INSECTICIDES AGAINST APHID VECTORS OF POTATO VIRUSES [1])

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SUMMARY

Periodic spraying of potato plots with the systemic insecticide Systox strongly reduced the spread of leafroll within the field, but not the spread into the field. It had hardly any influence on the spread of virus Y. The importance of alate aphids as vectors of potato viruses appears to be unexpectedly great. The influence of Systox and DDT on the aphid population was investigated. Both Systox and DDT slightly increased the yield in tubers. Methods for practical use of Systox against virus spread in seed potatoes are discussed.

INTRODUCTION

Since several viruses of potato are only spread by aphids, one might reasonably expect that control of the aphids in the crop would result in a reduction of the degree of infection by virus. However, the results of experiments with various aphicides against potato aphids have been rather unsatisfactory as to the spread of virus, at least in Europe. One of us in 1948 twice to three times a week killed all aphids by nicotine on a row of leafroll plants with 4 adjacent rows of healthy plants, but no favourable influence on the spread of virus could be observed. Also several aphicides developed after the last war had no effect on the spread of virus, though in some of them the residu remains aphicidal for a considerable time after application (MÜNSTER & MURBACH, 1952).

In the U.S.A. more satisfactory results were obtained (*De aardappel in de Ver. Staten,* 1951). By very frequent spraying of all potato fields in a large area of potato production (Maine) the aphid population of the area was kept at a low level. A reduction in virus-infection was observed in some years and this was ascribed to the spraying. But also there no confirmation could be obtained by field experiments of the usual type. This practice of regularly spraying potatoes with aphicides was soon generally accepted by the farmers, because it resulted in a marked increase in the yield, an increase which could be demonstrated in experiment also. Not only the direct damage caused by aphids was reduced, but also that by some other, non-European insects, while the insecticides generally used (DDT and Parathion) probably also have a direct influence on the yield of the crop.

SCHRADER developed a new type of insecticide during and after the war. These systemic insecticides are absorbed by the growing plant through the leaves or the roots and then transported to other parts of the plants, also to the new growth. So the whole plant is poisoned and, apparently, for a considerable time. Several of these insecticides are highly specific in their action against insects. After the poison has been absorbed by the leaves, there is no residu left and evaporation by the plants seems to be negligible (*Höfchen-*

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briefe, 1952, no 5). Only sucking insects are killed when feeding, but leaf-eating insects like caterpillars and larval and adult potato beetles suffer no harm after feeding on such poisoned plants.

In virus transport by aphids one has to distinguish between spread into the field and spread within the field. A potato field is always colonized by aphids born outside the field and some of them may carry virus when entering the field. Others may have no virus on arrival, but may take it up from a diseased plant in the field and later pass it on to healthy plants in the field. Aphids born in the field, especially when born on a plant containing virus, will be responsible for the rest of the virus infection. As we saw, elimination of the latter fraction which can be achieved with any efficient aphicide had little effect on the spread of virus. Aphids arriving loaded with virus cannot be prevented to infect at least some plants with virus. The problem looks nearly insolvable.

Some viruses can be passed on to a healthy plant a very short time after an aphid has imbibed them from an infected plant, but the aphid looses its infectivity soon afterwards. Virus Y of potatoes is such a non-persistant virus. In other viruses such as leafroll of potato, an aphid is not capable of infecting a plant with virus shortly after having absorbed it; there is an interval of many hours before an aphid becomes infective [2]), but in those (persistant) viruses a once infective aphid remains infective for the rest of its life. No insecticide kills immediately, so that transport of a non-persistant virus can not completely be checked. But one might expect some effect from a systemic insecticide where the poison is taken up simultaneously with the virus, if such a poison killed the aphid before the interval mentioned above had passed, i.e., in the case of leafroll, within about 24 hours (*Meded. NAK,* 1951).

We wanted to know what happened after the most intensive use of a systemic insecticide. Economic factors played no rôle in this experiment. The following items were investigated:

1 The influence on the aphids.
2 The influence on the natural insect enemies of the aphids.
3 The influence on the development of the crop and the yield.
4 The influence on the spread of virus.

We also wanted to know more exactly what DDT did, but we did not try to investigate its influence on the spread of virus. For the experiments with DDT we chose the variety *Noordeling,* as this frequently suffers directly from aphids by conspicuous deformation of the apical foliage. For the experiments with Systox we chose the variety *Bintje,* because of its great economic importance in the Netherlands.

