THE CHEMICAL CONTROL OF BLACK CURRANT REVERSION VIRUS AND ITS GALL MITE VECTOR (*PHYTOPTUS RIBIS* NAL.)

By J. M. THRESH

Abstract

Endrin, endosulfan, lime-sulphur, colloidal sulphur and fluoroacetamide were each applied five times to batches of healthy black currant bushes in 1963, in attempts to control the spread of reversion virus and its gall mite vector (*Phytoptus ribis* Nal.*) from adjacent unsprayed bushes. Endrin gave virtually complete control of mites and endosulfan and fluoroacetamide were almost as effective. However, endrin decreased the incidence of virus, whereas endosulfan and fluoroacetamide did not. Lime-sulphur and colloidal sulphur damaged growth and were the least effective materials against mites, yet they decreased virus infection.

The design of field experiments on the control of mites and reversion, and their relevance to commercial practice, are discussed in relation to the way in which the different materials affect mites.

The black currant gall mite *Phytoptus ribis* Nal. is a widespread and prevalent pest of black currants in Britain and infested buds fail to develop flowers or true leaves. The mite is even more important as the vector of reversion virus, the most virulent strains of which cause bushes to become virtually sterile.

There have been numerous experiments on the control of mites by sprays applied early in the growing season, when mites disperse from the old buds to the new. However, little attention has been given to the effects of these treatments on the spread of virus and the only data available are from the first experiment of this series (Thresh, 1964*a*). The results obtained were confirmed and extended in the experiment now reported.

Materials and methods

Experimental design

Five different spray treatments and unsprayed controls were replicated six times in a Latin square design, using two-year-old bushes of the variety Wellington XXX planted in six rows 8 ft apart in March 1963. Each of the 36 plots consisted of a row of 10 healthy mite-free bushes planted 2 ft apart, with large flowering bushes, which were heavily infested with mites and systemically infected with reversion virus, at the ends of each plot. Only the uninfested bushes were cut back after planting.

Spray treatments

1. Lime-sulphur (1%, with 0·012% dinonyl sulpho-succinate as wetter).
2. Colloidal sulphur (with 0·006% dinonyl sulphosuccinate as wetter).
3. Endrin (0·04%, with wetter in formulation).
4. Endosulfan (0·05%, with wetter in formulation).
5. Fluoroacetamide (0·05%, with wetter in formulation).
6. Unsprayed controls.

The colloidal and lime-sulphur preparations contained equivalent quantities of sulphur. The sprays were applied five times to run-off with a hand-operated 'Solo' sprayer, starting a week after the flowers began to open and subsequently at intervals of approximately 10 days, depending upon favourable weather. The young bushes were sprayed (omitting the infested ones alongside) on 6th, 15th and 25th May, and 4th and 19th June 1963.

* Referred to as *Eriophyes ribis* (West.) Nal. in early publications and now sometimes considered to be *Cecidophyopsis ribis* (West.).

Observations and records

The condition of the bushes was noted after each spray application. After leaf fall in November 1963 the shoots were measured to determine any effects of the spray materials on growth. The number of galls on each shoot was recorded in December 1963, as an accurate indication of the infestation by mites (Thresh, 1964*b*).

Symptoms of reversion were seen first in April 1964, when some of the flower buds appeared abnormally bright because the outside of the sepals was almost glabrous. Symptoms were always restricted to less than four of the twenty or more trusses of flowers on a shoot and each affected shoot was the result of a distinct infection by mites. Infected shoots were recorded four times during the blossom period and fortnightly in May, June and July as leaf symptoms developed. After such detailed observations in previous experiments, it was found unnecessary to retain the bushes for a third year to diagnose all the primary infection.

