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Tobacco mosaic virus (TMV)

Effects of infection with strains of TMV on the yields of unprotected tomato plants and of plants protected with attenuated strains of TMV as compared to varieties resistant to TMV

Tobakmosaik virus (TMV)

Udbytteforsøg med TMV-linier til ubeskyttede tomatplanter og til planter beskyttet med svækket TMV-linie sammenlignet med TMV-resistente sorter

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1. Abstract

Tomato cultures are commonly exposed to more or less severe attacks by TMV. The loss in yield varies according to the virulence of the TMV strain concerned, but a reduction of between 5 and 20 per cent. is not unusual.

In recent years attempts have been made to modify the damaging effects or to prevent the attacks altogether, either by protection of TMV susceptible varieties by prophylactic inoculation with attenuated strains of TMV, or by the use of tomato varieties resistant to TMV.

In order to determine the relative merits of the above methods, experiments were made with the variety 'Reverdan' which included inoculation with 3 different strains of TMV in unprotected and 2 strains in protected specimens, all of which were also compared to results obtained with 6 varieties resistant to TMV.

'Reverdan' unprotected plants:

The virulent strain of TMV reduced both the yield, the percentage of grade 1 fruits, the weight and size of fruits, and the profit value, and also delayed the time of harvesting and caused mottling of fruits. The common strain of TMV reduced only the profit value. The attenuated strain of TMV did not affect any of the phenomena studied.

The date of transmission of the infection affected the course of the development of symptoms, the yield and the profit value when the TMV strain used was the common one. Specimens inoculated on May 3rd developed less severe virus disease symptoms throughout the period of growth and achieved greater yields and profit values than did plants inoculated on March 20th.

'Reverdan' TMV protected plants:

The strains of virus used had no effect on the TMV-protected specimens. In spite of subsequent inoculation with, respectively, the common and virulent strains of TMV, the plants failed to develop any characteristic symptoms of virus disease throughout the period of growth.

TMV resistant varieties:

The strains of virus used showed no effects on the varieties resistant to TMV, although there

Key-words: Tomato, TMV, Attenuated TMV-strains, Cross-protection, Resistance.

was spontaneous development of leaf and fruit symptoms in 1.2 per cent. of the plants.

TMV resistant, protected and unprotected plants:

No differences in yield were found between varieties resistant to TMV, TMV protected plants, and control plants of the variety 'Reverdan'. Only unprotected plants inoculated with the virulent strain of TMV showed reduced yield values.

No differences were found between the profit values for the 4 best TMV resistant varieties, the TMV protected plants, and control plants of the variety 'Reverdan'. Only unprotected plants inoculated with, respectively, the common and virulent strains of TMV, were found to give lower profit values.

2. Resumé

Tomatkulturer bliver sædvanligvis udsat for mere eller mindre kraftige angreb af TMV. Udbyttetabene varierer alt efter TMV-liniens styrke, men en reduktion på mellem 5 og 20 pct. er ikke ualmindelig.

Forsøg på at nedsætte angrebene skadelige virkning eller helt at forhindre disse angreb er i de senere år blevet udført enten ved at beskytte TMV-modtagelige sorter med svækkede TMV-linier, eller ved anvendelse af TMV-resistente sorter.

For at kunne vurdere værdien af disse metoder, udførtes et forsøg med sorten 'Reverdan', omfattende 3 TMV-linier i ubeskyttede og 2 viruslinier i beskyttede planter, sammenlignet med 6 TMV-resistente sorter.

'Reverdan' ubeskyttede planter:

Den kraftige TMV-linie har reduceret henholdsvis udbyttet, procent frugter af 1. sortering, frugt-vægten, frugstørrelsen og værditallet samt forsinket frugthøsten og fremkaldt spætning i frugterne. Den alm. TMV-linie har kun reduceret værditallet. Den svækkede TMV-linie har ikke haft indflydelse på nogen af de undersøgte forhold.

Smittetidspunktet har haft indflydelse på symptomudviklingen, udbyttet og værditallet, hvor alm. TMV-linie har været anvendt. Planter inokuleret den 3/5 har udviklet svagere virussymp-tomer gennem hele vækstperioden og givet et større udbytte og værdital, end planter inokuleret den 20/3.

'Reverdan' TMV-beskyttede planter:

Viruslinierne har ikke haft nogen indflydelse på de TMV-beskyttede planter. Planterne har, trods efterfølgende inokulation med henholdsvis alm. og kraftig TMV-linie, ikke vist nogen karakteristiske virussymp-tomer gennem hele vækstperioden.

TMV-resistente sorter:

Viruslinierne havde ingen indflydelse på de TMV-resistente sorter. Spontane blad- og frugt-symptomer udvikledes dog i 1,2 pct. af planterne.

TMV-resistente, -beskyttede og ubeskyttede planter:

Der har ikke været forskel i udbyttet mellem de TMV-resistente sorter og de TMV-beskyttede planter samt kontrolplanter af sorten 'Reverdan'. Kun ubeskyttede planter, inokuleret med kraftig TMV-linie, har givet mindre udbytte.

