INTEGRATED CONTROL OF SUGAR-BEET VIRUS YELLOWS: CURRENT PRACTICES AND FUTURE PROSPECTS.

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Summary

Data is given from 13 countries on virus yellows incidence, damage, sources, and control measures - especially pesticide usage.

The major factors affecting incidence and damage are discussed. A guide is suggested to help growers to decide if and when to spray his crop(s) on receipt of an "area spray warning".

Sommaire

Treize pays ont donné les informations sur l'occurence de la jaunisse, les degats, les sources, et les methodes de lutte - principalement avec les insecticides.

Les facteurs les plus importants qui affectent l'occurence et les dégats de la maladie sont discutés. Une méthode est proposée pour aider les planteurs à décider d'une traitement et quand l'appliquer à la réception d'une avis de traitement "de zone".

Zusammenfassung

Aus 13 Ländern werden Angaben gemacht über die viröse Vergilbung hinsichtlich Auftreten, Schadensausmass, Virusquellen sowie Bekampfungsmassnahmen, insbesondere zum Insektizid-Einsatz.

Die wichtigsten Faktoren, die das Auftreten und das Schadensausmass beeimflussen, werden diskutiert. Es wird vorgeschlagen eine „Entscheidungshilfe" für die Anbauer zu schaffen ob und wann sie ihre Felder nach Erhalt einer Warnmeldung spritzen müssen.

INTRODUCTION

All pest and disease problems of sugar beet, as of other crops, demand an integrated approach to control; virus yellows, because of the great variability in its incidence in time and place, and the complexities of a disease spread by a pest, is especially demanding of such an approach. Indeed, the current multifaceted and interdependent control methods for virus yellows were evolved before the term "integrated control" became fashionable in plant protection (1). It was first discussed by the IIRB at its 1971 Winter Congress, where virus yellows was a major topic (2, 3, 4, 5, & 6). Subsequently, at the 1976 Winter Congress, Björling (7) and Dunning (8) reviewed control of virus yellows and, three years later, aspects of the profitability of its control were considered (9).

This paper presents the results of a questionnaire, among members of the IIRB's Pests & Diseases Study Group from 13 countries, covering the incidence of virus yellows, current control methods, and their integration; it also considers results of some recent research and suggests the need for even better understanding of aphid and virus epidemiology so that growers can modify area spray warning advice to the particular needs of each field.

NATIONAL INCIDENCE & DAMAGE

Records for 1972-5 from 16 countries were published in full by Björling (7), and for 1976-78 from 10 countries by Dunning & Byford (9). Table 1 gives the incidence and estimated yield loss in 10 countries for 1972-84 (see footnote to the Table re data from Greece, Ireland and Turkey).

Virus yellows has been considered as an important, or the most important, disease problem of sugar beet in Austria, Belgium, Denmark, England, France, Germany FR, Netherlands, Sweden and Switzerland since the early 1930's (10). Following a decade of relatively low incidence in most countries, the epidemic years of 1973-1976 emphasised the damage the disease could cause. However, incidence has again been low since then, although in some countries and in some years the disease caused significant yield loss, eg in Czechoslovakia in 1978-81, in France in 1978 and 1981-83, and in Switzerland in 1979.

Estimates of yield loss (Table 1) are imprecise because they are approximate calculations from estimated incidence of yellows; they are also imprecise because of lack of knowledge on the current effects of beet yellows virus (BYV) or beet mild yellowing virus (BMYV) on crop growth and yield, and how this is accentuated or mitigated by such factors as crop nutritional and water status in each season. In England, Smith & Hinckes (11) have shown that BMYV has been much more prevalent than BYV from 1982-84; because BMYV is considered to have a smaller effect on yield (12, 13) it is probable that much of the spraying to control virus yellows has been unnecessary in these years. However, in epidemic years BYV may be more prevalent than BMYV.

LOCAL INCIDENCE

Within each country there is, characteristically, much variation in incidence of virus yellows from area to area. For example, the low national incidence of 5.6% at the end of August in England in 1983 is derived from the average incidence in each of 13 factory areas, viz: 0.1,

Table 1 VIRUS YELLOWS: INCIDENCE AND DAMAGE, 1972-84

% Virus Yellows Nationally at end of August (estimated national loss in sugar yield)