The site of the field was in an area, where aphids are generally abundant and where virus diseases consequently spread so rapidly that seed-growing is almost impossible. Each of the 18 plots consisted of 20 × 21 plants spaced at 50 cm. In the 9 plots with virusfree Bintje the middle row consisted of

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2) The very important paper by KLOSTERMEIER (Wash. Agr. Exp. Sta., Techn. Bull. 9, March 1953) was received after our paper was in the press. He succeeded in transmitting leafroll by *Myzus persicae* from and to *Physalis angulata* within 20 minutes after the aphids could imbibe virus.

plants infected the year before either with leafroll (6 plots), or with virus Y (3 plots), but some of the plants with virus Y turned out to be also infected with leafroll. Each plot, and the whole field were surrounded by oats, sown densely in two rows about 15 cm apart. As earlier experiments had taught us, a screen of something slightly higher than the crop and at the same time not attractive to potato aphids prevents leakage of virus into adjacent plots. Walking aphids are stopped, flying aphids may land before the screen, but not immediately after it; should they land or climb on it, then they generally take off again at a rather steep angle which will take them over the adjacent rows.

In 1951 two systemic insecticides were available (Pestox III or Schradan and Systox) both developed by the same firm. Information on their toxicity to mammals and aphids made us choose Systox (C_2H_5O \ S // P–O . CH_2 . CH_2 . SC_2H_5; C_2H_5O /). (*Höfchenbriefe,* 1952, no 4). This was applied as a spray in a concentration of 1 % (active substance in the concentrate 50 %) (on 3 plots with leafroll and 2 plots with virus Y) in a quantity of 1300 l/ha when the plants came up (25 May), and afterwards in quantities of 2000 l/ha at 10 days intervals till the plants died (7, 16, 22 June, 3, 14, 25 July, 3 August). Special precautions were taken in handling Systox, and rubber gloves, rubber apron, rubber boots and a gas mask were always used. DDT was applied as "wettable powder" in a concentration of 0.4 % in the same quantities on 11 and 20 June, 3, 13 and 25 July. On three plots the uppersides as well as the undersides of the leaves were sprayed in order to imitate American spraying praxis. All the parallels were sprayed in the same way with water.

The influence on the aphid population

None of the described methods for estimating the aphid population was satisfactory. One wants data on the population per square unit or per plant which can be assessed by the British method of examining one hundred picked leaves or by the Dutch method of threshing entire plants over a board. In our case, however, changing or displacing the population was not permitted. In 1951, a very large population of green peach aphids was predicted which made examination of whole plants impossible. Therefore we very carefully examined on one stem of a plant: 1) the largest lowest leaf, 2) the largest leaf halfway the stem, 3) the whole apex with those leaves which were not yet completely unfolded. Depending on the time required 50–10 plants were examined. The aphids were classified in larvae, adult apterae, and alatae and identified with a pocket lens as to the species. This method gives no clue as to the actual number of aphids per plants, because with the time the number of leaves per plant increases. But counts made on the same day are mutually comparable, which was essential. As far as possible the aphids were counted 8–9 days after spraying. After some unpleasant experiences the Systox plants were handled with thin surgical gloves. In Systox plots the threshing of plants was tried to detect aphid concentrations which were too small to be found by examining leaves or plants. The following potato aphids were found: *Myzus (Nectarosiphon) persicae* Sulzer, *Aphis nasturtii* Kltb. (formerly *Aphis rhamni*), *Macrosiphum euphorbiae* Thos., *Aulacorthum solani*

Kltb. and *Myzus* (*Nectarosiphon*) *ascalonicus* Doncaster. Only the first two species were sufficiently numerous to be taken into consideration.

On both varieties of potato the majority of the aphids first occurred on the basal leaves, but in *Noordeling* the population later shifted to the top of the plant, in correlation with an increased dropping of the lower leaves. This question is of importance for the examination of aphid attraction by potato varieties.

Table 1. Numbers of larvae of *Myzus persicae* at different levels on the plants.

Variety	Bintje			Noordeling		
Date	Basal leaf	Middle leaf	Apex	Basal leaf	Middle leaf	Apex
14-VI	20	10	0	61	12	1
20/21-VI	247	40	45	246	66	91
29/30-VI	1270	263	146	1147	396	386
10-VII	3568	1084	582	1403	733	1339
24-VII	16	10	55	1	5	36
2-VIII	8	6	13	6	7	16

Noordeling is known to suffer more from aphids than several other varieties and therefore has the reputation of getting more aphids. The sum of the aphid counts, however, shows that *Noordeling* had fewer aphids than *Bintje*. As *Bintje* produced more leaves than *Noordeling* these differences would have been still stronger if expressed in number of aphids per plant. It appears therefore that *Noordeling*'s reputation of having more aphids than other varieties is undeserved, and also, that judging varieties on their attractivity for aphids is more difficult than expected. The high aphid population in the apices of the plants of *Noordeling* resulted in conspicuous damage to the foliage.

The cause of the shifting of the aphid population in *Noordeling* may lie in the susceptibility of this variety to Mg-deficiency. It reacts on Mg-deficiency by yellowing and later dying of the lowest leaves. In the experimental field *Noordeling* actually showed slight symptoms of Mg-deficiency.

