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The characteristics of mineral oils in relation to their inhibitory activity on the aphid transmission of potato virus Y

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Abstract

In greenhouse trials paraffinic mineral oils, characterized by a viscosity gravity constant (VGC) of 0.790-0.819, and with viscosities between 12 and 30 cSt at 37°C (66-150 SUS) proved to have the best aphid transmission inhibiting activity of potato virus Y to red peppers. The activity decreased rapidly with decreasing viscosities but only slowly with increasing values.

Effective oils are fürther characterized by an unsulfonated residue (USR) of 95-100, indicating the near or total absence of aromatic structures, which are inactive and known to be phytotoxic. The paraffine-pourpoint should be below 0°C, indicating that n-paraffines do not form a very important part of the oil, since they are also inactive. Naphthenic structures seem equally inert, their percentage in the oil depending on the origin of the crude oil, because they cannot be separated from the paraffinic structures by refining procedures.

Mineral oils which one commercialize for agricultural practice normally have an USR above 95 and a paraffine-pourpoint below 0°C. Therefore, the information on the classification, based on a VGC value and on the viscosity, is already sufficient to allow an evaluation of those oils of their suitability as inhibitor of the virus transmission by aphids.

Additional keyword: Capsicum annuum.

Introduction

Since Bradley et al. (1962) and Bradley (1963) showed that mineral oil inhibits the transmission of potato virus Y and other stylet-borne viruses, most of the subsequent research has been carried out with paraffinic mineral oils, which showed the best virustransmission inhibiting properties among the various types of oil studied.
Literature on physico-chemical properties, determining this interesting feature of the mineral oils is scarce.
From evaluation of literature on the action of mineral oils on virus transmission by aphids, we can confirm the finding of Peters (1977) that nearly all researchers used different oils in their studies. Further they usually provided little or no information on the physico-chemical properties and this makes it difficult to compare the various results. These facts incited us to publicise and discuss our information on up to nine different characteristics in the hope of promoting the understanding for the physicochemical properties of mineral oils and facilitating the comparision of results.
One of these characteristics is the viscosity which Vanderveken (1968) has already suggested might be of importance. Wyman (1971) reported that a low viscosity oil (45 SUS = 6 cSt at 37°C) was more effective than three oils with higher viscosity (80, 140 and 310 SUS = 16, 30 and 67 cSt at 37°C) in the greenhouse against the transmission of beet mosaic virus. De Wijs et al.

(1979), however, recommended a viscosity of at least 12 cSt (= 66 SUS) for fürther research in this area, based on their results from greenhouse trials with potato virus Y on red peppers.
With regard to our earlier conclusions (De Wijs et al., 1979) we studied in more detail the physico-chemical characteristics of mineral oils in relation to their virus transmission inhibiting properties.

Materials and methods

Mineral oils.- Proveniance, biological tests. Mineral oils and mineral oil fractions were provided by Deutsche BP-AG and BP (Schweiz) AG. Characteristics of these oils are given in Tables 1 and 2.
Oils nos 33-38 were produced in the laboratories of the Deutsche BP-AG in very small quantities, especially for our biological tests. Therefore fewer characteristics could be determined than for oils nos 1-31 and 39.
The oils were mixed with 10% Emulsogen M before preparing the water emulsions. The relatively high percentage of emulgator was necessary to obtain stable emulsions in water of the mineral oil fractions with viscosities above 100 cSt (462 SUS) and of the aromatic and polar oil fractions.
Emulsion of oil no 36 which broke too fast, was prepared and strongly agitated just before and even during application to assure a regular distribution of the oil onto the test plants.
Oil emulsions were sprayed with low pressure equipment, using an amount of 25 ml on 25 red pepper plants (Capsicum annuum cv California Wonder) with at least two fullgrown normal leaves. Oil concentrations of 0.25 and 0.75 % were tested since higher concentrations masked the differences between the oils as we found earlier (De Wijs et al., 1979). Per treatment 100 plants were used unless otherwise mentioned.
The red pepper plants which served as a check, were not sprayed. Sunoco 7E oil, containing 1.2% emulgator of its own, served as standard throughout the trials. Twentyfour hours after application of the oil emulsions each test plant was inoculated with potato virus Y using two aphids (Myzus persicae) which had previously been starved for 1-2 h. The acquisition access period on oil free virus diseased red pepper plants was 2-5 min and the inoculation access period on the test plants 2-5 h after which the aphids were killed with an insecticide. The test plants were incubated in a greenhouse at 20-24°C, about 50% relative humidity and a daylength of at least 16 h. Virus symptoms were read two weeks after inoculation.