Country	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Austria	2	8 (1)	9 (1)	17 (2)	8 (1)	1 (-)	2 (-)	4 (-)	2 (-)	2 (-)	2 (-)	2 (-)	2 (-)
Belgium	18 (4)	34 (7)	83 (26)	35 (10)	9 (2)	1 (-)	1 (-)	1 (-)	1 (-)	1 (-)	1 (-)	1 (-)	1 (-)
* Czechoslovakia				14 (4)	29 (18)	4 (1)	19 (6)	15 (5)	10 (3)	43 (20)	9 (3)	9 (3)	5 (1)
Denmark	15 (2)	40 (6)	20 (2)	20 (3)	4 (2)	<1 (-)	3 (1)	<1 (-)	3 (1)	2 (-)	<1 (-)	<1 (-)	<1 (-)
England	5 (1)	14 (3)	62 (18)	37 (9)	19 (5)	1 (-)	1 (-)	<1 (-)	2 (-)	8 (2)	2 (-)	6 (1)	2 (-)
France	18 (4)	12 (4)	40 (16)	30 (9)	8 (4)	6 (2)	12 (4)	6 (1)	5 (1)	15 (3)	12 (3)	14 (3)	5 (1)
Germany FR	25	2 (-)	60 (10)	90 (17)	30	<5	<5	<5	<5	<5	<5	<5	<5
Netherlands	26	27	47 (7)	44 (3)	21 (2)	4 (-)	4 (-)	2 (-)	3 (-)	2 (-)	2 (-)	2 (-)	1 (-)
Sweden	2 (-)	11 (2)	4 (<1)	4 (<1)	4 (<1)	1 (-)	2 (-)	2 (-)	<1 (-)	<1 (-)	1 (-)	1 (-)	<1 (-)
Switzerland	10 (2)	20 (5)	30 (10)	60 (14)	53 (14)	5 (1)	6 (1)	15 (4)	7 (1)	6 (1)	7 (1)	2 (-)	1 (-)

* Figures in brackets are estimated % loss in root yield, not sugar yield.

Based on Questionnaires to members of IIRB Pests & Diseases Study Group. See Björling (7) for fuller details and more countries, for period 1972-75, and Dunning & Byford (9) similarly for 1976-78.
Data from Greece, Ireland and Turkey ommitted from this Table: incidence and damage insignificant.

0.2, 0.4, 0.7, 0.8, 1.2, 2.5, 2.9, 2.9, 3.1, 10.8, 15.1 and 23.2%; each of these factory area figures is the average of counts in 15 to 40 randomly-selected fields (5 per fieldman, number of fieldmen per factory varying). Fig 1 shows the incidence for all 335 fields in which counts were made in 1983; the distribution is extremely skewed, and 14% of fields had a damaging (>10%) incidence of virus yellows, despite the national incidence being so low. More precise identification of the areas, and especially the fields, at risk is essential so that control measures can be concentrated on them.

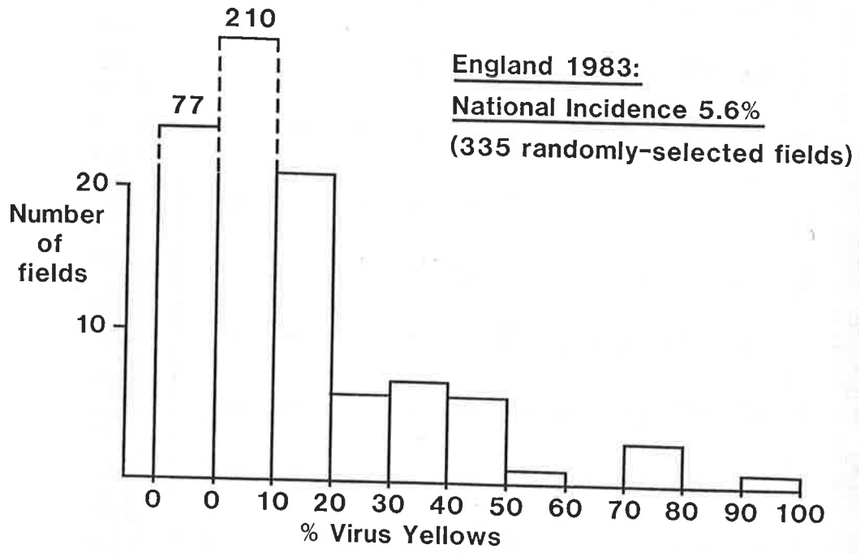

Fig.1. British Sugar plc fieldmen's counts of virus yellows incidence in 335 randomly-selected fields in 1983; the number of fields with no virus yellows and in each category between 1 and 100%.

SOME MAJOR FACTORS AFFECTING INCIDENCE AND CROP DAMAGE IN THE ABSENCE OF PESTICIDE TREATMENT.

National and local incidence, and the damage caused by the disease in any particular field, is affected by many factors that are often interrelated (Fig 2.).

Climate Climatic conditions are a major factor affecting incidence of the **disease.** In England, and in other countries (7) the mid 1970's epidemic **years** followed a series of mild winters which permitted outdoor survival **of aphids** and virus host plants. In contrast, a severe winter prevents **their** outdoor survival.