The results of the various treatments are summarized in the following table.

Table 2. Numbers of *Myzus persicae* counted per 20 plants.

Variety	Bintje		Noordeling		
Date	Sprayed with Systox	Not sprayed with Systox	Sprayed with DDT upper- & underside	Sprayed with DDT upperside	Not sprayed with DDT
14-VI	0–0–0	2–4–30	1–4–24	2–7–24	2–11–73
20/21-VI	0–0–0	1–42–324	0–25–218	1–43–320	1–47–409
29/30-VI	1–0–0	5–167–1699	1–22–222	4–155–1653	9–193–1928
10-VII	49–0–49	156–322–5234	90–7–382	82–180–2847	110–187–3475
24-VII	4–0–8	12–7–80	11–7–170	11–27–214	4–3–41
2-VIII	0–0–0	0–4–27	1–1–17	1–17–121	2–3–28

The three groups of figures represent the number of alatae, adult apterae and larvae on apex plus middle leaf plus lowest leaf per 20 plants. 5–167–1699 means : 5 alatae, 167 adult apterae, and 1699 larvae.

In the Systox plots by examining leaves no aphids were found until 29 June,

but also threshing gave no results, so that one must assume that no aphids occurred in such plots. From 29 June till 24 July great numbers of alate aphids developed and many landed on plants treated with Systox. They there produced larvae, but we never succeeded in finding a second instar larva. Evidently the larvae died very soon after feeding. During this period we tested the toxicity of the plants by putting healthy alate *Myzus persicae* on leaves of Systox-treated plants in wide tubes. The aphids fed and died very soon, invariably well within 24 hours. Aphids feeding under similar conditions on leaves of untreated plants multiplied normally up to a week. Therefore it seems improbable that an aphid could live longer than 24 hours after feeding on a Systox plant which had been treated 8–9 days before. After the end of the flight period no more aphids were found on the Systox plants. Systox appears to be a remarkably efficient aphicide, because colonization of plants between treatments was utterly impossible, and even larval development was excluded.

Spraying with DDT on the uppersides of the leaves reduced the number of aphids to some extent, but especially in the lower part of the plant the aphids multiplied strongly. Spraying both on the uppersides and the undersides had a much more satisfactory effect, especially after the lowest leaves died. But treatments by both methods finally resulted in a higher population in the plots sprayed with DDT than in those sprayed with water. Under natural conditions the number of aphids, after the population has reached its maximum, suddenly drops very strongly, partly because alatae are formed which fly away, but mainly because the voracity of the predators suddenly exceeds the increase of the aphid population through birth. Since DDT kills the enemies of the aphids it seems obvious that the larger number of aphids on DDT-plants after 24 July is a result of the reduced activity of the aphid enemies. But as we shall see presently this conclusion is premature.

For completeness' sake we also give the data on *Aphis nasturtii* Kltb.

Table 3. Numbers of *Aphis nasturtii* Kltb. counted per 20 plants.

Variety	Bintje		Noordeling		
Date	Sprayed with Systox	Not sprayed with Systox	Sprayed with DDT upper- & underside	Sprayed with DDT upperside	Not sprayed with DDT
14-VI	0–0–0	1–1–3	1–2–3	1–3–17	1–1–2
20/21-VI	0–0–0	0–0–11	0–0–5	0–3–145	0–1–6
29/30-VI	0–0–0	0–7–57	0–1–4	0–8–61	0–4–34
10-VII	1–0–0	6–2–2	5–3–25	6–11–189	0–2–32
24-VII	0–0–1	5–2–26	3–7–47	5–3–47	0–1–4
2-VIII	0–0–0	1–2–18	2–7–46	2–7–46	1–5–19

The statistical value of these figures is very small because this aphid is strongly gregarious. Some plants may have hundreds or even thousands of aphids while plants nearby may have none of this species. In our experimental field this species was not numerous and the only method of obtaining reliable data would have been the examination of all plants, which was not practicable. But as to Systox the results obtained with *Myzus persicae* are fully confirmed, because also by threshing plants in Systox plots no aphids could be found before the 10th of July.

By error one plot with a row of virus-Y, which should have been sprayed with water was once sprayed with Systox (1 %, 2000 l/ha). The influence on the aphid population is shown in the following table.

Table 4. Numbers of *Myzus persicae* counted on twenty plants of the variety *Bintje*.

