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# PLANTHOPPER-TRANSMITTED VIRUS DISEASES OF CEREALS IN SWEDEN

K. LINDSTEN

Dept. of Plant Pathology, Agricultural College of Sweden
S-750 07 Uppsala 7, Sweden

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The occurence and epidemiology of oat sterile dwarf virus, cereal tillering disease virus and wheat striate mosaic virus in Sweden has been discussed. Cereal tillering disease is so far only know in Sweden.

## INTRODUCTION

The first insect-transmited cereal disease, barley yellow dwarf, became known in 1957 in Sweden. At present three additional leafhoppertransmitted (oat blue dwarf, wheat dwarf and aster yellows) and three planthopper-transmitted diseases have been recognized. In this paper the planthopper-transmitted diseases and their disease agents will be briefly dealt with.

Two of the planthopper-transmitted diseases seem to be identical with oat sterile dwarf (OSD) and wheat striate mosaic (WSM), respectively, and will also be called by these names (cf. Lindsten, 1959, 1961 and 1966). The third planthopper-borne disease, cereal tillering disease (CTD), which was recognized first in 1971, does not seem to be known in any other country but its virus (CTDV) is likely to be related to maize rough dwarf virus (Lindsten *et al.*, 1973).

## METHODS AND RESULTS

*Symptoms and host range.* — Characteristic symptoms of both OSD and CTD are dwarfing and increased tillering. OSD often causes vein-swellings and frequently also easily noticeable enations. The development of enations is lacking or less pronounced on CTD-attacked plants, except on maize.

CTD causes more severe damage on attacked plants than OSD, with the exception of oats and possibly a few grasses. In contrast to OSD, which usually causes severe damage only to oats in Sweden, CTD is likely to be most serious to barley (Fig. 1).

The host range, at least as regards symptom-showing plants, seems to be wider for the disease agent of CTD than for OSD (Table 1). Owing to differences in resistance to virus inoculation within the species and variation among various isolates, especially of OSD, the host ranges may include some more of the species listed in the table. Thus it has only recently been found that *Alopecurus myosuroides*, listed in Lindsten *et al.* (1973) as a symptomless species after OSDV-inoculation, can be severely damaged by OSD (unpublished).

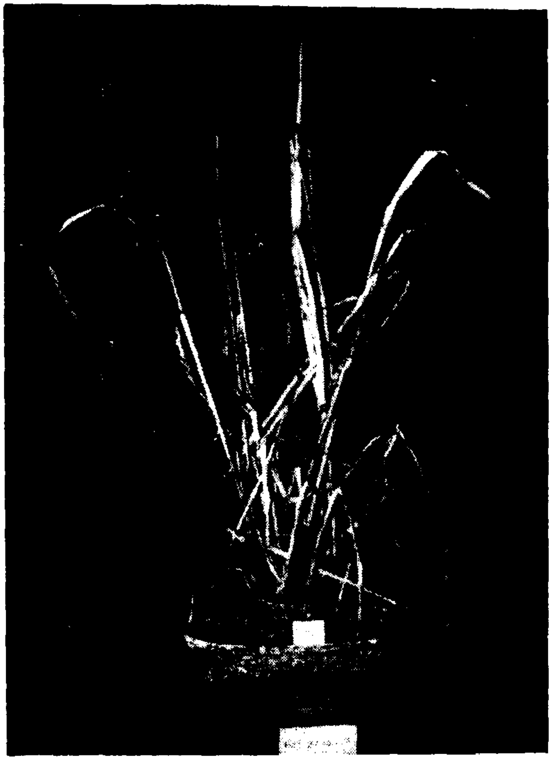

Fig. 1. — Cereal tillering disease (CTD) damages barley more severely than oats, and infected barley plants, as shown above, develop practically no heads

Infektivno bokorenje cerealija (CTD) je mnogo štetnije za ječam nego za ovas, i inficirane biljke ječma, kao što gornja slika pokazuje, obično ne formiraju klas

The symptoms of WSM show up as elongated chlorotic streaks which may gradually enlarge to blotches covering the major part of the leaves. Infected oats and also some grasses frequently change the chlorotic areas to a reddish discolouration. Plants attacked by both OSD and WSM also occur in the field even if one or the other type of symptoms then may dominate.