Watson et al (14) and Heathcote (15) showed that disease incidence in England is correlated with January-April temperatures; low incidence invariably follows if these four months are colder than average. However, low rainfall, low wind speeds, and high temperatures during May and June aid multiplication of surviving overwintering aphids, their dispersal to

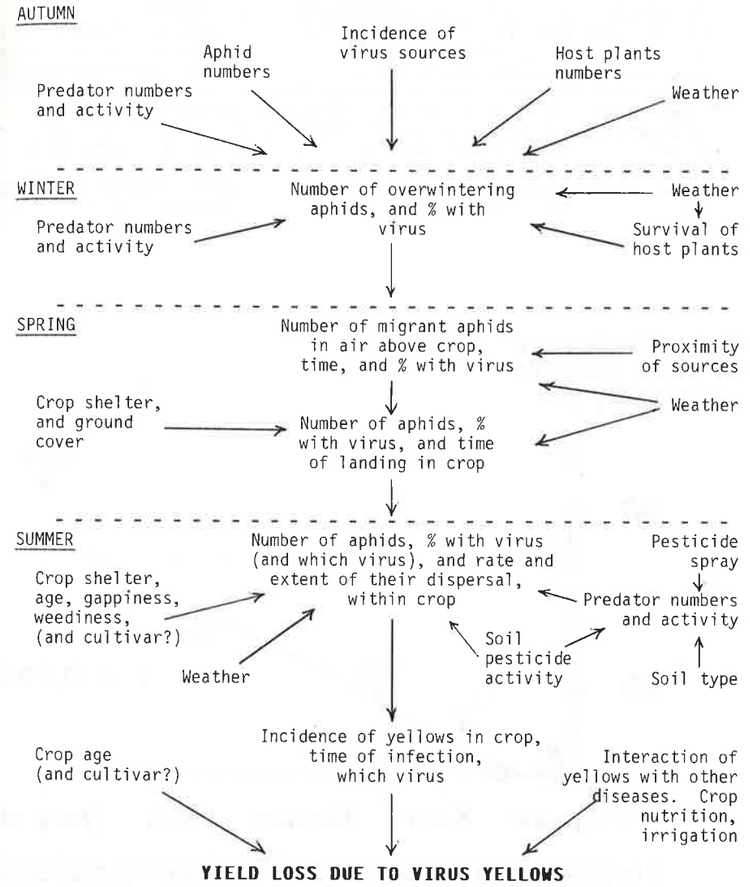

Fig.2. Some factors affecting incidence of virus yellows in a crop, and the resulting loss of yield.

beet crops and their movement within crops; such weather conditions can, at least in part, offset adverse effects of a cold January-April and make accurate forecasting of years of moderate incidence difficult (15). Nevertheless, since 1976, national incidence has been low in England, as has been forecast each year (Fig.3). Other countries have not so far been able to establish similar relationships to aid their forecasting.

The extent of aphid and virus overwintering. The international questionnaire asked for information on the current sources of overwintering of virus and aphids, their relative importance, and which virus or viruses were involved. Results are listed in Table 2 for those countries able to supply the information, and the measures taken to control seed crop and clamp sources are given in Table 3. Seed crops are now only of local importance as overwintering sources of both aphids and virus in some countries, and mangold and fodder-beet clamps are rarely of importance.

Virus yellows is not a problem in Greece or Turkey; nevertheless, in Greece seed crops are separated by at least 30km to avoid endangering the root

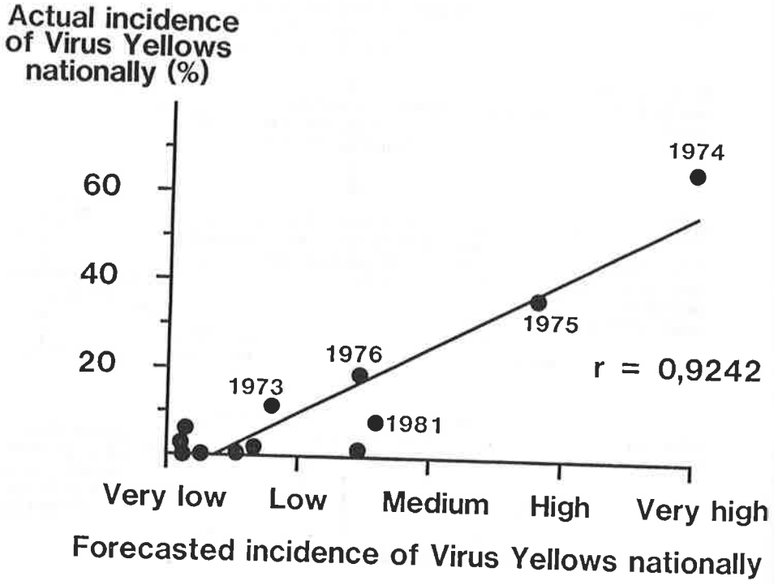

Fig.3. The forecasted national incidence of virus yellows in England for the years 1973 to 1984, (using the formula of Watson et al 14), and the actual incidence as counted by British Sugar plc fieldmen in up to 750 randomly-selected fields per annum.