Results

Phytotoxicity

Fluoroacetamide has now been withdrawn from use on all agricultural crops, but it has never been used commercially on black currant bushes because it damages the leaves and decreases yield (Dicker and Tew, 1962). Typical symptoms were recorded in May and June 1963, when all the bushes sprayed with fluoroacetamide developed rolled chlorotic leaves. By July many of the axillary buds of sprayed bushes had developed into short shoots, suggesting that apical dominance had been affected. By observing other sprayed bushes alongside the experimental area the main varieties were ranked, in order of decreasing susceptibility :

$$\left\{\begin{array}{l}\text{Westwick Choice}\\ \text{Goliath}\end{array}\right\} > \text{Wellington XXX} > \text{Baldwin} > \left\{\begin{array}{l}\text{Mendip Cross}\\ \text{Boskoop Giant}\end{array}\right\}$$

There was some recovery of the experimental bushes by the end of the season, which may have been associated with the unusually heavy rainfall in July and August. Total shoot growth was decreased by 16%, compared with untreated controls ($P < 0{\cdot}05$).

The old leaves of all the bushes sprayed with lime-sulphur and colloidal sulphur showed conspicuous chlorosis and some necrosis and defoliation in May and June 1963. Growth was then stunted compared with unsprayed bushes and those receiving endrin or endosulfan. Varieties differed in sensitivity to sulphur damage, with Goliath the most susceptible :

$$\text{Goliath} > \left\{\begin{array}{l}\text{Wellington XXX}\\ \text{Baldwin}\end{array}\right\} > \text{Mendip Cross} > \text{Boskoop Giant}$$

The sulphur damage was less noticeable by July, and, as in the fluoroacetamide plots, late growth showed considerable recovery. Lime-sulphur and colloidal sulphur decreased total shoot growth by 17% and 23% respectively ($P < 0{\cdot}01$). The effects might have been greater but for the damage caused by the leaf-spot fungus *Pseudopeziza ribis* Kleb., which was particularly severe on bushes not receiving sulphur, as in experiments at Long Ashton (Smith, 1964).

The spread of mites

All the unsprayed bushes became infested with mites in 1963. The mean number of galls per bush was 12·4, compared with only 3·2 on similar bushes at the same site in the 1962 experiment. This provides additional circumstantial evidence that the dispersal of mites is not dependent on aphids ; the commonest aphid is usually *Hyperomyzus lactucae* L., which was rare on the experimental bushes in 1963, but numerous on some bushes in 1962, when its distribution was not correlated with the spread of mites.

As in the 1962 experiment, the incidence of galls was not influenced by proximity to the sources of mites. The absence of the gradients of dispersal which have been observed in other experiments was presumably because all the bushes were within 10 ft of a source of mites, which could spread from the opposite ends of each plot.

The chemicals differed greatly in preventing the establishment of mites and could be divided into three groups, between which large and consistent differences were recorded. Endrin was outstandingly successful, and endosulfan and fluoroacetamide were almost as effective, in decreasing the number of galls to a low level. Lime-sulphur and wettable sulphur were much less effective and almost all the sprayed bushes became infested, although with fewer galls than the unsprayed controls (Table I).

TABLE I

EFFECT OF DIFFERENT SPRAY MATERIALS ON THE INCIDENCE OF BLACK CURRANT GALL MITE

Treatment*	% Infested		
	Bushes	Shoots	Buds
Lime-sulphur	98·0	36·3	3·4
Colloidal sulphur ..	93·0	36·0	2·7
Endrin	1·6	<0·1	<0·1
Endosulfan	43·0	3·9	0·3
Fluoroacetamide ..	21·6	3·6	0·2
Unsprayed	100·0	57·0	8·3

* Each material applied 5 times to 60 bushes exposed to mites spreading from unsprayed bushes nearby.