*Tab. 1. — Comparison of characteristics of CTDV, OSDV and MRDV*[1]

Upoređenje odlika CTDV, OSDV i MRDV

| Host range and symptoms | CTDV | OSDV | MRDV |
|---|---|---|---|
| Oats | +, eD, eT, nE | +, eD, eT, e-sE | +, eD, eT, nE |
| Barley | +, " " " | +, mD, e-mT, m-sE | +, " " " |
| Wheat | +, " " " | +, sD, sT, nE | +, " " " |
| Maize | +, mD, nT, eE | +?, e-sD, nT, nE? | +, mD, nT, eE |
| *Agropyron repens* | +, nS | —, nS | |
| *Alopecurus myosuroides* | +, e-mD, sT, nE | +, eD, eT, eE | |
| *Digitaria sanguinalis* | +, m-sD, mT, nE | , nS | +, mD, mT |
| *Echinochloa crus-galli* | +, e-mD, mT, sE | , nS | +, mD, mT, sE |
| *Holcus lanatus* | +, eD, eT, sE | +, mD, mT, e-sE | |
| *Lagurus ovatus* | +, eD, eT, nE | +, eD, eT, e-sE | |
| *Lolium perenne* | +, e-mD, mT, sE | +, mD, mT, m-sE | +, mD |
| *Phleum pratense* | +, sD, sT, nE | —?, nS | |
| *Poa annua* | +, eD, sT, m-sE | +, eD, e-mT, e-sE | |
| *P. pratensis* | —?, nS | —?, nS | |
| *Setaria viridis* | +, eD, eT, nE | , nS | |
| Transmission | | | |
| *Laodelphax striatellus* | + | — | + |
| *Javesella pellucida* | — | + | + |
| *Dicranotropis hamata* | + | + | |
| *Ovarial transmission* | — | — | + |
| Morphology of virus part. | isometric about 65—70 nm | isometric about 65—70 nm | isometric about 65—70 nm |
| serological relationship | +? | —? | +? |
| cross-protection test | — | — | |

D = dwarfing, T = tillering, E = enations, S = noticeable symptoms, e = excessive, m = moderate, s = slight, n = none.
Sign lacking = no information at present available.
A question mark after a sign indicates insufficient evidence.

*Distribution and economic importance.* — As shown in Fig. 2, so far OSD has been restricted to the middle part of Sweden. The yield reduction in oats caused by OSD has, however, sporadically amounted to 50% and even more in large areas of this part of the country. The damage caused was very severe during the early part of the 1960's (L i n d s t e n, 1970) and in 1973 the damage caused by OSD was again severe, especially in the most western part of Sweden.

CTD might be presumed to be an even more severe disease of cereals than OSD especially as it not only damages oats but also other cereal crops and those even more than oats. However, so far severe damage caused by CTD has been established only in a few localities situated in the country of Östergötland and in one locality about 30 miles north of Uppsala (Fig. 2). The reason for this very limited distribution (so far) of CTD is not fully known but probably the comparatively low frequency of natural vectors is a strong limiting factor for the disease.

WSM has been found all over Sweden where cereals are grown but as a rule only in low frequencies and this disease seems to be of only minor economic importance.

[1]) Data on MRDV according to L o v i s o l o (1971) and H a r p a z (1972).