Table 2 OVERWINTERING SOURCES OF VIRUS YELLOWS AND THEIR CURRENT IMPORTANCE

Country	Overwintering Source	Which Virus	Relative importance
Austria	Seed crops	BYV	Slight
	Winter spinach	BYV	Slight
Belgium	Weeds	BYV+BMYV	Slight recently
Denmark	Glasshouses	BYV+BMYV	Slightly increasing
	Oilseed rape	BMYV?	Under investigation
England	Seed crops	BYV+BMYV	Moderate locally
	Oilseed rape	BWYV	Slight - moderate
	Weeds (including oilseed rape, turnip, beet groundkeepers)	BYV+BMYV+BWYV	Moderate, considerable locally
France	Seed crops	BYV+BMYV	Important locally
	Winter spinach	BMYV	Slight to moderate
	Oilseed rape	?	?
	Fodder beet	BYV+BMYV	Moderate locally
	Weeds	BYV+BMYV	Moderate
Germany FR	Oilseed rape	BMYV?	?
	Clamps and groundkeepers	BYV+BMYV	Slight
	Weeds	BYV+BMYV	Moderate
Netherlands	Groundkeepers	BYV+BMYV	Slight
	Weeds	BYV+BMYV	Slight-moderate
	Fodder beet	BYV+BMYV	Moderate locally
	Red table beet	?	" "
Sweden	Glasshouses	BYV+BMYV	Slight locally
	Groundkeepers	BYV+BMYV	Moderate, after mild winter
Switzer-land	Glasshouses	BMYV	Considerable locally
	Weeds	BMYV	Moderate

Czechoslovakia - weeds are of considerable importance, especially Capsella bursa-pastoris and Sonchus arvensis for BMYV. Stellaria media is of moderate importance for both viruses, and Viola tricolor of slight importance for BMYV.

crops, and in Turkey it is advised that basic (elite) seed secklings be grown at higher altitudes which are free from virus - this is principally to protect the seed crop from the damaging effects of virus infection.

Table 3 MEASURES TO DECREASE APHID AND VIRUS SPREAD FROM TWO MAJOR OVERWINTERING SOURCES.

Country	Seed crops	Beta clamps
Austria	Seed & root crops separated.	
Belgium	Seed & root crops separated, and aphids controlled on seed crop (legal obligations).	Clamps forbidden after May 1st.
Czechoslovakia	Seed & root crops separated	Not now an important source.
Denmark	Seed crops guarded by regular spraying (contract term).	Late clamps recorded, and growers advised to clear before April 1st.
England	Seed & root crop separated (not all), aphids must be controlled (contract term). Heavily infected crops destroyed in winter.	Clamps recommended to be cleared before beet emerge.
France	Seed & root crops separated, plus intensive aphicidal treatment of seed crops.	Clearing of clamps before sowing of root crop.
Germany FR	Routine spraying (an extremely small area).	Not now an important source.
Netherlands	Seed crops separated from virus yellows area. Seed crops destroyed if excessive aphids & virus (very small area).	No clamps or ground keepers after April in virus yellows area.

Switzerland - no seed crops, and clamps unimportant.
Sweden - no overwintering of aphids, except sometimes in glasshouses. No clamps. No fodder beet in sugar-beet areas.

Groundkeepers and weeds can act as overwintering field hosts for aphids and virus, provided the winter is not severe, but their importance relative to other sources is not known; no special measures are adopted other than the normal practices of good farming.

Evolution of agricultural practices demands constant attention to possible new overwintering sources. For example, beet remnants on cleaner-loader soil heaps can now be an important virus source following a mild winter, so advice must then be given to clear them before emergence of the beet crop. Similarly, can the big increase in area of overwintered oilseed rape pose a threat, even if only of aphids? Smith & Hinckes (11) have shown it to be a source of aphids and of beet western yellows virus (BWYV) but, fortunately

this virus probably spreads little directly to sugar beet although it can be transmitted indirectly via weeds.

Glasshouses are a local source of aphids and viruses in all countries, but especially in those with a continental climate. The work of Hani (16) shows the importance in Switzerland of glasshouse crops of Swiss chard (Beta vulgaris flavescens crispa); aphids must be controlled in winter to prevent them spreading BMYV in the spring from the glasshouse to nearby crops.

Crop Agronomy. Field studies have shown that aphid and virus incidence are less on early than late-sown crops, and there is a similar decrease with increasing plant population (17). Recent work by Jepson (18) and Smith & Hinckes (11) has explained some of the mechanisms of this effect, which is of considerable importance in contributing to field to field variation in virus incidence and damage. However, from the questionnaire answers, it seems that only in England, Germany FR and Switzerland are the benefits extolled of early sowing and high plant populations to decrease aphid and virus incidence and crop damage.