Der har ikke været forskel i værditallet mellem de 4 bedste TMV-resistente sorter og de TMV-beskyttede planter samt kontrolplanter af sorten 'Reverdan'. Kun ubeskyttede planter, inokuleret med henholdsvis alm. og kraftig TMV-linie, har givet et mindre værdital.

Nøgleord: Tomat, TMV, Svækkede TMV-linier, Krydsbeskyttelse, Resistens.

3. Introduction

Every year tomato cultures are attacked by tobacco mosaic virus (TMV). There are several strains of the virus, and in most cases tomato plants are attacked by tomato virus strains. Different tomato virus strains vary greatly in their effects on tomato cultures; in the following they are referred to exclusively as the TMV strains.

Attacks by virulent strains of TMV cause severe reductions in growth, fruit quality and yield. Attacks by more moderate strains of TMV which occur most frequently (common strains of TMV) cause less severe damage, but a reduction in yield of between 5 and 20 per cent. is not unusual (Paludan 1968, 1973).

Attacks by weak (i.e., deliberately attenuated) strains of TMV have shown that in this case also different strains of virus vary in their effects on development of symptoms and profit values.

In addition to the identity of the virus strain the effect of an attack of TMV depends also on the date of infection and on the variety of host plant used (Paludan 1975).

As a natural extension of the experiments which included the effects of a range of strains

of TMV from attenuated to virulent ones on the tomato culture, a series of experiments was laid out at the State Glasshouse Experiments, Virum, during 1974 in order to compare the relative advantages of protection of TMV susceptible varieties by early inoculation with attenuated strains of TMV and of the use of varieties resistant to TMV.

In addition to the experiment in which specimens of 'Reverdan' were inoculated with TMV, sample plots of 6 of the most promising TMV resistant varieties were grown in the same glasshouse, thus affording the opportunity of a direct comparison of the data obtained.

4. Methods

4:1 Experimental arrangement

The TMV susceptible variety 'Reverdan' was used for the infection trials which included a total of 7 differently treated units, 3 of which were inoculated early in the period of growth (23rd Jan. at the 3-leaf stage) with an attenuated strain of TMV (Fig. 1, left) in order to protect the plants against subsequent attacks by TMV. Two months later (20/3; 2nd cluster

Table 1. TMV infection trials with the variety 'Reverdan'
TMV-infektionsforsøg i sorten 'Reverdan'

Treatment		TMV strains inoculated date <i>TMV-linier inokuleret den</i>		
<i>Behandling</i>	<i>Forsøgsled</i>	25/1	20/3	3/5-74
TMV protected plants	1	attenuated <i>svækket</i>		
TMV-beskyttede planter	2	attenuated <i>svækket</i>	+ common <i>alm.</i>	
	3	attenuated <i>svækket</i>	+ virulent <i>kraftig</i>	
Unprotected plants	4		attenuated <i>svækket</i>	
Ubeskyttede planter	5		common <i>alm.</i>	
	6		virulent <i>kraftig</i>	
Control <i>Kontrol</i>	11			common <i>alm.</i>

in bloom) two of the units received additional inoculations of, respectively, a common and a virulent strain of TMV (Fig. 1, right, 2) At the same time 3 other units comprising untreated healthy plants received inoculations of, respectively, attenuated, common and virulent strains of TMV. Due to a subsequent, spontaneous transmission of the virulent strain it became necessary also to protect the untreated control plants; they were inoculated with the common strain of TMV on May 3rd.

The experimental arrangement for the TMV infection trials is shown in Table 1.

The TMV tomato strains included the following:

Attenuated, Danish strain TMV K 58⁸⁴ type 0
Common TMV strain K 60 (parent strain of above)

Virulent TMV strain K 57 (virulent yellow stripe strain).

The TMV resistant varieties of tomato used and their genes of resistance are specified in Table 2.

nation they were thinned to 1 specimen per container. Later the plants were established at set distances.

In the glasshouse the specimen plants were transplanted on February 19th, 1974, at distances of 100 cm. between rows and 35 cm. between individual plants, i.e., 2.95 specimens per m². Instead of tying up the plants the method of gradual lowering was employed. The plants were lowered approximately half a metre each time, so that the clusters of fruit eventually were all placed on a common, low system of netting raised approximately 40 cm. above ground. In this way uniform conditions of ripening for all fruits were ensured throughout the period of ripening. At the same time it was made possible accurately to record virus disease symptoms in the new growth throughout the season of growth. The tomatoes were harvested in 91 separate pickings over the period of from 10th May to 28th November.

4:3 Virus

The tomato plants were inoculated with TMV infected juice by means of tweezers and a small

Table 2. The TMV resistant tomato varieties used and their genes of resistance
TMV-resistente tomatorter og resistensgener

Treatment <i>Forsøgsled</i>	Varieties <i>Sorter</i>	Genes of resistance <i>Tm gener</i>
13	'Lindgreen 422-73'	Tm/+ , Tm-2 ² /+
14	'Pagham Cross'	Tm/+ , Tm-2/Tm-2 ²
15	'Virase'	Tm-2 ² /Tm-2 ²
16	'W W 116-Stella'	Tm-2 gl*/Tm-2 ²
17	'W W 152'	Tm-2 ² /Tm-2 ²
18	'W W 173'	Tm/+ , Tm-2 ² /Tm-2 ²

* = gen from *Lycopersicum glandulosum*

The different combinations of the experimental arrangement gave a total of 13 experimental units each of 54 plants distributed on 3 repeats.