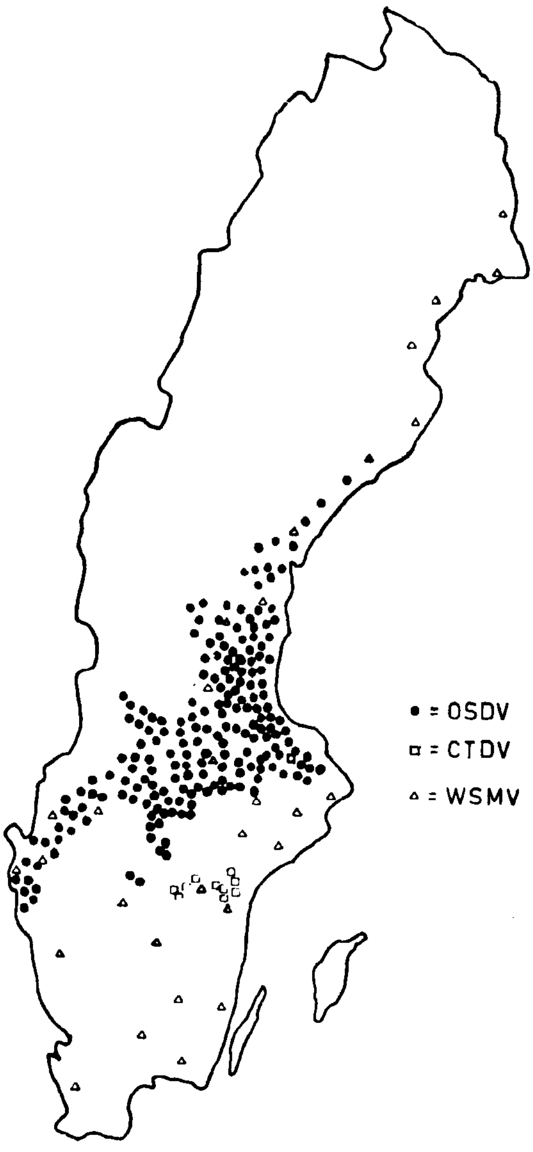


Fig. 2. — Distribution of planthopper-borne viruses in Sweden, findings during 1960—1973.
Raširenost virusa koje prenose cikade u Švedskoj, rezultati za period 1960—1973. godinu

*Disease agents.* — OSD was originally described as a virus disease owing to its symptoms, transmission etc. (Prusa *et al.*, 1959; Lindsten 1959, 1961). A mycoplasma-like organism as the causal agent has also been suggested (Brcak & Kralik 1969). Anyhow, now there is strong evidence that OSD is caused by an isometric virus of about 70 nm (Brcak *et al.*, 1972; Linsten *et al.*, 1973) and experiments in progress are further verifying this.

CTD is caused by a virus morphologically similar to OSDV (Lindsten *et al.*, 1973). Electron microscopic investigations of ultrathin sections of CTDV-infected maize roots displayed in the phloematic part of the stele virus-like particles, crystals and aggregates of particles and tubular structures very similar to those described for maize rough dwarf virus (MRDV) by Conti & Lovisolo (1971) and Lovisolo (1971).

Attempts to find any special virus- or mycoplasma-like structure which might be correlated with WSM has so far been unsuccessful in our laboratory. However, in the literature WSM is generally considered to be a virus disease and is therefore included as such in this report.

The disease agents of all three diseases mentioned are transmitted in a persistent manner. In Sweden, transovarial transmission seems to occur only for WSMV but neither for OSDV or CTDV. So far, an antiserum has been prepared only against CTDV. Preliminary tests indicate no positive reaction with this antiserum against OSDV.

*Vectors.* — A number of different transmission experiments show that OSDV is transmitted by *Javesella pellucida* F. but not by *Laodelphax striatellus* Fallén. CTDV, on the other hand, is transmitted by *L. striatellus* but so far none of the isolates tested are transmitted by *J. pellucida.* A third delphacid, *Dicranotropis hamata* Boh., can act as a vector for both OSDV and CTDV. However, this latter planthopper seems to be of very little importance as a vector under natural conditions.

Cross-protection tests (unpublished) by feeding CTDV-infective *L. striatellus* exclusively on OSDV-infected oat plants showed that the larvas of the following generation were non-infective in the first and second larval stage but became CTDV-infective to a considerable extent when becoming older. Using OSDV-infective *J. pellucida* on CTDV-infected oats gave similar results with OSDV. As no trans ovarial transmission occurs, these tests not only show that no cross-protection between the viruses seems to occur in the plants, but also that the two viruses have different and specific vectors.

The total minimum length of the sum of the acquisition feeding period, the latent period and the inoculation feeding period was found to be 14 days for CTDV (Lindsten *et al.*, 1973) and the other two viruses also seem to be rather similar in this respect.

*Epidemiology.* — Not only WSMV, which owing to its high transovarial passage might be able to survive in the vector without any alternating plant host, but also OSDV and CTDV are very dependent on their vectors for overwintering. Even if no virus-transmission through the eggs occurs for these two latter viruses there is thus strong evidence that the larva of both *J. pellucida* and *L. striatellus* become infested to a considerable extent with OSDV and CTDV, respectively, already in the autumn. Both these species generally overwinter in the second or third nymphal stage in Sweden and a great part of the vector population is frequently found to be viruliferous in and after the winter diapause. All three viruses are therefore able to survive and overwinter in their vectors.