Crop cultivar. Sugar-beet resistance to, or tolerance of, virus yellows has not been achieved, probably because the variable incidence of the disease cannot make it a high priority for the plant breeder; selected lines (19) invariably suffered lower yields and quality in the absence of the disease. The introduction of the cultivar Vytomo in 1974 was a step forward, but in 1985 a commercially-available cultivar with some tolerance to virus yellows is reported only from Germany FR; its use is, however, very limited. Continued work on breeding for tolerance/resistance is reported by Czechoslovakia, Denmark, England and Germany FR.

Natural control of the aphid vector of virus yellows. Diseases (eg Entomophthora) and natural enemies of aphids, viz. arthropod predators (coccinellids, chrysopids, syrphids, carabids, staphylinids and arachnids) and parasites (hymenopterans), exert a controlling influence on populations throughout the year. After aphid invasion of beet fields the density-dependent ones are mainly of value in preventing excessive aphid populations arising and in leading to their decline. However, it is mainly the density-independent polyphagous predators, such as the field-resident carabids, staphylinids and arachnids, that are important in helping to control populations early in the season (20), and hence contributing to control of virus spread (21). Carabids are particularly important, and are more prevalent on heavy than on light soils (22).

The importance of these latter natural enemies has been discovered in the last decade. It has emphasized the need to use only pesticides that do not harm them; except in France, pirimicarb, which is harmless to many predators (22), is now the most frequently used aphicidal spray (Table 4); this usage is in contrast to that a decade ago (8) when organophosphorous insecticides were the most extensively used products in all countries. Other work (23) has shown that soil-incorporated gamma-HCH can be harmful to these polyphagous predators, and its usage can lead to increased incidence of virus yellows. The possibilities of actually increasing the numbers of predators by the use of soil-incorporated organic matter is currently being studied by the OILB/IIRB Seedling Pests Study Group.

Table 4 APHICIDE SPRAYS USED TO CONTROL VIRUS YELLOWS (LISTED IN ORDER OF DECREASING FREQUENCY OF USE).

Country			
Austria	demeton	pirimicarb	dimethoate
Belgium	pirimicarb	ethiofencarb	
Czechoslovakia	dimethoate	fenitrothion	pirimicarb
Denmark	pirimicarb (75%)	demeton-S-methyl (20%)	pyrethroids (5%)
England	pirimicarb (60%)	demeton-S-methyl (40%)	
France	deltamethrin + heptenophos	pirimicarb	oxydemeton-methyl
*Germany FR	pirimicarb	demeton-S-methyl	parathion
Netherlands	pirimicarb	oxydemeton-methyl	phosphamidon
Sweden	pirimicarb	oxydemeton-methyl	dimethoate
Switzerland	pirimicarb	ethiofencarb	

* methamidophos also used, but less extensively than the products listed in the Table.
Greece and Ireland - no sprays applied to control virus yellows.

PESTICIDE TREATMENTS USED.

In most countries seed-furrow-applied granules are used as a prophylactic against a broad range of root-eating and leaf-eating pests. Little of this usage is solely or even primarily to control aphids and yellows but Table 5 gives the percentage of crop treated in each country with aldicarb or thiofanox, both of which give good control of aphids early in the season; this bonus effect can decrease, or even remove, the need for spraying. Carbofuran, carbosulfan and terbufos also give some control (Table 6).

Aphicide sprays are used extensively in many countries (Table 7), a Spray Warning Scheme advising growers of the need for, and the timing of, spray application in their area.

INTEGRATION OF CONTROL MEASURES.

Of the above factors affecting incidence and damage only climate is completely outside the grower's control; attention to the other factors can, and should, be integrated into a control system, with pesticide treatments applied when and where necessary, to give the best decrease of damage combined with economy of cost and lack of harmful side effects. In practice most of the factors are taken into account in most of the countries (Table 8), with the exception of resistant or tolerant crop cultivars of which none are available. Crop cultivars with resistance to

Table 5 % OF NATIONAL AREA TREATED WITH ALDICARB OR THIOFANOX (SEED-FURROW GRANULES) AT SOWING.

Country	1976	'77	'78	'79	'80	'81	'82	'83	'84
Belgium	75	85	85	80	75	65	55	50	48
Denmark	3	3	2	2	1	1	1	1	1
England	27	40	36	28	28	28	26	31	28
France	52	45	35	32	29	30	32	34	33
Netherlands	27	26	23	18	12	12	12	12	10
Switzerland	10	10	<5	<2	<2	<2	<2	<2	<2

Austria: aldicarb & thiofanox not permitted.
Czechoslovakia, Greece and Turkey: no aldicarb or thiofanox granules used.
Germany FR: annual data unavailable but <10% of crop (mainly aldicarb).
Ireland: granules used against soil pests only.
Sweden: experimental usage 1979 - 83 (16ha total trials area in 1983) but registration not permitted.