4:2 Culture

The tomato plants were sown on December 14th, 1973, directly in 11 cm. cardboard containers, two seeds per container. After germi-

piece of foam rubber. The tweezers were sterilized in the flame of a spirit-lamp and the foam rubber replaced between each application in order to avoid transmission of any seed-borne additional infection. The inoculum consisted of a 1 per cent. virus dilution to which had been added carborundum powder.

In order to prevent undesired transmission of virus from the earliest inoculated specimens,

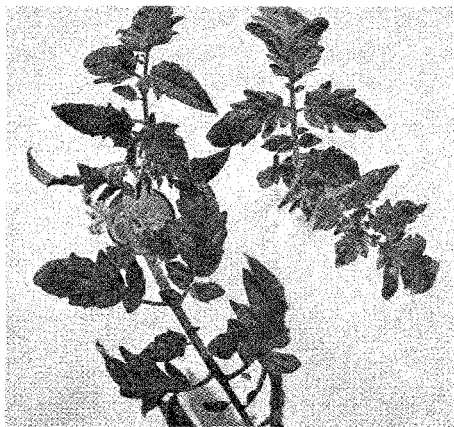


Fig. 1. The tomato variety 'Reverdan' infected with an artificially attenuated strain of TMV, left, and with the common (i.e., parent) strain, right.

Tomatsorten 'Reverdan' inficeret med kunstig svækket TMV-linie t.v. og almindelig TMV-linie (forældrelinien) t.h.



Fig. 2. The variety 'Reverdan' infected with the virulent strain of TMV.

Sorten 'Reverdan' inficeret med kraftig TMV-linie.

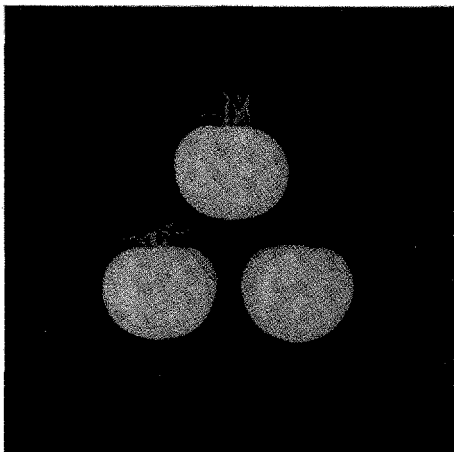


Fig. 3. Tomato fruits of the variety 'Reverdan' infected with the virulent strain of TMV.

Tomatfrugter af sorten 'Reverdan' inficeret med kraftig TMV-linie.

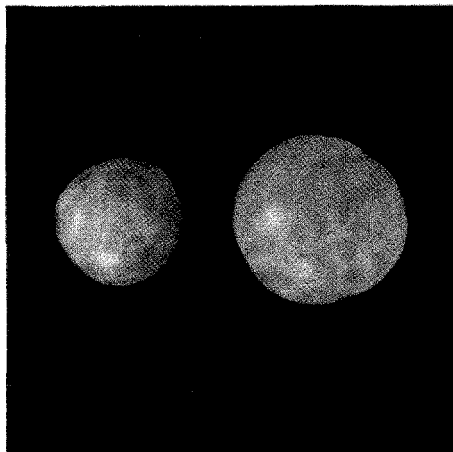


Fig. 4. Fruits of a TMV resistant variety with spontaneous fruit symptoms.

Frugter fra TMV-resistent sort med spontane frugtsymptomer.

Foto: J. Begtrup

they were isolated by means of low plastic walls during the initial period of growth. When transplanted to the glasshouse the plants from infected and non-infected plots were placed in separate rows, interspersed with rows of varieties resistant to TMV.

The untreated plants which were to be inoculated only 4 weeks after being transplanted to the glasshouse were tested for possible virus infection immediately prior to inoculation by sapinoculation to detached leaves of *Nicotiana tabacum* 'Xanthi'. In no case was TMV infection demonstrated in these plants.

4:4 Recordings and measurements

Virus disease symptoms in the leaves were assessed about once a month. Symptoms included mottling and leaf deformities due to retarded growth in certain areas. The following classification was used.

Evaluation	Mottling	Deformities
Karakter	Spætning	Deformiteter
1	symptomless	symptomless*)
	ingen symptomter	ingen symptomer
5	mottling*)	leaflets tapering*)
	alm. spætning	spidse småblade
9	severe mottling*)	leaflets rugosed*)
	kraftig spætning	rynkede småblade

The above recordings were made for all 27 plants in each experimental unit. Fruit measurements and recordings were arranged as follows:

Tomatoes were harvested thrice a week, and tomato yield in kg. per plot was established for each day of harvesting. Every 7th harvesting date the kg. yield of tomatoes was divided into grades 1, 2 and 3, plus rejects, while the numbers of fruits and the fruit weight were distributed among the sizes < 35, 36-40, 41-47, 48-57, 58-70, and > 70 mm. Fruit symptoms were also recorded as numbers of fruits with waxy spots, with green back, and with hollow centres, as well as other viral disease symptoms such as necrotic spots*), red-yellow mottling*), granulation, glassiness*), and internal browning*).