Perennial grasses are thus not necessary for the overwintering of any of the three viruses. However, as virus reservoirs over longer periods some of the perennial grasses may be of importance for the survival of the agents.

The life cycle of *J. pellucida,* which has only one generation each year in Sweden, and the development cycle of OSDV when oats are used as a host crop are shown in Fig. 3. *J. pellucida* seems to be able to use barley, oats and wheat about equally well but at least one of these is generally required as a host crop for efficient egg-laying. However, oats are not only much more damaged by OSD than the other two but are apparently also much better as a virus donator to the young larvas. This finding has been successfully used in controlling OSD (L i n d s t e n, 1970) and will be further dealt with below.

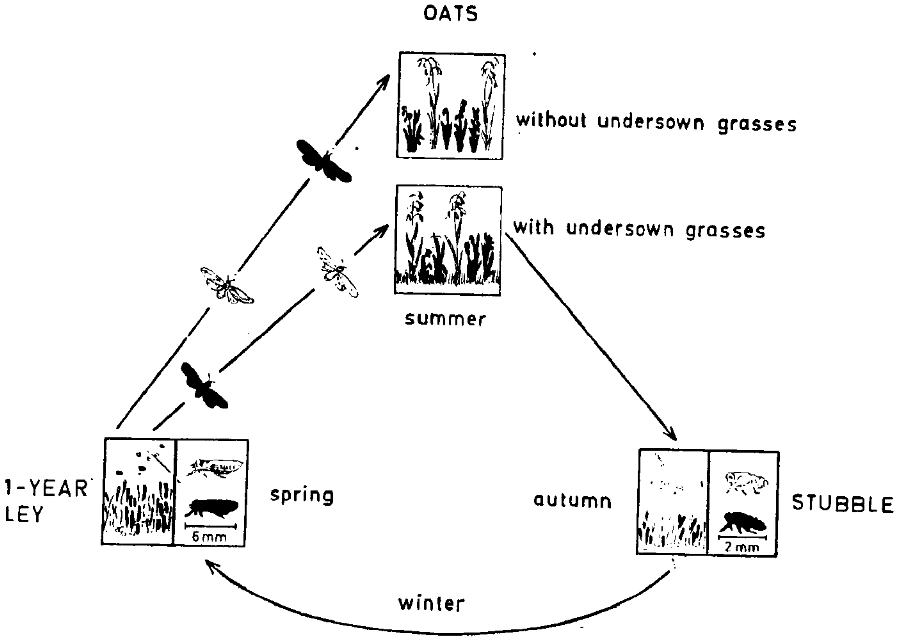


Fig. 3. — Schematic representation of the development cycle of OSDV in Sweden. Virus-infected plants and infective *J. pellucida* are marked in black

Šematski prikaz razvojnog ciklusa sterilne zakržljalosti ovsa (OSDV) u Švedskoj. Virozne biljke i infektivne *J. pellucida* obojene su crno

As idicated in Fig. 3, undersown leys are a prerequisite for severe outbreaks of OSD, at least under Swedish conditions, as it is practically only the first year leys which supply easily transmissible OSDV, in the form of infective planthoppers, if the stubble in cereal fields is carefully ploughed down.

The epidemiology of CTDV is not very well known at present but it may be somewhat similar to that found for OSDV. Only one or possibly two generations of *L. striatellus* occur per year in Sweden. No differences between crops of barley, oats or wheat as regards availability of CTDV to the larvas have, however, been found and CTDV is therefore likely to be much more difficult to control.

*Control.* — Many efforts have been made to control OSD in Sweden but both chemical control, breeding of resistant varieties and a number of other measures have given variable and unsatisfactory control of the disease, as summarized in L i n d s te n (1961). In this paper, however, also considerable differences in infectivity were reported for *J. pellucida* collected on stubble after oats in comparison to planthoppers collected on stubble after other cover crops.