Date	Once sprayed with Systox	Sprayed with water	Regularly sprayed with Systox
14-VI	0–0–0	2–4–30	0–0–0
20/21-VI	0–1–0 [3]	1–42–324	0–0–0
29/30-VI	0–0–5	5–167–1699	1–0–0
10-VII	78–3–245	156–322–5234	49–0–49
24-VII	5–10–123	12–7–170	4–0–8
2-VIII	0–0–3	0–4–27	0–0–0

The plot was sprayed on 16 June. The first apterae were found on 10 July. The time required for a *Myzus persicae* to reach the adult stage from birth at that time was about 12 days; this means that on 28 June or earlier the toxicity of the plants had dropped to a level at which newborn aphids could develop. In other words: 12 days after spraying once with Systox aphids could survive feeding on poisoned plants and would presumably have been able to transmit leafroll virus from a poisoned leafroll plant to a healthy plant. The influence of this single treatment with Systox on the aphid population is comparable to that of regularly and very intensive spraying with DDT.

THE INFLUENCE ON THE INSECT ENEMIES OF APHIDS

Simultaneously with the aphids all instars of aphid enemies were counted. The results are summarized in:

Table 5. Aphid enemies counted per 20 plants.

Variety	Bintje		Noordeling		
Date	Sprayed with Systox	Sprayed with water	Sprayed with DDT upper- & underside	Sprayed with DDT upper-side	Not sprayed with DDT
10-VII	1–0–0–0	10–47–0–8	0–0–0–0	16–23–0–4	75–28–0–7
24-VII	1–0–0–0	2–1–0–5	1–0–0–2	1–0–0–0	0–2–0–3

(10–47–0–8 stands for 10 Syrphid-eggs or newly hatched larvae, 47 older Syrphid-larvae, 0 eggs of Coccinellids, 8 Coccinellid-larvae or pupae).

These figures suggest that Systox and DDT have a fatal influence on the insect-enemies, but the conclusion is premature. The numbers of aphid enemies attracted appears to be a function of the density of the aphid population. Therefore a reduction of the aphid population results in less egg-laying by the enemies and control measures which reduce the number of aphids will automatically decrease oviposition by aphid enemies.

Systox as such is a general insecticide. One must therefore expect that aphid

[3] This adult apterous specimen was dying when found. It was most probably carried into this plot by the clothes of an assistant about 6 hours before.

enemies which are present during spraying with Systox are killed. But residual action is excluded after – within a couple of hours – the poison has been absorbed by the plant or has evaporated from the surface of the leaves. After that period contact of aphid enemies with the leaves is not dangerous and not even evaporation of the poison from the plant plays a rôle.

Apparently the influence of Systox on the aphid enemies is restricted to toxicity during application and to causing shortage of food between sprayings.

DDT is known to have considerable, and also residual activity against several of the most important enemies of aphids. Almost only the larvae of Syrphids past their first instar escape. In fact many dead Syrphids and some dead Coccinellids were found in the plots sprayed with DDT, so that there is some reason to hold DDT responsible for favouring some increase in aphid population by its reducing the insect enemies, though this has not been proven.

The influence on the plants

Spraying with Systox had no detectable influence on the development of the crop.

Counts on 16 July in *Noordeling* showed that DDT had some influence on the dropping of the leaves. In plots sprayed with water the number of leaves dropped was 3½ per stem, in those in which the leaves were sprayed with DDT from above 2½ per stem and in those in which the leaves were sprayed with DDT both on the upperside and the underside 1½ leaf per stem. It is not clear whether this difference must be ascribed to the direct influence of DDT or to the resulting differences in the infestation by aphids.

Both Systox and DDT increased the yield of tubers:

Table 6. Yield in kg per are.

Variety	Bintje	Noordeling
Sprayed with Systox or DDT	356	270
Sprayed with water	338	252

The differences are small but an increase is statistically reliable. No difference in yield could be found between plots sprayed with DDT in the normal way and those which had been sprayed with DDT both on the uppersides and the undersides of the leaves.

Some earlier experiments with DDT, made in order to find out whether with DDT a profitable increase of production could be obtained, gave the following results:

Table 7. Influence of DDT on the yield (in kg per are).

Number of times and concentration	C.I. 567 1947	C.I. 655 1948	C.I. 660 1948	C.I. 784 1949	C.I. 931 1950
Not sprayed	424	317	503	358	478
3 × with DDT 0.5 %	421	319	519	380	486
3 × with DDT 1 % .	414	312	516	–	–
Reliable difference ..	none	none	none	19	none

Only the experiments C.I. 784 of 1949 showed that by three times spraying with DDT the yield could be increased with statistical reliability. C.I. 660 of 1948 and C.I. 931 of 1950 show some increase, but this was not sufficiently reliable.

The influence on the virus infection

Two tubers of each plant (except of those used as sources of infection) were harvested and planted in 1952 in such a way that two fields resulted in each of which every plant had the same position as the motherplant in 1951. This field was repeatedly examined for virus diseases. Each motherplant of which one or two tubers appeared to be infected was registered as infected in 1951 (vide crosses on the maps). The differences between the objects were not very large.

Table 8. Influence of Systox on the spread of virus.