Table 6 USAGE OF SEED-FURROW-APPLIED GRANULAR PESTICIDES WITH SOME APHICIDAL ACTIVITY (LISTED IN DECREASING ORDER OF FREQUENCY OF USE).

Country					
Austria	carbofuran				
Belgium	aldicarb	carbofuran	terbufos	thiofanox	carbosulfan
Denmark	carbofuran	aldicarb	thiofanox		
England	aldicarb	thiofanox	carbofuran	carbosulfan	
France	aldicarb	carbofuran	terbufos	carbosulfan	thiofanox
Germany FR	aldicarb	carbofuran	terbufos		
Netherlands	aldicarb	carbofuran	thiofanox		
Switzerland	aldicarb	carbofuran	terbufos	carbosulfan	furathiocarb

Austria: carbofuran usage less than 3% of beet area.
Greece, Ireland, Sweden, Turkey: granular pesticides not used to control virus yellows.
Czechoslovakia: approximately 30% of crop treated with methiocarb granules.

Table 7 % OF NATIONAL AREA OF SUGAR BEET SPRAYED EACH YEAR TO CONTROL APHIDS AND VIRUS YELLOWS.

Country	1976	'77	'78	'79	'80	'81	'82	'83	'84
Belgium	15	15	15	20	25	35	45	50	50
Czechoslovakia						>70	>70	>70	82
Denmark	95	90	100	100	90	90	110	80	50
England	86	14	6	68	7	70	10	55	33
France	73	34	32	49	30	54	57	70	63
Netherlands	90	35	5	44	26	47	32	70	45
Sweden	1	1	5	1	1	8	39	23	9
Switzerland	25	25	10	<5	<5	<2	<2	<2	<2

Austria : usually between 60 & 80% of the area; to control aphids, not yellows.
Greece, Ireland and Turkey: no sprays applied to control virus yellows.
Germany FR: annual figures not available, but varies from <10% to 70% depending on aphid infestation and virus threat.

aphid infestation and multiplication, and/or tolerance of virus yellows infection, are a goal of some seed breeders but even partial resistance and/or tolerance would be an important factor in an integrated control programme.

Measures continue to be taken to decrease overwintering sources of aphids and yellows (clamps, seed crops, glasshouses); any temptation to neglect these, because of current low incidence of yellows, must be avoided.

Early sowing, and high and uniform plant populations, are encouraged as a means of controlling damage only in England, Germany FR and Switzerland. However, because these practices are of such great value to good yields per se they are the objective of all growers irrespective of the threat of a virus yellows attack. Nevertheless, the knowledge of these agronomic effects can be used to advantage in a "decision path" for spray-warning advice (see later, under "Prospects").

Spraying the crop with aphicide is still the most extensively used control method but this is not simply dictated by the calendar; in all countries care is taken to determine that there is a need for spraying and, as a result, the percentage of the crop sprayed varies greatly from year to year. For example, in the Netherlands 90% of the crop was sprayed in 1976 but only 5% in 1978 (Table 7). In England there is similar variation, and this closely follows the spray warning advice given by the factory fieldmen (Fig 4). The timing of this advice is as optimal as possible, and is based

Table 8 INTEGRATION OF SOME OF THE CONTROL METHODS FOR APHIDS AND VIRUS YELLOWS: EXTENT OF ACTION AND OF DIRECT ADVICE TO GROWERS. (+ slight - +++ considerable.

COUNTRY	CONTROL AT SOURCE (Seed Crops, Clamps, Greenhouses).	CROP AGRONOMY (Early Sowing, Full Plant Population).	CHEMICAL CONTROL		
			Build-up of aphid population monitored.	Advice (via radio, post, etc) on need & timing of spraying.	Aphicides recommended that do not harm beneficial insects.
AUSTRIA	-	-	++	++	++
BELGIUM	+++	-	++	+++	+++
CZECHOSLOVAKIA	++	-	*	*	++
DENMARK	+++	-	+++	+++	+++
ENGLAND	+++	++	+++	+++	+++
FRANCE	++	-	+++	+++	++
GERMANY FR	++	++	+++	+++	+++
NETHERLANDS	+++	-	+++	+++	+++
SWITZERLAND	++	++	++	++	+++

* Czechoslovakia - spray warning system only for A.fabae at present: a system for M.persicae under investigation.
Sweden - Virus yellows not a problem: control measures are against A.fabae only.