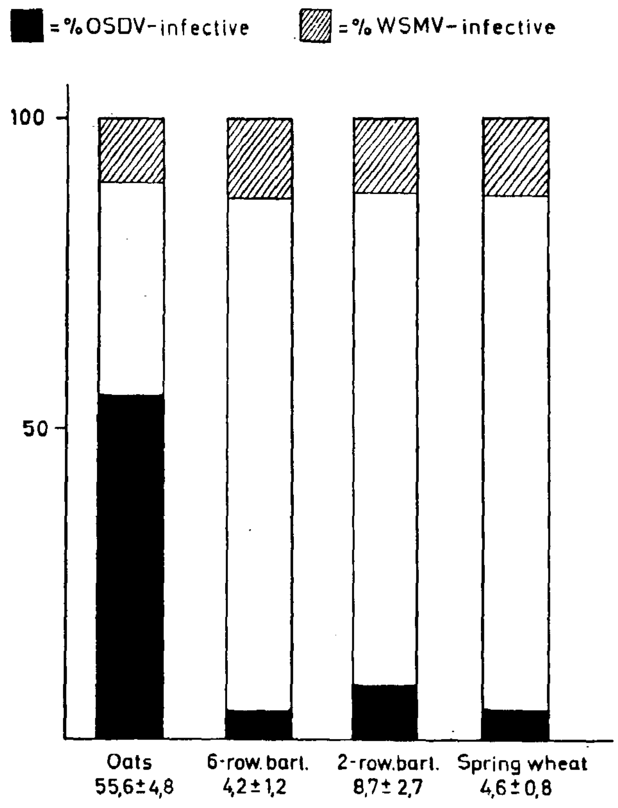


Fig. 4. — Mean % infective *J. pellucida* in undersown leys after different cover crops in field experiments during 1963—1967. (From Lindsten, 1970).

Prosečan procenat infektivnih *J. pellucida* u travnom podusevu posle različitih pokrovnih useva u poljskim ogledima u toku perioda 1963—1967. (Rezultati od Lindsten-a, 1970).

As mentioned under epidemiology, oats seem to be a better OSDV-donator than barley and wheat when used as a cover crop for undersowing and this has been verified in a great number of experiments is which several thousands of planthoppers were tested (Fig. 4).

However, avoidance of oats as a cover crop in order to control OSD was started to be recommended already in the early sixties (Lindsten, 1964). Such a simple measure as the replacement of oats with barley when used as a cover crop for the undersowing of leys turned out to be very successful for the control of OSD and is likely to have largely reduced the damage caused by this disease (Lindsten, 1970). As the larvas of *J. pellucida* will become infective to some extent also in a barley crop, as seen from Fig. 4, a prerequisite for good success with this kind of control measure is that the planthopper population is not extremely extensive. Fortunately, this seldom seems to occur in Sweden. Therefore, as shown in Fig. 5, the replacement of oats with barley or wheat when used as a cover crop will push the curve with short dashes, representing the normal case in the field, strongly to the right and the yield depression caused by OSD will be largely eliminated and even become negligible from a practical point-of-view.

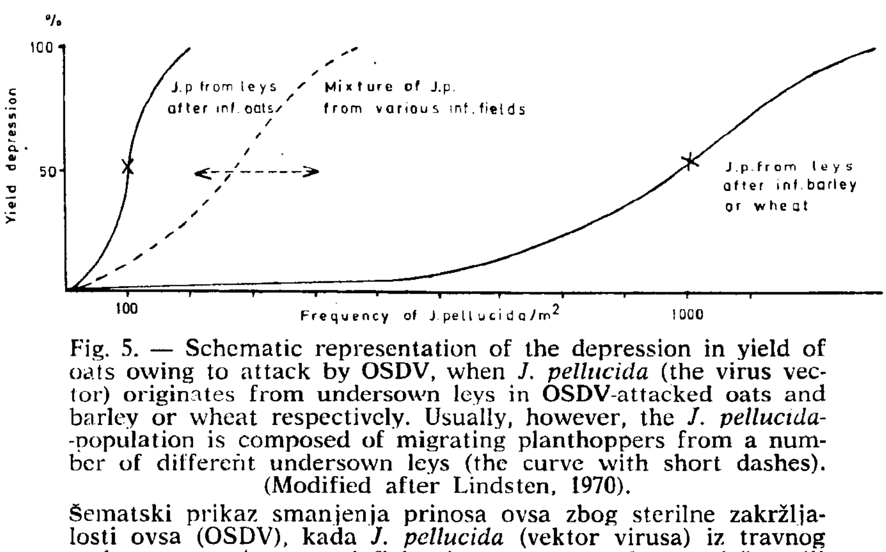


Fig. 5. — Schematic representation of the depression in yield of oats owing to attack by OSDV, when *J. pellucida* (the virus vector) originates from undersown leys in OSDV-attacked oats and barley or wheat respectively. Usually, however, the *J. pellucida*-population is composed of migrating planthoppers from a number of different undersown leys (the curve with short dashes). (Modified after Lindsten, 1970).