	Sprayed with Systox	Sprayed with water
Leafroll	20.0 % infected	34.1 % infected
Virus-Y	60.4 % infected	– –

However, the results can be analyzed in a more satisfactory way. If one calculates the percentages of leafroll plants in the rows parallel to and starting from the implanted leafroll plants, it appears that in the plots treated with Systox the distribution of infected plants is rather regular, but in the plots sprayed with water the rows adjacent to the cources of infection show a much higher percentage of infected plants than the more distant rows.

Table 9. Distribution of leafroll infection in % in the rows parallel to the secondary diseased plants.

Row	1	2	3	4	5	6	7	8	9	Average
Sprayed with Systox; some leafroll plants in the middle	11	14	17	20	18	18	21	20	21	17.8
Sprayed with Systox; 1 row of leafroll plants in the middle	18	25	18	25	25	21	20	27	22	22.2
Sprayed with water; 1 row of leafroll plants in the middle	74	49	30	28	21	24	25	19	37	34.1

In the plots treated with Systox the sources of infection have no influence on the adjacent plants. As the infection in the fourth to eighth row is about equally high in plots sprayed with water, as in those sprayed with Systox, and also of the same level as in those plots where only a few leafroll plants were implanted, it would seem that this percentage of 18–28 is rather independent both of the treatment with Systox and of the number of sources of infection available in the field. We assume that this basic percentage of infection was caused by aphids which were infective when they entered the plots. Such aphids would have been capable of infecting plants before they died by imbibing Systox. On the other hand aphids which arrived free from virus from

outside the plot evidently died before they could pass on the virus to a healthy plant after having taken up virus from a plant poisoned with Systox.

Our maps often show a conspicuously stronger infection of the rows near the oat-screen and — with respect to the sources of infection — on the inner side of the oat-screens. It would seem that flying aphids are stopped by the oat-screen and that this is the cause of the locally higher virus infection.

This discussion may be summarized as follows:

1 Systox has stopped the spread of virus from implanted secondary diseased leafroll plants; this infection penetrated only two to three rows deep in those plots which were sprayed with water.
2 Systox had no influence on the infection in more remote rows, since the degree of infection there is comparable to that in plots sprayed with water.
3 If in the plots no secondary diseased plants had been present the effect of the treatment with Systox would most probably have been insignificant.

The picture for virus Y is very different.

Table 10. Distribution of virus Y infection in % in the rows parallel to the secondary diseased plants.

Row	1	2	3	4	5	6	7	8	9	Average
Sprayed with Systox row of virus-Y infected plants in the middle	87	83	79	58	56	48	49	42	42	60.4
Sprayed with Systox; no virus-Y source present	20	19	11	14	19	15	16	25	14	16.9
Sprayed with water; no virus-Y source present	7	13	21	18	14	15	13	12	11	13.8

By mistake the plot which should have been sprayed with water was once on 16 June sprayed with Systox, vide p. . .

In the plots sprayed with Systox in which tubers with virus Y were implanted the infection penetrated very deeply into the rows of healthy plants. In plots in which only leafroll was present as a source of infection, the percentage of plants infected with virus Y amounted to about 15% and the infection was rather evenly distributed over the plot, independent of the fact whether they were sprayed with Systox or with water. We ascribe this 15% of infection to aphids carrying virus Y when entering the plots.

The experiment permits of the following conclusions:

1 The concentric spread of virus Y from secondary diseased plants was very much stronger than that of leafroll.
2 Systox has little or no value in preventing the spread of virus Y from secondary diseased plants.

It is clear that the method which we used for determining the virus infection is open to criticism. The "plant", developing from one tuber, after some time consists of a number of plants which have no interrelation beyond standing in a close group; each of such plants produces its own tubers. If only one of those individual plants later is infected with virus, its tubers will eventually contain virus, but the tubers from the other plants of the complex, developed from the same mothertuber, will not contain virus. The two tubers of each "plant" which we planted were only a minor part of the total progeny of the

mothertuber. In the case of both tubers giving rise to a healthy plant the "motherplant" was registered as not infected, though this does not imply that the whole progeny was healthy.

It has been suggested that apterous aphids are largely responsible for the spread of infection within the "plant", i.e., the complex of plants developing from one tuber. Our data give some information on this, for we know in how many cases only one or both of the two tubers from one "plant" were infected.

Table 11. Percentages in which both tubers taken from a "plant" considered to be infected contained virus.