The physico-chemical characteristics of a mineral oil. The following informatiom is taken from the BP technical use recommendations for process oils (Prozessöle, BP anwendungstechnische Beratung), in which also the methods for determination or calculation of the different characteristics are described. Mineral oils are, basically, a mixture of aromatic, naphthenic, paraffinic and polar structures, if any, mostly ring structures with sulphur and nitrogen. The ratio in which they occur in the crude oil depends on the origin of the oil. Fractions are obtained by refinement and these are defined by physical and chemical constants which are used in the tables and defined below.

1. VGC = viscosity-gravity-constant, a unit calculated with the aid of the viscosity and the specific weight. According to this unit, mineral oils are classified as follows:

paraffinic mineral oil	= 0.790-0.819
slightly naphthenic mineral oil	= 0.820-0.849
naphthenic mineral oil	= 0.850-0.899
slightly aromatic mineral oil	= 0.900-0.939
aromatic mineral oil	= 0.940-0.999
highly aromatic mineral oil	= 1.000-1.049

2. cSt = centistokes at 37°C, the kinematic viscosity.
SUS =- Saybold Universal Seconds, a viscosity unit used in USA.
3. The paraffine-pourpoint = lowest temp. in °C at which the oil flows. This point is dependent on the formation of a crystalline skeleton of n-paraffines. This unit has replaced the solidification point which is now out of date.
4. USR = Unsulfonated residue, 0-100.
Mineral oils with an USR under 90 are, in general, phytotoxic due to a high content of aromatic structures. A high USR indicates the near (95 < USR < 100) or total (USR= 100) absence of unsaturated paraffines and aromatics.
5. The distribution of the carbon atoms:
Ca: percentage carbon atoms in aromatic structures,
Cn: the same as Ca but in naphthenic structures,
Cp: the same as Ca and Cn but in paraffinic structures.
6. Sp.W. = Specific weight, determined at 15°C. At constant viscosity, the aromatic character of an oil fraction increases with the specific weight.

Paraffinic oils:	Sp.W. 0.845-0.860,
Naphthenic oils:	Sp.W. 0.861-0.939,
Aromatic oils:	Sp.W. 0.940-1.000.

7. n^{20}_{D}, the refractive index at 20°C. The higher the n^{20}_{D} , the higher is the aromatic or polar content of the oil.
8. MW = Molecular weight, the mean MW of the molecules in the mineral oil fraction; dependent on the viscosity.
9. The boiling range, dependent on the viscosity, measured under low pressure and recalculated for 1 Bar (1 atm). The beginning of the boiling range is measured after 0, 5 or 10 % of the oil has been distilled, the end, after 90, 95 or 100 % has been distilled.

Beginning:	0% distilled, for oils nos 6-12, 15;
	5% distilled, for oils nos 13, 14, 21;
	10% distilled, for oils nos 16-19, 21, 22-3 1.
End:	90% distilled, for oils nos 22-31;
	95% distilled, for oils nos 1-19;
	100% distilled, for oils no 21.

Results and discussion

Paraffinic and slightly naphthenie mineral oils. The results from the oils nos 1-19 and 22-31, presented in Table 1 and Fig. 1, allow the following conclusions: The virus transmission inhibiting acitivity of paraffinic and slightly naphthenic oils depends on their viscosity. The most active oils have viscosities between 12 and 30 cSt (66-150 SUS). It can be seen that the activity is rapidly lost with decreasing viscosities below 12 cSt, but diminishes only slowly with increasing viscosities above 30 cSt. Apparently the activity is not totally lost, even in oils with very high viscosities. There was no difference in activity between paraffinic and slightly naphthenic oils.

n-Paraffines. n-Paraffine I (oil no 20, 14-16 carbon atoms) and III (oil no 21, 16-18 carbon atoms) are not active (Table 1). n-Paraffines with longer carbon chains are solid at room temperature. No n-paraffines exist with the required viscosity which produces activity. n-Paraffines determine the paraffine-pourpoint of mineral oils. Oil no 31, which is solid at room temperature contains about 1/7 n- and isoparafines and from that are 1/7 isoparaffines. This oil is therefore less active than other paraffinic oils at comparable viscosity. The paraffine-pourpoint of mineral oils should be therefore below O°C, indicating that n-paraffines do not form a very important part of the oils.