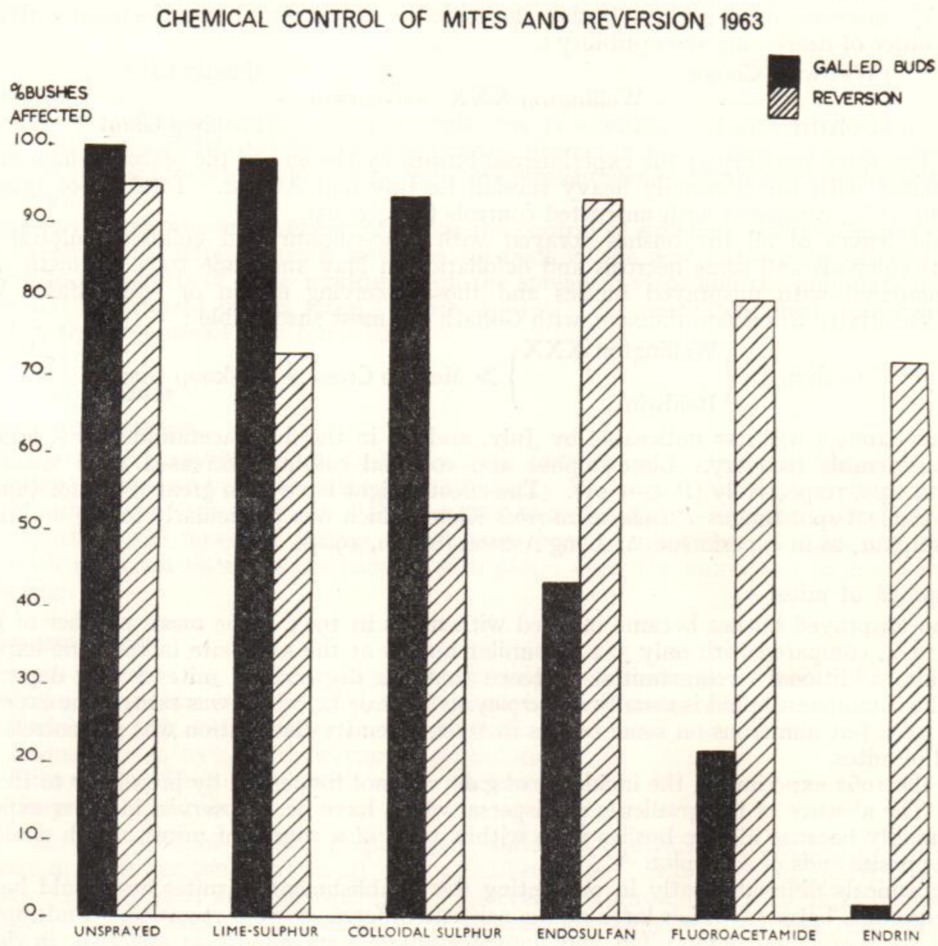

FIG. 1

The effect of different spray treatments on the incidence of black currant reversion virus and its gall mite vector.

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The spread of reversion virus

Symptoms of reversion virus developed during the second year of the trial. About half the infections were diagnosed on the blossom symptoms and the remainder during the subsequent observations of leaves. All but three of the 60 unsprayed bushes became infected and the incidence of virus was so high that inevitably some bushes became infected more than once, with several branches having affected flowers. Other bushes developed leaf symptoms on branches quite remote from those with affected flowers, which could not have occurred if virus had been introduced at a single point of inoculation. It was impossible to distinguish each distinct infection and the numbers observed were about half those expected from the 'multiple infection' transformation of Gregory (1948) (Table II).

TABLE II

EFFECT OF DIFFERENT SPRAY MATERIALS ON THE INCIDENCE OF BLACK CURRANT REVERSION VIRUS

Treatment†	Bushes infected		Distinct infections	
	Percentage	Number	Observed	Estimated (Gregory, 1948)
Lime-sulphur	73·3	44*	45	79
Colloidal sulphur ..	51·7	31*	36	44
Endrin	71·7	43*	46	76
Endosulfan	93·3	56	84	160
Fluoroacetamide ..	80·0	48	51	97
Unsprayed	95·0	57	97	180

† Each material applied 5 times to 60 bushes exposed to virus spreading from unsprayed bushes nearby.

* Difference from unsprayed controls significant at the 5% level.

As in the previously described experiment, the ability of the different spray materials to decrease the incidence of virus was not correlated with their effectiveness against mites. The bushes sprayed with fluoroacetamide and endosulfan developed few galls, yet the number which developed reversion symptoms was not significantly less than that in the unsprayed controls. Fluoroacetamide decreased the number of shoots which developed symptoms, indicating that under less extreme conditions there would have been fewer infected bushes than in the endosulfan and unsprayed plots.

Endrin, lime-sulphur and colloidal sulphur decreased the number of bushes which became infected with virus and halved the number of affected shoots (Table II).