Infection in plots with secondary leafroll sprayed with Systox	Leafroll	31 %
Infection in plots with secondary leafroll sprayed with water	Leafroll	45 %
Infection in plots with a few secondary leafroll plants sprayed with Systox	Leafroll	34 %
Infection in plots with secondary virus-Y sprayed with Systox	Virus-Y	54 %
Infection in plots without secondary virus-Y sprayed with Systox	Virus-Y	33 %
Infection in plots without secondary virus-Y sprayed with water	Virus-Y	30 %

It is evident that spraying with Systox lowered the number of infected stems per "plant" to some extent, for in the plots sprayed with water in 45 % of the cases both samples were infected, whereas in the plots sprayed with Systox this figure is certainly lower. Evidently the influence of Systox on the percentage of infected tubers is more favourable than table 8 and 9 suggest. But in virus-Y such an influence of spraying with Systox is not evident.

Table 12 shows the percentages of tubers containing leafroll virus as they are distributed over the plots [4]).

Table 12. Distribution of tubers infected with leafroll in % in rows parallel to the row of secondary diseased plants.

Rows	1	2	3	4	5	6	7	8	9	Average
Sprayed with Systox, a few leafroll plants in the middle	9	8	11	12	14	13	14	13	14	12.0
Sprayed with Systox 1 row of leafroll plants in the middle	12	13	13	15	17	14	14	18	15	14.6
Sprayed with water 1 row of leafroll plants in the middle	59	36	24	19	14	14	15	13	27	24.6

Evidently Systox does not stop the infection by leafroll or virus-Y brought into the plots by aphids which picked up the virus outside the plot. It is therefore not surprising that we did not find any influence of DDT on virus infection, because the plots of the variety *Noordeling* contained none or few sources of infection.

Our experiments partly explain, why frequently no correlation is found between the number of aphids counted on the plants in a potato field and the degree of infection by aphid-borne virus diseases. Undoubtedly a part of the standing aphid population contributes to the spread of virus, but in plots sprayed with Systox the whole standing aphid population was wiped out and nevertheless a considerable amount of virus infection occurred. This infection can only have been caused by alatae which were not born in the plots. And

[4]) In this case each "plant" of table 9 has been given the value ½ in case only one of the two planted tubers was infected.

such alatae, which according to our observations are highly mobile, would almost completely escape detection by the customary methods of assessing the aphid population in a potato field.

The differences between the spread of leafroll and that between virus-Y in plots sprayed with Systox where sources of virus were available, agree remarkably well with the theories about persistant and not-persistant viruses (vide p. 189). Virus free aphids picking up leafroll virus plus Systox died before they became infective (within 24 hours), but such aphids picking up virus-Y became infective long before they died, which resulted in a very heavy infection of the rows of healthy plants. It is evident, that none of the known aphicides could to any considerable extent prevent the spread of virus-Y within the field by aphids entering the field.

PRACTICAL RESULTS

The experiments show that Systox would have no important effect in a field which contained no sources of infection. The same situation develops if the sources of infection have been removed before the aphids begin to arrive. In agricultural practice it will generally not be possible to remove the diseased plants in time, e.g., because, the symptoms of leafroll may take some time to develop. Especially in varieties like *Bintje, Voran, Meerlander,* etc., the symptoms of leafroll are not distinct until a considerable time after the plants come up. Virus-Y plants, which can be recognized when still very small, are generally removed in time, but leafroll in this country remains a problem, because the aphids in some years arrive very early, before the symptoms are sufficiently distinct.

In roguing the diseased or suspected plants are removed as early as possible and carried out of the field in a closed sack. If, however, at the time of roguing aphids are already present on the plants it is almost unavoidable that at least some of the aphids fall off when the plant is removed. As such aphids contain virus, roguing itself can contribute to the infection of plants by virus. Also the transport of the plants through the field, or dumping the plants near the field can result in the dissemination of virus-infected aphids.

If plants with leafroll are present one may expect less virus infection after applying Systox. Spraying an entire field with Systox would make it possible to postpone roguing of leafroll plants till the symptoms become quite distinct. For Systox makes leafroll plants almost harmless. And also the removal of diseased plants is possible without the danger of disseminating aphids with virus, because no aphids will be left.

A curious consequence of treatment with Systox is, that for the health of the harvested seed it does not matter whether few or many leafroll plants were planted in the crop. For only infection coming from outside the field would seem to be of any importance if Systox is applied as we did. Of course the diseased plants would have to be removed from the crop to prevent their tubers being harvested as seed.

The spraying of whole potato fields with Systox has disadvantages. Systox is a dangerous poison. It enters the human body in various ways and also the vapour is dangerous. Handling Systox therefore requires special precautions and it would also seem dangerous to stay under the lee of a field which has just been sprayed with Systox. Also the frequent handling of plants loaded with Systox (as in counting aphids), may cause local spasms of the muscles of

the arms. In removing plants treated with Systox rubber gloves should be used. All these measures against poisoning no doubt can be taken, but familiarity breeds contempt. The antidote against this and similar poisons (atropine) is known but the doctors in general are not yet acquainted with the symptoms of Systox poisoning.