* See illustrations, Tidsskr. f. Planteavl 79, 1975, pp. 277-278

The profit values (Danish Kroner/m²) were calculated on the basis of average values supplied by GASA sales organisation at Odense for the period 1967-1971.

The data obtained were treated statistically by Data Analytical Laboratories by means of EDB computers. Where significant differences were found between the experimental units, the LDS₉₅ values are given in the tables.

The following results show the effects of the different strains of TMV and of different dates of infection on, respectively, unprotected and TMV protected plants of the variety 'Reverdan', as well as the reaction of the varieties resistant to TMV.

5. Results

5:1 Recordings of symptoms

5:1:1 Mottling symptoms

The development of mottling symptoms in the TMV susceptible variety 'Reverdan' was affected by the strains of TMV employed, the date of inoculation and the protective measures applied.

Results of the two former treatments may be seen in Fig. 5. Plants inoculated with the attenuated strain of TMV remained on the whole free from symptoms throughout the period of growth.

The common strain of TMV caused common chlorotic mottling of the apical leaves until September 18th; subsequently the symptoms disappeared altogether. The virulent strain of TMV caused a very pronounced yellowish white mottling of the leaves and chlorotic longitudinal stripes on the stem up to and including the month of July (Fig. 2). Subsequently the symptoms were gradually reduced. Yellow chlorotic mottling was also found in the fruits (Fig. 3).

The date of transmission of the infection affected the development of symptoms. Early inoculation with attenuated and common strains, respectively, caused the development of more pronounced symptoms than did inoculation at a later date with the identical strain of virus.

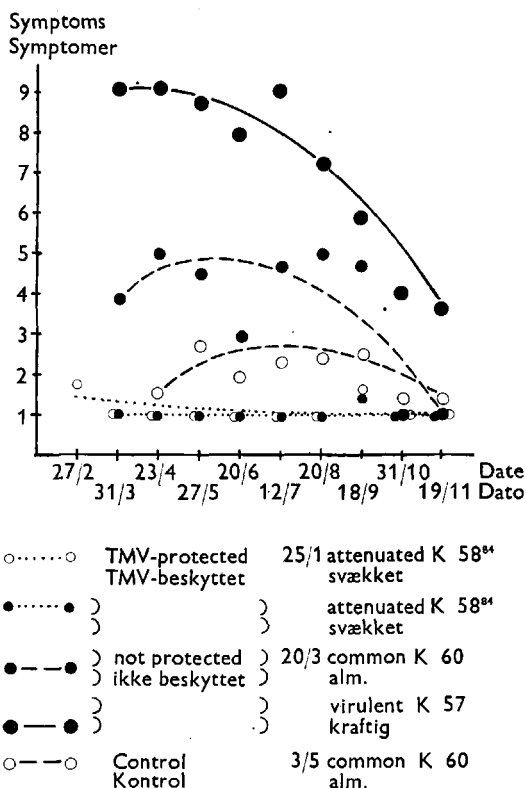


Fig. 5. Mottling symptoms in 'Reverdan' caused by 3 different strains of TMV at 3 inoculation dates (mean values of 3 experimental units).

Spætnings symptomer i 'Reverdan' inokuleret med 3 TMV-linier på 3 smittetidspunkter (gennemsnit af 3 parceller).

Plants infected with attenuated strains of TMV presented symptoms only during the first month following inoculation, whereas those with the common strain of TMV continued to develop symptoms throughout the growing season.

With regard to the development of mottling symptoms there proved to be, throughout the period of growth, an interaction between the strains of TMV employed and the TMV protected/unprotected plants. The results as of June 20th may be seen in Table 3.

In the case of the protected tomato plants no differences were found between the strains of virus used, indicating that protection was complete. The unprotected plants showed both mutual differences between the 3 different strains of TMV used, and a difference from the unprotected plants.

No development of mottling symptoms was found among the 6 varieties resistant to TMV with the exception of 4 out of a total of 324 plants. In the variety 'Virase' symptoms occurred in 2 plants (3.7 per cent.) during the months of, respectively, September and October, and in the variety 'Stella' likewise 2 plants (3.7 per cent.) during the months of May and July. These spontaneous symptoms manifested themselves at first as a mottling of the younger leaves, followed by severe leaf roll in the upper leaves and cessation of growth. The fruits

Table 3. Mottling symptoms caused by 3 strains of TMV in TMV protected and in unprotected plants

Spætnings symptomer den 20/6 forårsaget af 3 TMV-linier i henholdsvis TMV-beskyttede og ubeskyttede planter

Treatment Behandling	Date of inoculation Inokulationsdato	TMV strains / linier			LSD _{.95}
		attenuated svækket	common alm.	virulent kraftig	
TMV protected TMV-beskyttet	25/1 ¹⁾ + 20/3	1.0 ²⁾	1.0	1.0	0.9
Unprotected Ubeskyttet	20/3	1.0	2.9	7.9	0.9
	LSD _{.95}	1.3	1.3	1.3	