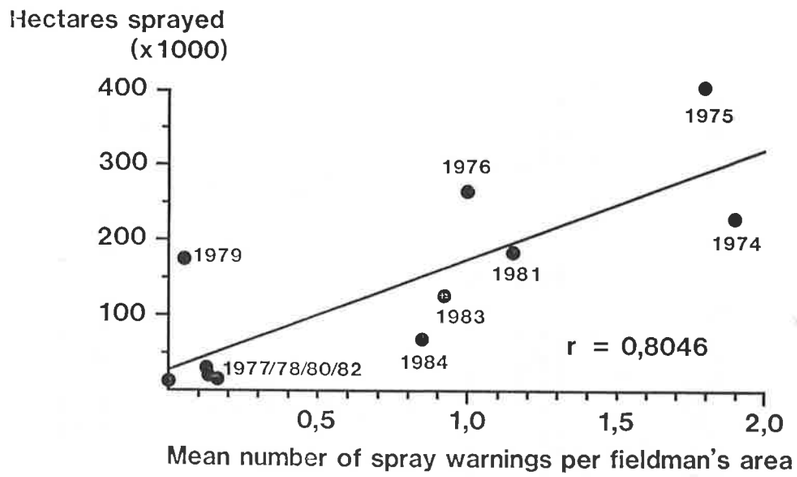

*Fig.4. The effect of the extent of British Sugar plc spray-warning advice each year on the total area of sugar beet sprayed with aphicide, 1974-84 (1974 - rather low response by growers to advice due to several previous years low incidence of virus yellows; 1979 - virtually all spraying was to control **A.fabae** late in season, after the annual virus yellows spray-warning advice scheme had ended.*

on knowledge of aphid migration (suction traps, water traps) and crop infestation (plant counts), advice being given to growers by post, radio or 'Prestel'. Furthermore, the aphicide sprays recommended are mainly those that do not harm beneficial insects.

DISCUSSION AND FUTURE PROSPECTS.

Virus yellows incidence has been relatively low in most countries for each of the last eight years; therefore, there has inevitably been less impetus for research and, in some countries, perhaps even for preventive measures such as good hygiene.

The equally low incidence in the 1960's was at that time thought to be due to the good effects of the control measures being applied in each country, especially crop hygiene plus the then newly introduced spray warning system. However, this theory was proved wrong by the epidemic years of 1973-76, when virus yellows was more severe than ever before, the epidemic being considered to be largely the result of mild winters favouring survival of aphid and virus. Since then January-April temperatures have been colder in England, and yellows incidence has been low; inevitably, mild winters will return and lead to serious outbreaks of the disease in England. Virus yellows is most prevalent in the countries surrounding the southern North Sea (south eastern England, north eastern France, north

western Belgium, south western Netherlands) and, previous epidemics having occured concurrently in all these countries, they are likely to do so again.

If January and February are very mild then in England growers will be warned early in March that there is a probability of a serious attack of yellows; such a warning can help decisions on use of seed-furrow-applied aphicidal granules. Similarly, special attention to control of aphids at over-wintering sources is encouraged.

However, only during May does the likely scale of an attack become clear from the summation of knowledge on the previous autumn's aphid and virus levels, the winter weather, the spring sources, the suitability of spring weather for aphid multiplication and dispersal, the time of first flights of aphids into the crop, and the general state of the crop. Once the crop has emerged, very early invasions of aphids will be controlled by seed-furrow-applied granules but their persistence is not good, especially in wet springs. Control must then rely on spraying to kill or repel the aphids. How can the art of spray warning advice, based on the integration of all this knowledge, become more of a science?

Decisions on spraying require two considerations: (a) the general threat for the area and (b) the threat to each particular field.

(a) Sugar factory decision on when to give general spray-warning advice for an area. This is based on the general threat to crops in the area. In addition to the well-known factors referred to above recent research has brought in new factors that have to be considered:

1. What sources of aphids and virus are there in the area? The work of Smith & Hinckes (11) on oilseed rape, and of Hani (16) on Swiss chard in glasshouses, emphasises the need to know of all possible sources of aphids, and especially of virus, in the area, and whether the main virus is BYV, BMYV or BWYV. BYV is the most damaging virus, and knowledge on sources of the viruses can help partially to quantify the risk of crop damage. For the future it is hoped that it will be possible to develop a "crop-infectivity-index" as is done for barley yellow dwarf virus (25), integrating number and time of aphid flight with the proportion carrying one or other virus. ELISA can be used to determine whether migrating winged aphids are carrying virus (26) but, unfortunately, cannot distinquish betweeen BMYV and BWYV. Nevertheless, it may be feasible to base the infectivity index solely on BYV, the more damaging virus.

2. How resistant to aphicides are the aphids? Work reviewed by Rice (27) demonstrates the variable incidence of resistance, and shows how resistance greatly increases the difficulty of control. If resistant aphids predominate, then only the most effective aphicides can be used and spraying must be repeated because persistence of effect is poor.