Šematski prikaz smanjenja prinosa ovsa zbog sterilne zakržljalosti ovsa (OSDV), kada *J. pellucida* (vektor virusa) iz travnog poduseva posejanog u inficirani usev ovsa, odnosno ječma ili pšenice. Međutim, obično populacija *J. pellucida* je mešavina migrirajućih cikada sa različitih travnih poduseva (isprekidana linija). (Modifikacija po Lindstenu-u, 1970).

*Variation among isolates of OSDV.* — A certain variation in the incubation time, the severity of symptoms and perhaps particularly in the amount and size of enations produced by OSDV, has been frequently noticed by the author. Part of this variation has undoubtedly been due to various environmental factors, time of inoculation, plant age etc. However, in one locality, Mölltorp, situated south of the earlier OSD-diseased area, diseased oat plants were recently found which indicated attack by a very mild type of OSDV (Lindsten, 1973). Isolates of this mild type of OSDV, probably to be considered as a mild strain of OSDV, have later been repeatedly found, especially in the western part of Sweden. Experiments in progress indicate that this mild strain of OSDV does not seem to change in pathogenecity or in other properties by alternating transmission to host plants and the vector (Fig. 6).

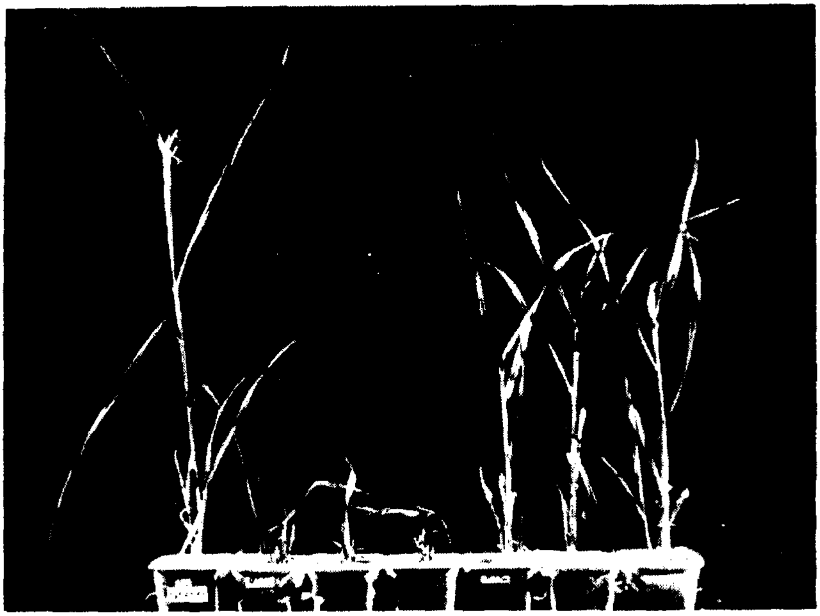

Fig. 6. — Mild isolates of OSDV always produced mild symptoms also in successive transmissions. To the left, a healthy, oat plant, and 3 plants showing symptoms of a severe isolate of OSDV, to the right 3 plants with symptoms caused by a mild isolate of OSDV.

Blagi izolati OSDV uvek izazivaju blage simptome i kod sukcesivnih prenošenja. Levo zdrava biljka, zatim tri biljke inficirane jako patogenim izolatima OSDV, tri biljke desno zaražene blagim izolatima OSDV.

*Comparison of OSDV and CTDV with other viruses.* — Similarities and differences in characteristics of Swedish isolates of OSDV and CTDV have been comprehensively dealt with in Lindsten *et al.* (1973). Some of these have also been considered in the present paper and are summarized in Table 1. In this table available relevant data on MRDV has also been included. As seen from the table, CTDV and MRDV have many characteristics in common and are likely to be closely related, maybe even related on the strainal level.