1) Protected with attenuated strain of TMV. Beskyttelse med svækket TMV-linie

2) 1-9, where 1 represents absence of symptoms and 9 the most severe symptoms
 1-9, hvor 1 er uden symptomer og 9 de kraftigste symptomer

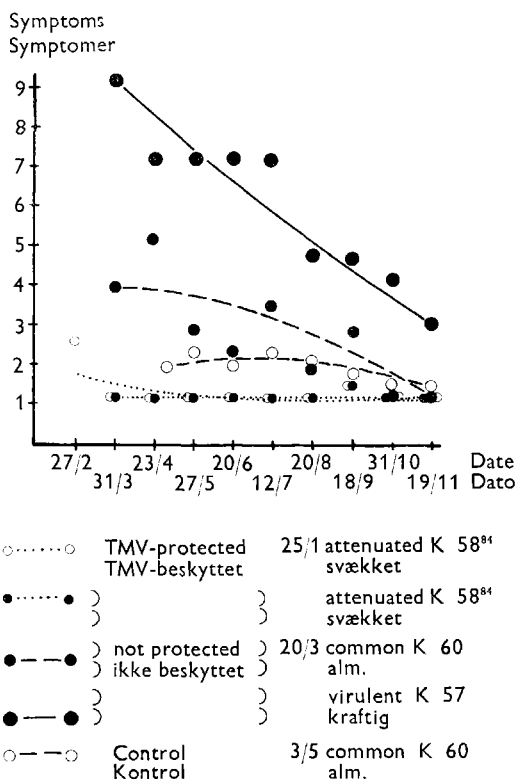


Fig. 6. Leaf retardation in 'Reverdan' caused by 3 different strains of TMV at 3 inoculation dates (mean values of 3 experimental units).

Bladdeformering i 'Reverdan' fra 3 TMV-linier og ved 3 smittetider (gennemsnit af 3 parceller).

were also totally destroyed as they developed severe, brown, circular depressions on a yellow background (Fig. 4).

5 : 1 : 2 Leaf deformities

The occurrence of more or less deformed leaves (leaflets rugosed or tapering) was affected in the TMV susceptible variety 'Reverdan' by differences in strains of TMV employed, dates of inoculation, and protective measures applied. Fig. 6 shows the results of the two former treatments.

The attenuated strain of TMV caused no significant changes in leaf morphology. The common strain of TMV caused the development of tapering leaflets during the initial month following inoculation; subsequently the symptoms gradually receded. The virulent strain caused the formation of very conspicuously curled leaflets as soon as 11 days after inoculation. The severe symptoms receded somewhat after the first month, but up until the month of July the plants remained obviously affected by the virus strain, showing open apices and a retarded development of both leaves and shoots. Subsequently the symptoms receded gradually.

Postponement of the date of inoculation modified the development of symptoms both

Table 4. Leaf retardation caused by 3 strains of TMV in TMV protected and unprotected plants, respectively

Bladdeformering den 20/6 forårsaget af 3 TMV-linier i henholdsvis TMV-beskyttede og ubeskyttede planter

Treatment Behandling	Date of inoculation Inokulationsdato	TMV strains / linier			LSD _{.95}
		attenuated svækket	common alm.	virulent kraftig	
TMV protected TMV-beskyttet	25/1 ¹) + 20/3	1.0 ²)	1.0	1.0	0.5
Unprotected Ubeskyttet	20/3	1.0	2.1	7.0	0.5
	LSD _{.95}	0.6	0.6	0.6	

1) Protected with attenuated strain of TMV. Beskyttelse med svækket TMV-linie

2) 1-9, where 1 indicates absence of symptoms and 9 the most severe symptoms.

1-9, hvor 1 er uden symptomer og 9 de kraftigste symptomer

in the case of the attenuated and the common strain of TMV.

In the development of leaf deformities there also proved to be, throughout the growing season, an interaction between the strains of TMV used and the TMV protected/unprotected plants. Results as of June 20th are shown in Table 4.

As in the case of the mottling symptoms, there appeared to have been no difference in the protected tomato plants between the effects of the different strains of virus employed, since protection was complete. In the case of unprotected plants there was a difference from the protected plants, as well as mutual

differences between the 3 different strains of virus used.

Leaf deformities occurred in only 4 plants from among the TMV resistant varieties, as mentioned in the section on mottling.

5:2 Fruit yield

In the case of the TMV susceptible variety 'Reverdan' the yield was affected by the choice of strains of TMV, dates of infection, and type of protection. The results, including also those for TMV resistant varieties, are shown in Table 5.