Naphthenic oils. The highly naphthenic oil no 39 showed no activity at all at a viscosity of 27 cSt (128 SUS) where paraffinic mineral oils have a good activity (Table 2). This result suggests that the naphthenic structures in the paraffinic mineral oils do not contribute to the activity of these oils, but represent merely an inactive fraction.

Aromatic components in mineral oils. Oils no 34-33-35 represent a range of oil fractions with increasing content of aromatic structures, of which oil no 35 is aromatic. Oil no 36 has a high polar content but an aromatic behaviour. Unfortunately the viscosity of the very small quantity received, could not be determined but is very high. Also oil no 38 is aromatic. It can be seen from table 2 that the two oils no 35 and 36 are less active than oils no 33 and 34. However, these results are not conclusive since the increase in viscosity is also related to a decrease in activity as we saw earlier. Therefore, a special oil fraction with a high content of aromatic components, no 38, was produced by Deutsche BP-AG, but with a viscosity of only 11.2 cSt (63 SUS) which ought to be favourable for the inhibition of the virus transmission. This oil, however, showed no activity and was phytotoxic. These results suggest that the aromatic components are of no importance for the virus transmission inhibiting properties of mineral oils. In addition it is known that aromatic oils are more phytotoxic than naphthenic or paraffinic oils, a fact sustained here by the results of the aromatic oils no 35 and 38, which showed phytotoxicity even at the low concentration of 0.25 and 0.75%. Therefore, mineral oils known to be recommended as adjuvants to insecticides and fungicides and as inhibitors of the virus transmission by aphids must be paraffinic or naphthenic in nature with unsulfonated residues (USR) of 95-100.

Polar components in mineral oils. Oil no 37, in which polar components were concentrated showed no activity (Table 2). Although the high viscosity of the oil will partially prohibit a good activity, the total lack of activity observed suggests that polar components are of little or no importance but that they could possibly have a negative influence on the virus transmission inhibiting properties of the oil. In addition the oil was phytotoxic to red peppers.

Conclusions with regard to the most effective oil type. Summarizing our results we can now define the mineral oil with the best virus transmission inhibiting properties. This is a paraffinic mineral oil, VGC 0.790-0.819, with a viscosity between 12 and 30 cST at 37°C (66-150 SUS), a boiling range of 370-420°C and a mean molecular weight of 340-380. The last mentioned three characteristics are interdependent. The unsulfonated residue should be 95-100, indicating the near or total absence of aromatic structures, which are inactive and known to be the cause of phytotoxicity. The paraffine-pourpoint should be below 0°C, indicating that n-paraffines do not form a very important part of the oil, since they too are inactive. The oil should contain as little as possible of naphthenic structures because they also seem to be inert and only tend to increase the viscosity.

Mineral oils commercialized for agricultural practice mostly meet these requirements with the possible exception of that for the naphthenic structures. These cannot be separated from the paraffinic structures by refinement and, therefore, the percentage of carbon atoms forming part of naphthenic structures will depend on the origin of the crude oil.

Conclusions with regard to the importance of the physico-chemical properties. As we see from the results the effectiveness of a mineral oil as an inhibitor of virus transmission by aphids can be evaluated by the four following characteristics:

1. the classification of the oil based on the viscosity gravity constant (VGQ);
2. the viscosity;
3. the paraffine-pourpoint and;
4. the unsulfonated residue (USR).

The effectiveness of the oil is mainly determined by the first three characteristics and of these, the first two are most important. The USR is of high importance for its safe use in agriculture.

All other characteristics have some value if the information on the above mentioned is incomplete. If no classification or USR is given of a mineral oil, the distribution of the C-atoms (5), the specific weight (6) or refractive index (7) can provide information. The distribution of the C-atoms allows in addition a more precise placing of the mineral oil within its classification by the VGC value.
If the viscosity is not known, molecular weight (8) and boiling range (9) can provide information because they are dependent on the viscosity.
In our case we mentioned these data for comparison purposes and as general information to allow the evaluation of the relative importance of these characteristics.

