficult. Therefore, experiments have been made to find out whether coloured sticky traps may be used for monitoring *F. occidentalis*.

Moffitt (38) and Yudin *et al.* (75) found that in the field *F. occidentalis* preferred white sticky traps. Robb and Parrella (57), Elliott *et al.* (20) and Lindquist *et al.* (34) all used yellow sticky traps for monitoring *F. occidentalis* in greenhouses, and they found that, by means of these traps, attacks could be detected at very low thrips densities and one or two months before plant damage occurred. However, Brødsgaard (11) found that *F. occidentalis* discerns clearly between different shades of blue, and that the preference of *F. occidentalis* for one definite shade of blue was ten times as great as for white and yellow colours.

Sticky traps in this blue colour has therefore become a very efficient tool for detecting initial attacks and monitoring development of attacks.

As these sticky traps catch a large number of the adult thrips, they also act as a supplement to biological control by means of predatory mites, for, as mentioned before, the predatory mites do not prey on the adult stages of the thrips.

Conclusion

Since *F. occidentalis* was brought to Northern Europe from North America around 1983 it has only established permanent populations in glasshouses (37). This explains why, the problems caused by this thrips species has, after all, been limited as in most cases it has been possible to isolate the attacks. At the same time, it is a fact that dispersion has only occurred with plant material. This means that a quarantine period for newly imported plants, before they are introduced into the production glasshouses, will practically eliminate the problems. The situation will change, however, if *F. occidentalis* establish permanent populations outdoors in Northern Europe. In this case the growers may risk that the thrips spread actively over longer distances, and that outdoor populations infest the glasshouses, which is the case e.g. in California.

Whether *F. occidentalis* is able to establish permanent populations outdoors in Northern Europe depends on its ability to survive the winters here. It has been stated that *F. occidentalis* may survive at least 5 days at -2°C (30°F) (2). In Holland this thrips species has been found outdoors as late as October (37). In Denmark it has been found outdoors in the beginning of November after short periods with -8°C (*H. Brødsgaard* unpub.). The possibilities of *F. occidentalis* of surviving the winters in protected sites outdoors should be further investigated as this will be of vital importance for the future control strategies.

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