The virulent strain of TMV reduced the yield as compared to the attenuated and the

Table 5. Total yield. *Udbytte i alt*

TMV susceptible / <i>modtagelig</i> 'Reverdan'		kg/m ²	TMV resistant varieties <i>TMV-resistente sorter</i>	
Control <i>Kontrol</i>	common TMV <i>alm. TMV</i>		kg/m ²	
		33.1		
TMV protected <i>TMV- beskyttede</i>	attenuated TMV <i>svækket TMV</i>	31.7	31.4	'Lindgreen'
	common TMV <i>alm. TMV</i>	31.4	32.3	'Pagham Cross'
	virulent TMV <i>kraftig TMV</i>	32.2	32.2	'Virase'
Unprotected <i>Ubeskyttede</i>	attenuated TMV <i>svækket TMV</i>	30.8	30.7	'W W 116 Stella'
	common TMV <i>alm. TMV</i>	30.2	35.1	'W W 152'
	virulent TMV <i>kraftig TMV</i>	26.7	30.5	'W W 173'

LSD_{.95} : 2.7 between TMV protected treatments, *mellem TMV beskyttede forsøgsled.*

» : 2.7 between unprotected treatments, *mellem ubeskyttede forsøgsled.*

» : 3.1 between control, TMV protected and unprotected treatments, *mellem kontrol, TMV-beskyttede og ubeskyttede forsøgsled.*

» : 2.9 between TMV resistant units, *mellem TMV-resistente forsøgsled.*

» : 3.0 between TMV resistant and TMV protected treatments, *mellem TMV-resistente og TMV-modtagelige forsøgsled.*

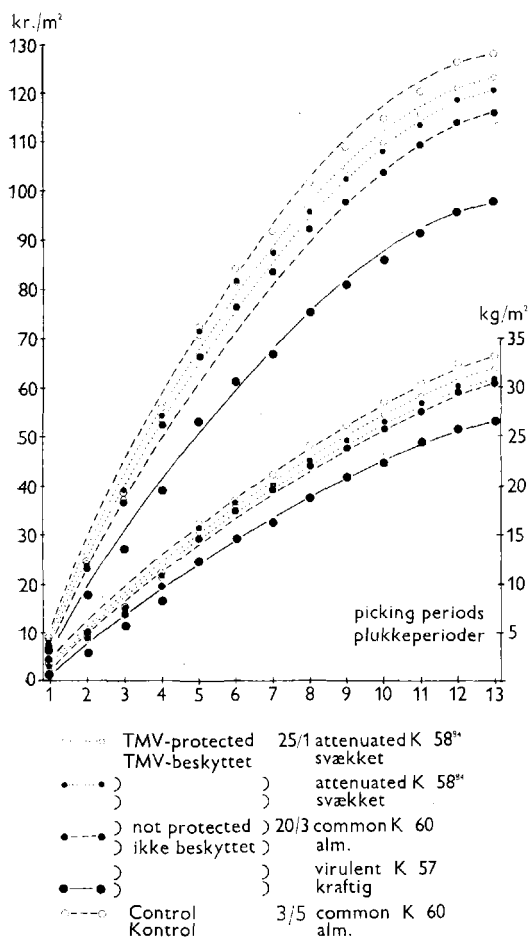


Fig.7. Accumulated yield and profit values for 14-day picking periods for 3 different strains of TMV and 3 inoculation dates (mean values of 3 experimental units).

Opsummerede udbytte- og værdital i 14 døgns plukkeperioder i 'Reverdan' med 3 TMV-linier og 3 smittetidspunkter (gennemsnit af 3 parceller).

common strain by 11.6 and 13.3 per cent., respectively. The virulent strain also appears to have reduced the yield to such an extent that it has become significantly lower than those of all other experimental units. The attenuated strain failed to produce significant reductions regardless of date of infection.

Late inoculation of control plants with the

common strain of TMV on May 3rd produced a better yield than early transmission (20th March) of the identical strain to unprotected plants.

The TMV protected plants produced a better yield than unprotected specimens inoculated with a virulent strain.

The accumulated yield values in 14-day picking periods are shown in Fig. 7 which includes 5 of the 'Reverdan' experimental units. Plants from control unit and the TMV protected experimental unit gave the highest yields, which furthermore increased more strongly throughout the picking period than did the yields from the other experimental units.

With regard to yields, there is also evidence of an interaction between the strain of TMV used and the TMV protected/unprotected plants (Table 5); this is primarily due to the fact that inoculation with the virulent strain of virus caused a very low yield in unprotected plants.

For the TMV resistant varieties (Table 5) the yields tallied with those obtained with 'Reverdan' with two exceptions, i.e., that of 'W W 152' which gave the highest yield of any experimental unit, and that of the virulent strain of TMV in unprotected plants of 'Reverdan' which gave the lowest yield.

5:3 Grading

The percentage of grade 1 fruits in the TMV susceptible variety 'Reverdan' was affected only by infection with the virulent strain of TMV. The results, which also include the TMV resistant varieties, are shown in Table 6.

In unprotected plants of the variety 'Reverdan', the virulent strain of TMV reduced the percentage of grade 1 fruits by about 15 per cent. as compared to the control units.

The TMV resistant varieties varied considerably with regard to their yields of grade 1 fruits; 2 varieties exceeded the 'Reverdan' control by 10-15 per cent., 2 were on a par with the controls, and yet another two were lower by about 25-28 per cent.