(b) Growers decision on whether, and when, to spray his crop. Having received a general aphid and yellows spray warning for his area, the grower should decide on the degree of risk to his field(s). In England we are endeavouring to give values to the factors that influence virus infection in a particular field to enable the grower to reach a decision (Table 9); the values suggested are tentative, and need further experimental results and/or survey results to justify or modify them. The use of such a

Table 9 GROWER'S DECISION ON SPRAYING A FIELD WHEN AREA SPRAY-WARNING RECEIVED (ENGLAND).

	Score 1	2	3	4	5
Date of Sowing	Very early (before 31 March)	Early (1-15 April)	Medium (16-30 April)	Late (1-15 May)	Very late (after 15 May)
Plant Population (1000/ha)	Very good (>95)	Good (80-95)	Average (70-80)	Poor (55-70)	Very poor (<55)
Soil Pesticide Used	Aldicarb or Thiofanox	Carbofuran Carbosulfan Terbufos	Nil	Gamma-HCH	
Field Shelter		Exposed	Average	Sheltered	
Soil Type		Heavy	Medium	Light	
Local Virus Sources		None		Yes (BMYV)	Yes (BYV)

The Score Total gives a measure of the need for, and urgency of, spray treatment when the area spray warning is received from the factory. A very low total figure (minimum 7) means that spraying is unnecessary; a medium total means that spraying can be delayed till a second warning is received; a very high total (maximum 27) means that the crop is at greatest risk and should be sprayed immediately.

decision aid, integrating all the major known field factors that influence incidence of aphids and yellows, helps the grower to decide on the need for, and urgency of, spray treatment for each particular field.

Furthermore, the use of such a system would enable the sugar factory to modify the timing of their spray warning advice for the area; rather than wait until they thought the time optimal for the average crop they would send it earlier - the crops most at risk would then be sprayed, but the spraying of crops less at risk would be delayed until a second spray warning, and crops least at risk not sprayed because infection in them would cause insufficient damage to justify the cost of spraying.

Extensive and correct use of such decision aids lie in the future, as do the use of alternative chemicals (27) that repel aphids from feeding on and infecting plants with virus.

In general far too much pesticide is currently being applied to control rather low levels of virus, which is probably mainly BMYV; treatment is therefore often unprofitable. We need to minimise use of pesticides in years of low disease incidence, reserving it for extensive and effective usage in epidemic years. Aphid resistance to pesticides would then be less likely to develop into a major problem and sugar production would be more economical.

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THE TWO VIRUSES: THE EFFECTS OF THEIR DIFFERENT EPIDEMIOLOGIES ON CONTROL STRATEGIES

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Summary

Surveys of the incidence of beet yellows virus (BYV) and beet mild yellowing virus (BMYV) in the English root crop from 1981 to 1984 showed that BMYV was the main cause of virus yellows.

Studies of virus movement within plants showed that field-grown plants inoculated with BYV rapidly became sources of infection whereas those inoculated with BMYV remained poor sources of infection until later in the season.

Strains of beet western yellows virus (BWYV) which infect sugar beet were found in oilseed rape, and Myzus persicae was shown to overwinter in this crop.

The implications of these findings for control strategies are discussed.

Sommaire

Des enquetes sur la distribution de la jaunisse grave de la betterave (BYV) et la jaunisse moderée (BMYV) dans les cultures de la betterave en Angleterre de 1981 a 1984 montraient que BMYV etaient la plus importante.

Des etudes du deplacement des virus au sein des betteraves poussant au champ, on a constate qu'apres l'inoculation les plantes deviennent rapidement sources de BYV, tandis que les plantes inoculees avec BMYV ne deviennent sources de virus que plus tard dans la saison.

Des souches de beet western yellows virus (BWYV) qui peuvent etre transmissible à la betterave etaient trouvees dans colza et Myzus persicae peut hiverner sur cette plante.

L'importance de ces resultats pour les methodes de lutte contre la jaunisse est discuté.

Zusammenfassung

Informationen über das Auftreten von BYV und BMYV in englischen Zuckerrübenkulturen von 1981 bis 1984 zeigten, dass der BMYV die vorwiegende Ursache der Vergilbungskrankheit war.

Untersuchungen über Virusbewegung innerhalb der Pflanzen zeigten, dass feldangebaute, mit BYV inokulierte Pflanzen sich rasch als Infektionsverbreiter erwiesen, während die mit BMYV inokulierten sich bis spät in der Wachstumsperiode als nur leicht aktiv bemerkbar machten.

Stämme des BWYV die Zuckerrüben befallen, wurden in Ölrettich gefunden und man stellte fest, dass Myzus persicae den Winter in dieser Kulter überlebte.

Die durch diese Feststellungen zu ziehenden Folgerungen für weitere Kontrollmassnahmen werden diskutiert.