The poison penetrates the whole plant and therefore also the tubers. Since seed which receives no certificate and also the large sized certified seed is often sold as ware, the danger of Systox-poisoned potatoes being eaten is not imaginary. As long as it is not known how poisonous the tubers may become and how long they remain poisonous, spraying of entire fields of potatoes with Systox should not be permitted [5]).

According to our experiments another application of Systox is possible and not very dangerous. If only leafroll plants and those suspected of leafroll are sprayed with Systox, only small quantities of the Systox are required so that portable apparatus can be used. The man who would do the roguing, in this case does not remove the diseased plants and those suspected of having leafroll, but he sprays them with Systox, after which they cease to be a potential danger for the rest of the field. The diseased plants can then be removed a week later, while those plants which had been injustly suspected can be left. If a dye is added to the spray it is also possible for a non-specialist in virus diseases later to remove the coloured plants. Because only few plants — of which the tubers have to be removed in any case — are treated, it is hardly possible that tubers containing Systox would be sold as ware. We believe that the latter method, roguing after spraying with Systox of the sources of infection, will give a lower percentage of infection by leafroll than the method at present used in the Netherlands. As to other virus diseases the customary method of roguing must be continued. Systox may be very valuable in aphid control but its influence on the many non-persistent virus diseases is highly insufficient. Apart from this there are, of course, several virus diseases in potatoes which are not transmitted by aphids.

ACKNOWLEDGEMENT

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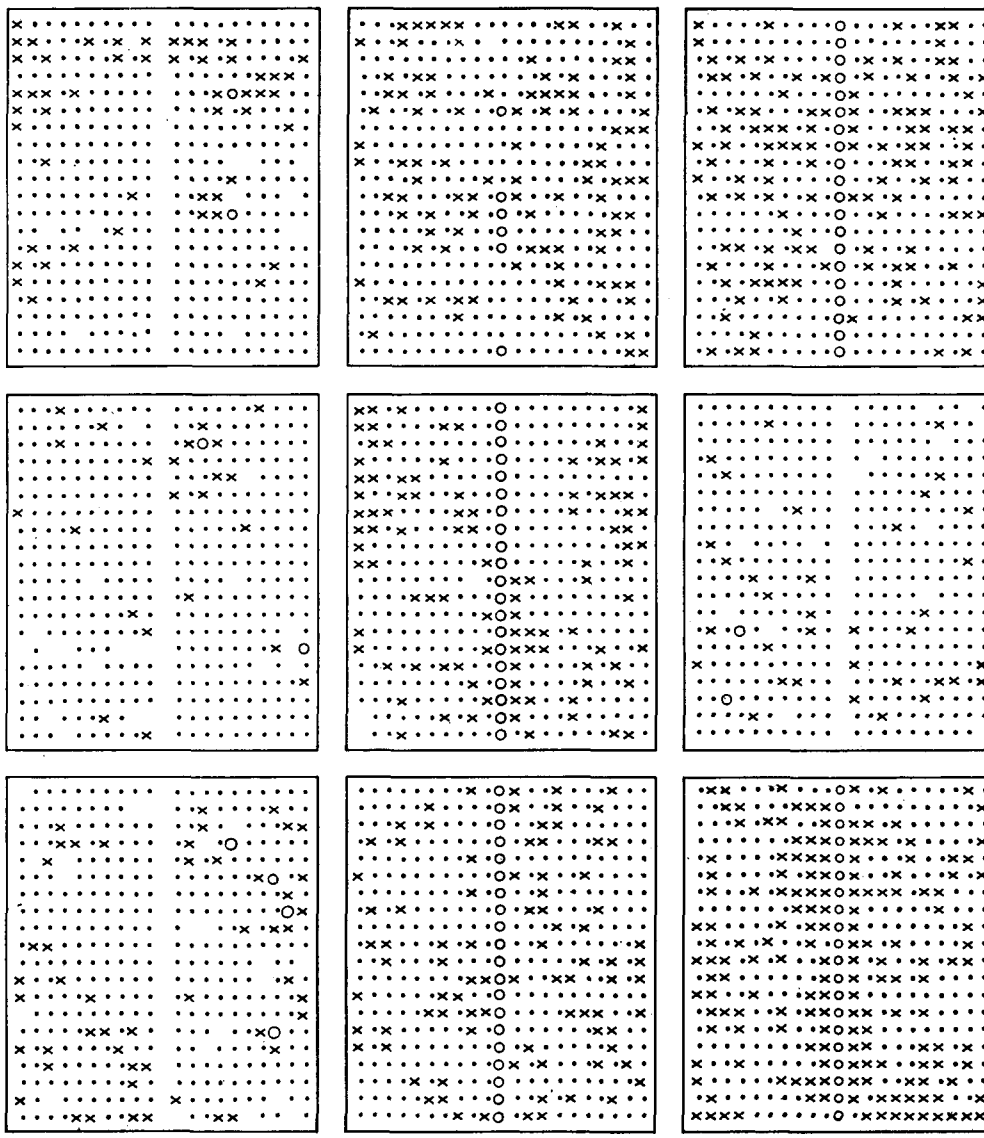
5) The Netherlands Phytopathological Service kindly asked us to remind Dutch readers, that Systox may as yet not be used for spraying potatoes.