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Samenvatting

De eigenschappen van minerale oliën met betrekking tot de verhindering van de bladluisoverdracht van aardappelvirus- Y

In kasproeven bleken minerale paraffine oliën, gekenmerkt door een VGC (viscositeits-dichtheidsconstante) van 0.790-0.819 en een viscositeit tussen 12 en 30 cSt bij 37°C (66-150 SUS) de beste werking te bezitten tegen de overdracht van aardappelvirus Y naar paprika door bladluizen. De werking verminderde snel bij afnemende viscositeiten beneden 12 cSt, maar slechts langzaam bij toenemende waarden boven 30 cSt. De minerale olie met de meest gunstige eigenschappen met betrekking tot verhindering van de virusoverdracht wordt verder nog gekenmerkt door een USR (niet sulfoneerbare rest) van 95-100. Dit betekent het geheel of bijna geheel afwezig zijn van aromatische verbindingen, die bekend zijn om hun fytotoxische eigenschappen en bovendien niet werkzaam zijn. Het stollingspunt moet bij voorkeur onder 0°C liggen, wat betekent dat n-paraffinen geen al te belangrijk bestanddeel van de olie vormen, aangezien deze eveneens onwerkzaam zijn. Naphthenische structuren bleken ook onwerkzaam te zijn. Het gehalte hiervan in de oliefractie hangt echter van de herkomst van de ruwe olie of, omdat ze niet door raffineren van de paraffinestructuren kunnen worden gescheiden. Minerale oli~n die aanbevolen worden voor landbouwkundige doeleinden, bezitten normalerwijze een USR boven 95 en een stollingspunt onder 0°C. Dit betekent dat informatie over de aard der oliën op grond van een VGC waarde en over de viscositeit voldoende is om dergelijke oliën te beoordelen op hun geschiktheid de virusoverdracht door bladluizen te kunnen verhinderen.

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Table 1. Characteristics and potato virus Y (PVY) transmission inhibiting activity of paraffinic and slightly naphthenic mineral oils nos 1-31.

	BP sample no, name	Spec. Weight		Viscosity		Boiling range	Mol. Weight	
		at 15°C	VGC	cSt	SUS	°C at 1 Bar	MW	USR
	Check'							
	Sunoco 7 E'	0.847	0.805	14.2	74	380[3]	320	96
1	paraffinic		0.806	19	95	373-419	380	92
2	paraffinic		0.812	18.9	93	373-419	355	97
3	Paraff inic		0.810	18.7	92	373-419	355	98
4	paraffinic		0.805	17.9	89	373-419	355	100
5	paraffinic		0.796	18	87	373-419	340	100
6	paraffinic		0.797	32.5	152	372-456	380	92
7	paraffinic		0.803	57.5	265	383-524	420	92
8	paraffinic		0.797	110	508	418-534	460	92
9	slightly naphthenic		0.820	133	614	420-535	500	92
I0	slightly naphthenic		0.820	179	830	420-571	540	92
11	paraffinic		0.807	325	1500	432-620	590	92
12	paraffinic		0.805	563	2600	464- -	610	92
13	paraffinic		0.818	83.5	385	392-449	440	99
14	slightly naphthenic		0.820	79	345	392-449	420	100
15	paraffinic		0.798	48.6	225	379-469	380	100
16	paraffinic		0.807	25.6	121	394-443	380	93
17	slightly naphthenic		0.823	8 52	52	311-340	200-300	92
18	slightly naphthenic		0.823	8.5	53.7	313-369	200-300	92
19	slightly naphthenic		0.830	8.4	53.4	315-365	200-300	91
20	n-Paraffin 1				22	-	210	
21	n-Paraffin 111			2.6	34.7	258-290	240	99

Table 1 continued

	BP sample no, name	Spec. Weight	Distribtion of C-atoms			% PVY transmission		% of check	
		at 15°C	%Ca	%Cn	%Cp	0.25%	0.75%	0.25	0.75
	Check'					73	73	100	100
	Sunoco 7 E'	0.847	4	30	66		25		34
1	paraffinic		1.5	32	66.5	29	20	40	27
2	paraffinic		3	31.5	65.5	32	22	44	30
3	Paraff inic		2	33	65	37	19	51	26
4	paraffinic		1	35	64	34	20	47	27
5	paraffinic		0	38	62	29	28	40	38
6	paraffinic		2	31	67	53	29	73	40
7	paraffinic		2	31.5	66.5	58	39	79	53
8	paraffinic		2.5	31	66.5	50	44	68	60
9	slightly naphthenic		3	34	63	41	42	56	58
I0	slightly naphthenic		3	35	62	61	41	84	56
11	paraffinic		7.5	28.5	64	63	48	86	66
12	paraffinic		7	29	64	54	55	74	75
13	paraffinic		0	40	60	39	39	53	53
14	slightly naphthenic		0	40	60	41	.33	56	45
15	paraffinic		0	40	60	41	26	56	36
16	paraffinic		1	33	66	30	26	41	36
17	slightly naphthenic		5	38	57	63	43	86	59
18	slightly naphthenic		11	33	56	54	32	74	44
19	slightly naphthenic		5	37	58	55	34	75	47
20	n-Paraffin 1			0	100	61	65	84	89
21	n-Paraffin 111		0	0	100	86	83	118	114