Table 6. Percentage of grade 1 fruits. *Pct. frugter af 1. sortering*

	TMV susceptible / modtagelig 'Reverdan'		TMV resistant varieties TMV-resistente sorter	
		Pct. I	Pct. I	
Control <i>Kontrol</i>	common TMV <i>alm. TMV</i>	65.7		
TMV protected TMV- beskyttede	attenuated TMV <i>svækket TMV</i>	65.5	80.1	'Lindgreen'
	common TMV <i>alm. TMV</i>	69.2	76.6	'Pagham Cross'
	virulent TMV <i>kraftig TMV</i>	66.9	62.4	'Virase'
Unprotected <i>Ubeskyttede</i>	attenuated TMV <i>svækket TMV</i>	65.2	62.7	'W W 116 Stella'
	common TMV <i>alm. TMV</i>	64.4	40.1	'W W 152'
	virulent TMV <i>kraftig TMV</i>	50.3	37.9	'W W 173'

5:4 Distribution of size and weight

The distribution of sizes and weights of fruits of the variety 'Reverdan' was affected only by infection with the virulent strain of TMV, where the difference were particularly obvious within the grades of 40-47 and 58-70 mm. Host reaction consisted in the formation of a

greater number of small fruits and fewer large ones.

Within the TMV resistant varieties there was considerable variation with regard to the distribution of sizes and weights. The results may be seen in Table 7.

Table 7. Fruits graded according to size (percentage values)
Størrelsesfordeling af frugter i pct.

Treatment <i>Forsøgsled</i>	Size range in mm / <i>Størrelsesfordeling mm.</i>					
	< 35,	36-40,	41-47,	48-57,	58-70,	> 70
'Reverdan'						
Control common TMV <i>Kontrol alm. TMV</i>	0.8	2.6	26.1	59.6	9.2	1.7
Unprotected virulent TMV <i>Ubeskyttet kraftig TMV</i>	1.1	2.9	35.0	55.0	3.8	1.1
TMV resistant varieties TMV-resistente sorter						
'Lindgreen'	0.3	2.1	38.6	54.8	4.1	0.0
'Pagham Cross'	0.4	4.2	34.3	53.4	6.9	0.8
'Virase'	2.0	5.4	33.4	52.5	6.6	0.0
'W W 116 Stella'	1.9	4.7	40.3	46.7	5.6	0.8
'W W 152'	0.8	2.7	18.5	48.9	23.8	5.3
'W W 173'	0.8	2.0	19.3	46.1	25.3	6.6

On the whole the TMV resistant varieties proved to yield smaller fruits than 'Reverdan'. However, 'W W-152' and 'W W 173' produced considerably larger fruits, with approximately 25 per cent. within the range of 58-70 mm.

The data concerning the distribution of fruit weight tallied with the above.

5:5 Fruit weight

In the variety 'Reverdan' the fruit weight was affected only by infection with the virulent strain of TMV. The results which include also the varieties resistant to TMV are shown in Table 8.

the virulent strain of TMV (Fig. 3). However, in this same variety were found no other viral symptoms such as granulation, glassiness, or internal browning.

In 2 of the varieties resistant to TMV some viral fruit symptoms were found in the form of brown to black, ill-defined and incomplete circular depressions and spots (Fig. 4). Fruits with symptoms were found only in a few specimens of the varieties 'Virase' and 'W W 116', where they accounted for 1.8 and 0.6 per cent. of fruits, respectively.

In 'Reverdan', fruits symptoms such as waxy spots, green back, and hollow fruits were af-

Table 8. Mean values for individual fruits. *Gennemsnitsvægt pr. frugt*

	TMV susceptible / modtagelig 'Reverdan'		TMV resistant varieties <i>TMV-resistente sorter</i>	
		g.	g.	
Control <i>Kontrol</i>	common TMV <i>alm. TMV</i>	65.5		
TMV protected <i>TMV- beskyttede</i>	attenuated TMV <i>svækket TMV</i>	64.2	59.5	'Lindgreen'
	common TMV <i>alm. TMV</i>	66.6	60.3	'Pagham Cross'
	virulent TMV <i>kraftig TMV</i>	64.8	58.2	'Virase'
Unprotected <i>Ubeskyttede</i>	attenuated TMV <i>svækket TMV</i>	62.3	55.9	'W W 116 Stella'
	common TMV <i>alm. TMV</i>	62.6	70.3	'W W 152'
	virulent TMV <i>kraftig TMV</i>	58.5	72.3	'W W 173'

Infection with the virulent strain of TMV reduced fruit weight by 10.7 per cent. as compared to the controls.

5:6 Fruit symptoms

Viral mottling occurred in 3.7 per cent. of the fruits from 'Reverdan' plants inoculated with

ected only by infection with the virulent strain of TMV. Development of these fruit symptoms in the varieties resistant to TMV was dependent of the varieties. The results may be seen in Table 9.

Table 9. Fruit symptoms. *Frugtsymptomer*

Treatment <i>Forsøgsled</i>	Per cent fruit with / <i>Pct. frugter med</i>		
	waxy spots <i>grønskjold</i>	green back <i>grønnakke</i>	hollow fruits <i>hule frugter</i>
'Reverdan'			
Control common TMV			
Kontrol alm. TMV	2.8	12.5	5.9
Unprotected virulent TMV			
Ubeskyttet kraftig TMV	7.6	15.9	11.0
TMV resistant varieties			
TMV resistente sorter			
'Lindgreen'	1.0	0.6	9.3
'Pagham Cross'	4.3	1.4	1.7
'Virase'	6.6	18.4	4.7
'W W 116 Stella'	3.2	9.5	5.0
'W W 173'	0.7	0.8	4.4
'W W 173'	3.5	17.0	6.7

5:7 Profit values

In the TMV susceptible variety 'Reverdan' the profit values were affected by choice of virus strain, date of infection, and protective measures applied. Results which include also the varieties resistant to TMV are shown in Table 10.