SPREAD OF LEAFROLL (VIRUS Y OMITTED)



V	I	II	VI	IV	III
VI	III	IV	Ia	II	V
IV	II	III	V	VI	I

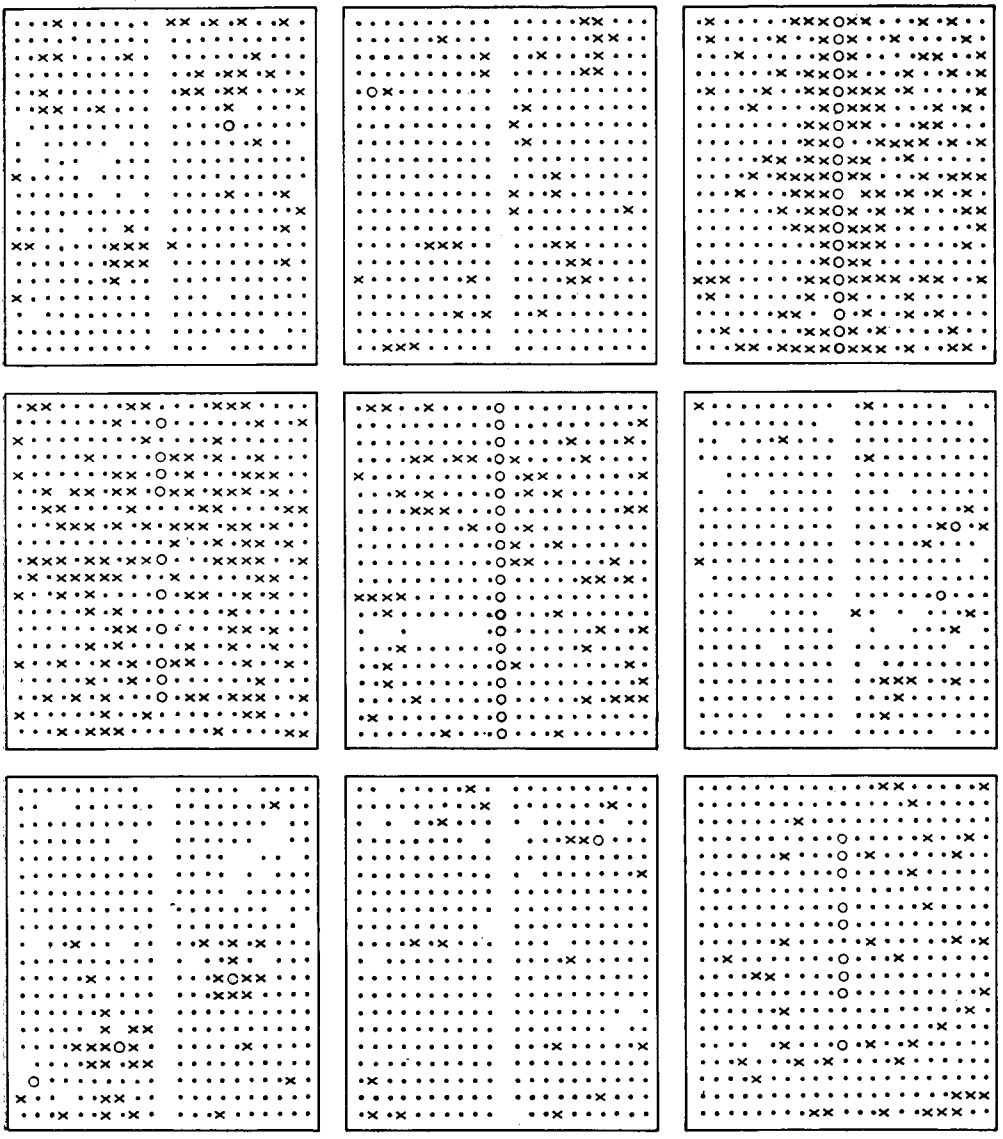
Variety *Bintje*

I Virus Y implanted (some also with leafroll) ; sprayed with Systox.

Ia As before ; once sprayed.

II Leafroll implanted ; sprayed with Systox.

III As before ; sprayed with water.



Variety *Noordeling*

IV Sprayed with DDT from above and from below.

V Sprayed with DDT from above.

VI Sprayed with water.

0 = implanted second season leafroll.

X = spread of leafroll.

• = no leafroll.