Table 1 continued

	BP sample no, name	Spec. Weight		Viscosity		Boiling range	Mol. Weight	
		at 15°C	VGC	cSt	SUS	°C at 1 Bar	MW	USR
	Check							
	Sunoco 7 E	0.847	0.805	14.2	74	380	320	96
22	BP solvent JD[4]	0.756	0.785	1.378	-	176-180	180	100
23	paraffinic	0.789	0.778	3.5	37.6	258-318	230	99
24	slightly naphthenic	0.851	0.823	7.7	51	311-332	250	91
25	paraffinic	0.849	0.807	14.5	75.3	349-378	320	91
26	paraffinic	0.864	0.819	19.7	96.2	370-393	340	91
27	paraffinic	0.845	0.796	19.8	96.7	371-406	360	92
28	slightly naphthenic	0.892	0.848	21.6	104.3	342-415	330	86
29	paraffinic	0.847	0.790	27.9	131.6	396-416	390	91
30	paraffinic	0.864	0.809	32.5	152	402-438	429	92
31	paraffiniC5	0.851	0.77	41	190	451-524	580	95

	BP sample no, name	Spec. Weight	Distribtion of C-atoms			% PVY transmission		% of check	
		at 15°C	%Ca	%Cn	%Cp	0.25%	0.75%	0.25	0.75
	Check					70	69	100	100
	Sunoco 7 E	0.847	4	30	66		24		35
22	BP solvent JD[4]	0.756	-	-	-	65	63	93	91
23	paraffinic	0.789	2	24	74	69	60	99	87
24	slightly naphthenic	0.851	5	38	57	63	44	90	64
25	paraffinic	0.849	4	35	61	45	20	64	29
26	paraffinic	0.864	3.5	33	63.5	32	27	46	39
27	paraffinic	0.845	6	29	65	32	20	46	29
28	slightly naphthenic	0.892	10.5	39	50.5	31	31	45	45
29	paraffinic	0.847	1.5	31.5	67	41	18	59	26
30	paraffinic	0.864	2	31	67	46	30	66	43
31	paraffiniC5	0.851	2	-30	-70	59	44	84	64

1 Check: test plants not sprayed.
2 Sunoco 7 E, containing 1.2% emulgator of its own, served as standard throughout the trials.
3 Boiling temperature after 50% of the oil has been distilled.
4 Mixture of C12 isoparaffines. Method used for measuring Ca, Cn, Cp irrelevant for this oil.
5 Oil no 31 is solid at room temperature.
Further explanation: see text.

Tabel 1. Aardappelvirus Y overdracht verhinderende werking en eigenschappen van paraffinische en enigszins naphthenische minerale oliën.

Table 2. Characteristics and potato virus Y (PVY) transmission inhibiting activity of oil fractions of which only small quantities have been received.
Oil concentrations sprayed: 0.25% or 0.75%

BP sample no, classification, name		Refr. index n 20/D	Spec. Weight At 15°C	Viscosity at 37°C cSt	SUS	% PVY Transmission 0.25%	0.75%	% of check at concentration 0.25%	0.75%
	Check[1]					70	69	100	100
	Sunoco 7 E[2]	1.468	0.847	14.2	74		24		35
33	naphthenic	1.5062	0.922	40.9	190	44	35	63	51
34	paraffinic	1.4722	0.874	16.9	84.7	41	32	59	46
35	aromatic	1.5785	1.010	88.5	409	66	42	94	61
36	polar	1.606		very high		63		90	
	Check						78		100
	Sunoco 7 E	1.468	0.847	14.2	74		34		44
37	polar	1.5763		181.2	837		77		99
38	aromatic	1.5780		11.2	63		72		92
	Check						88[3]		100
	Sunoco 7 E	1.468	0.847	14.2	74		59[3]		67
39[4]	naphthenic	1.4998	0.920	27	128		92[3]		105

1, 2, See table I for explanation.
3, Results from 50 test plants.
4, Oil no 39 mixed with 5% emulgator; USR = 90, Ca:Cn:Cp = 12:59:29.
Further explanation: see text.