OSDV, on the other hand, is certainly very similar to the other two viruses as far as morphology is concerned, which was also confirmed by Milne (personal communication), but deviates in many other respects from CTDV and MRDV, as pointed out by Lindsten *et al.* (1973), see also Table 1.

For further data on the relationship between MRDV and other viruses reference should be made to Lovisolo (1971) and Luisoni *et al.* (1973).

## CONCLUSIONS

Seven insect-transmitted cereal diseases are known in Sweden. The three planthopper-borne ones — oat sterile dwarf (OSD), wheat striate mosaic (WSM) and cereal tillering disease (CTD) — are dealt with in this paper. The latter has not been reported from any other country but its causal virus is similar in many respects to MRDV.

The symptoms and host ranges are discussed and it is concluded that the symptoms of CTD and OSD are rather similar but that CTD deviates from OSD by causing fewer enations, except on maize. With the exception of oats and a few grasses CTD also generally shows more severe symptoms and attacks more plants than OSD (Table 1).

The distribution of the three diseases in Sweden is shown in Fig. 2. So far, OSD has been the most important one and it is likely that the shortage of vectors is the limiting factor for CTD.

The disease agents of both OSD and CTD are concluded to be isometric viruses of about 65—70 nm. Attempts to find particles of WSM failed. All three disease agents are transmitted in a persistent manner but no evidence of transovarial passage was found for OSDV or CTDV.

*Javesella pellucida* F. and *Laodelphax striatellus* Fallén are vectors of OSDV and CTDV, respectively. Only *Dicranotropis hamata* Boh. was found to be a common vector of these two viruses.

The disease agents can all overwinter in their respective vectors. At least *J. pellucida* overwinters mainly in non-ploughed fields after cereals. Therefore in Sweden, OSDV-infected cereal fields with undersown leys will build up the main virus sources from which cereal fields become infected in the following year. However, extensive field experiments during a number of years have shown that the percentage of OSDV-infective planthoppers will become much higher when oats are used as a cover crop than when barley or wheat are used.

Various methods of controlling OSD are discussed and it is concluded that the replacement of oats by barley when used as a cover crop for undersown leys in OSDV-infested areas has been very successful and this is now generally recommended for such areas when necessary.

Finally, the variation between various isolates of OSDV is dealt with. Isolates which may be considered as a mild strain of OSDV have recently been found southwest of the infested area. The relationship between OSDV, CTDV and MRDV is also briefly discussed, see table.

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## VIROZE CEREALIJA U ŠVEDSKOJ, KOJE SE PRENOSE CIKADAMA

Klas LINDSTEN

### Izvod

Autor je proučavao tri nove viroze cerealija u Švedskoj: sterilnu zakržljalost ovsa, infektivnog bokorenja cerealija i prugasti mozaik pšenice. Virozno bokorenje cerealija do sada je jedino poznato u Švedskoj.

Virus sterilne zakržljalosti ovsa (OSDV) i virus infektivnog bokorenja cerealija (CTDV) izazivaju zakržljalost, pojačano bokorenje i sterilnost biljaka. OSDV izaziva i zadebljavanje nerava i enacije. Virus prugastog mozaika pšenice (WSMV) izaziva hlorotične crte, koje često prelaze u fleke.

OSDV je najznačajniji za ovas, CTDV za ječam a WSMV za pšenicu.

CTDV ima širi krug domaćina.

OSDV je raširen u centralnom delu Švedske i izaziva gubitke do 50%. CTDV je registrovan u nekoliko lokaliteta. WSMV je sporadičan po celoj Švedskoj ali bez većeg značaja.

OSDV i CTDV imaju izometrijske virusne čestice prečnika 65—70 nm. Međusobno su slični. CTDV je sličan sa virusom hrapave zakržljalosti kukuruza (MRDV).

*Javesella pellucida prenosi* OSDV a *Laodelphax striatellus* prenosi CTDV, dok *Dicranotropis hamata* prenosi oba virusa.

Sva tri virusa prezimljavaju u vektorima i spadaju u grupu perzistentnih virusa. Prouzrokovač prugastog mozaika pšenice prenosi se preko jaja na potomstvo. *J. pellucida* prezimljava uglavnom na nerazoranim njivama posle žita.

Korišćenjem ječma ili pšenice kao pokrovnog useva za trave umesto ovsa smanjuje se pojava OSDV.