Infection with the virulent strain of TMV reduced the profit values as compared to those for the attenuated and common strains by 16.6 and 18.7 per cent., respectively. Compared to the control unit the attenuated strain in unprotected plants reduced the profit value by 5.9 per cent.

Table 10. Profit values. *Værdital i alt*

TMV susceptible / modtagelig 'Reverdan'		TMV resistant varieties TMV-resistente sorter	
		Kr/m ²	Kr/m ²
Control <i>Kontrol</i>	common TMV <i>alm. TMV</i>	127.9	
TMV protected TMV- <i>beskyttede</i>	attenuated TMV <i>svækket TMV</i>	123.0	127.8 'Lindgreen'
	common TMV <i>alm. TMV</i>	123.4	128.3 'Pagham Cross'
	virulent TMV <i>kraftig TMV</i>	125.3	122.7 'Virase'
Unprotected <i>Ubeskyttede</i>	attenuated TMV <i>svækket TMV</i>	120.4	118.3 'W W 116 Stella'
	common TMV <i>alm. TMV</i>	117.4	124.4 'W W 152'
	virulent TMV <i>kraftig TMV</i>	97.9	111.2 'W W 173'

Late inoculation of the control unit with the common strain of TMV on 3rd May produced a higher profit value than an earlier date of inoculation (20th March) of unprotected plants with the same strain.

The TMV protected plants gave higher profit values than did unprotected ones inoculated with common and virulent strains of TMV.

Figure 7 shows the accumulated profit values in 14-day picking periods, and includes 5 of the 'Reverdan' experimental units. Plants from control unit and from the TMV protected experimental unit gave the highest profit values, which furthermore increased more strongly throughout the harvesting season than did the profit values from all other experimental units.

The profit values for the best of the varieties resistant to TMV equalled the highest ones found for the TMV susceptible variety 'Reverdan'.

6. Discussion

The strains of TMV employed have affected a considerable number of the phenomena measured and recorded in the present study. Significant effects were primarily obtained with the very virulent strain of TMV, whereas only slight differences were found between the effects of the attenuated and the common strains.

These results are in agreement with earlier Danish studies (*Paludan* 1968, 1973).

The attenuated tomato-strain of TMV of used in the present study was found effectively to protect against more virulent tomato strains of the same virus. This also agrees with earlier results (*Rast* 1972, *Paludan* 1973).

Different dates of transmission of the infection (i.e., 25th Jan. as against 20th March) with attenuated strains of TMV did not affect the results, in contrast to Danish investigations in 1973, where the percentage of grade 1 fruits was found to be reduced due to inoculation at the primary leaf stage. However, when the dates of primary infection compared were 20th March and 3rd May, and the virus used was the common strain of TMV, there

proved to be a difference, the later inoculation date producing the weaker symptoms and the higher yield and profit values.

No fruit symptoms were found to result from inoculation with attenuated and common strains of TMV, whereas mottled fruits developed following inoculation with the virulent strain of TMV. These results are in accordance with earlier Danish results from 1968 and 1973.

With regard to yield, the control unit of the variety 'Reverdan' given delayed protection did better than plants inoculated with common and virulent strains of TMV. However, in practice it cannot be assumed to be possible to maintain tomato plants in a healthy condition until the month of May, since it has been found that spontaneous infection of up to 100 per cent. of plants normally takes place during the first two months following transplantation. Hence it would appear to be more realistic to include only the yield values for the TMV protected plants. These exceed only the yield values from plants inoculated with the virulent strain of TMV, but not those from the varieties resistant to TMV.

The profit value from the control unit should be treated with the same reservation. However, the profit value from the TMV protected plants is higher than those from plants inoculated with either the common or the virulent strain of TMV, but not higher than the values from the best of the varieties resistant to TMV.

On the other hand, the results from the 'Reverdan' control unit also show that the longer it is possible to maintain the plants in a virus-free condition, the higher become the yield and the profit value.

A comparison between protection of TMV susceptible varieties with attenuated strains of TMV and cultivation of the best of the varieties resistant to TMV shows both methods to be feasible, and both superior to the use of unprotected tomato plants.

However, in the case of TMV prophylaxis it should be taken into consideration that a certain amount of additional work is involved, and

also that the risk remains of spontaneous infection with random strains of TMV prior to protective inoculation. Finally, there is also a possibility that an artificially attenuated strain of TMV may be contained with the common strain, or mutate back to the parent strain (Rast 1974).

7. Conclusion

According to the results of the present study, the damage inflicted on tomato cultures by the normally occurring spontaneous infection with TMV may be eliminated in one of the following two ways.

1. Protection at an early stage of TMV susceptible tomato plants with an attenuated strain of TMV.

2. The exclusive use of tomato varieties resistant to TMV.

8. Literature

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Manuskript modtaget den 1. september 1975.