Tabel 2. Aardappelvirus Y overdracht verhinderende werking en eigenschappen van oliefracties, waarvan slechts geringe hoeveelheden ter beschikking stonden.

Fig. 1. Relationship between the viscosity in cSt at 37°C of paraffinic and slightly naphthenic mineral oils and the inhibition of the transmission of potato virus Y (PVY) by aphids to red peppers. Oil nos 1-19 and 22-30. Oil concentration: 0.75%. Abscissa as logarithmic scale, ordinate as linear scale. The broken line has not been calculated but merely represents a help for the eye.

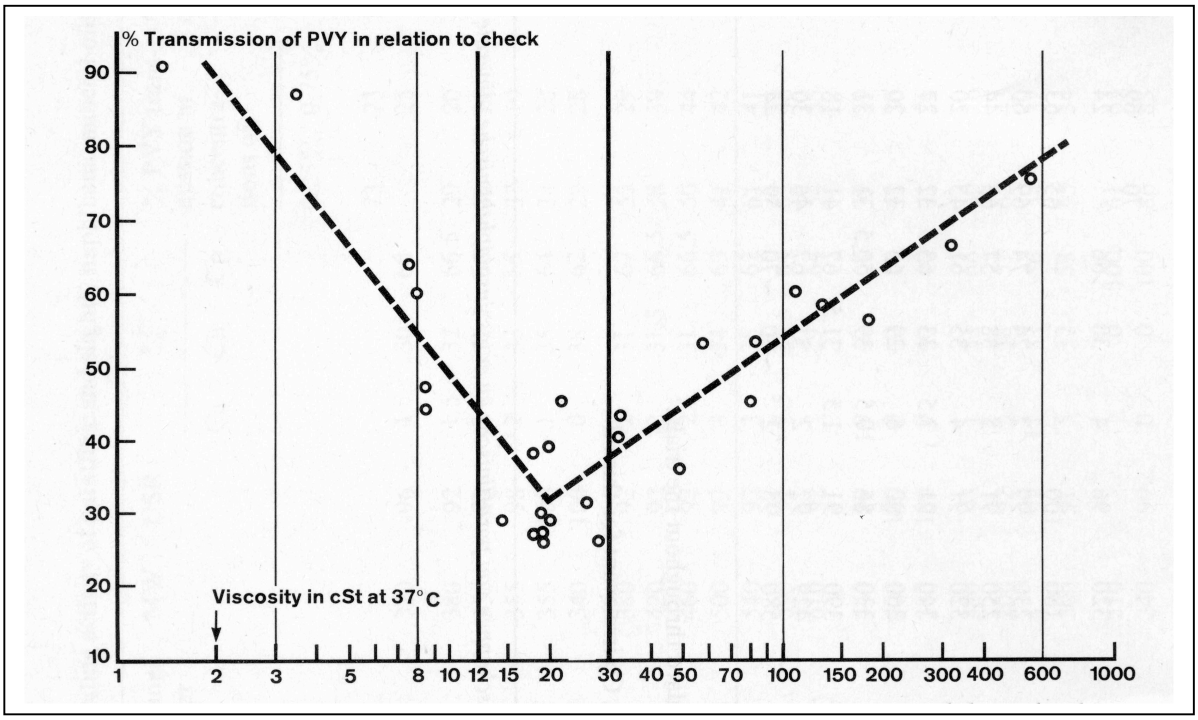

Fig.1. Relatie tussen de viscositeit in cSt bij 37°C van paraffine en enigszins naphthenische oliën en de verhindering van de overdracht van aardappelvirus Y (PVY) door bladluizen naar paprika. Olie nos. 1-19 en 22-30. Concentratie: 0.75%. Abscis in een logaritmische schaal, ordinaat in een lineaire schaal. De gebroken 1ijn is niet berekend maar is slechts bedoeld als hulp voor het oog.

Fig. 1a. based on the same data as figure 1, but as polynomous trendline.