In previous unpublished observations on the spread of mites and reversion in unsprayed plots there was a positive correlation between the incidence of new virus infections and the number of galls the previous winter. All the bushes with more than 40 galls developed reversion symptoms, which were found on only 25% of the bushes with less than 10 galls.

A similar relationship was found in the spraying experiments, but only after excluding the data for the bushes sprayed with endrin, endosulfan and fluoroacetamide. Thus it is impossible to predict the incidence of virus in a plantation from winter observations on galls, as discussed by Collingwood and Brock (1961) and Legowski and Gould (1964), who introduced the concept of a critical level of mite infestation above which plantations are likely to be so heavily infected with virus as to be uneconomic.

Discussion

The experimental design, with the sprayed bushes close to unsprayed sources of both mites and reversion virus, provided an extreme test of the effectiveness of the sprays. It simulated in an extreme form the situation at some commercial nurseries and many plantations, where healthy young bushes are exposed to infection from diseased bushes nearby. Thus it is hardly surprising that much virus spreads into young bushes, even though sprays prevent a permanent mite infestation. At one plantation in Kent, 35% of the bushes became infected with reversion virus within four years of planting, yet galls were rare because of annual spring applications of endrin. The planting material was satisfactory and the clear gradients of infection along the rows was evidence that virus had spread into the crop from severely affected bushes which had remained for two years along the upwind headland. Such spread can be decreased by very thorough and frequent sprays, although all the available materials have limitations. Lime-sulphur or sulphur may be phytotoxic and may allow sufficient mites and virus to become established for further spread to occur. Secondary spread is less likely with endrin or endosulfan, but the use of these materials is restricted because of their high mammalian toxicity and they are unlikely to prevent virus entering the crop. A better approach is to choose a site with adequate isolation and to remove all infected bushes in the vicinity.

Bushes which are to be certified under the present Ministry of Agriculture scheme must be isolated by at least 100 yards from other stocks and consequently they are not usually exposed to many mites from outside sources. Spread within the crop is much more important and to assess the effectiveness of chemicals under these conditions requires a special experimental design. One possibility is to plant sources of mites and reversion in the centre of each experimental plot and to spray them together with adjacent healthy mite-free bushes. Results obtained in this way are likely to differ considerably from those reported here, because the chemicals will kill many mites before they have left the galls and before they have been able to spread virus. Endrin and endosulfan may then be highly effective against both mites and reversion and they may reduce spread so greatly as to necessitate either increased replication or very large plots before valid comparisons can be made between treatments.

An ideal spray material for controlling mites and reversion by the usual spring applications would form a persistent, quick-acting, toxic deposit on plant surfaces and also eradicate mites in galls and in the vulnerable buds of new growth. Failure to protect against mites or to eradicate them adequately probably accounts for differences in the effectiveness of the various materials against mites and reversion. However, there is little information on the way in which the materials act. Lime-sulphur will kill mites by contact and also produces a toxic vapour considered to be sulphur (Goodwin and Martin, 1929). Few mites are killed within buds or galls (Jary, Austin and Pitcher, 1938) and lime-sulphur and probably colloidal sulphur seem to act primarily by protecting the new growth, so decreasing the number of mites which feed, transmit virus and cause galls.

The action of endrin, endosulfan and fluoroacetamide is quite distinct, as they can eradicate mites in galls and in young buds (Collingwood and Dicker ; Collingwood, Vernon and Legowski, 1960). The failure of endosulfan and to a lesser extent of fluoroacetamide to decrease the incidence of virus is explicable if they do not form a persistent deposit protecting the young growth, but act primarily by eradicating mites which have already transmitted virus. Endrin also seems to act primarily by eradicating established mites, although it protected bushes against virus when used weekly in 1962 and to a lesser extent when used at intervals of 10 days in 1963. Virus infection was decreased by lime-sulphur used fortnightly in 1962, but not by endrin used on the same occasions, suggesting that endrin has limited persistence, which is less than that of lime-sulphur.

A search is justified for persistent, quick-acting materials which will control both mites and reversion and which are less dangerous to use and less phytotoxic than those now available. Further attention should be given also to the way in which the different materials act. If they are unsatisfactory in protecting sprayed bushes, then conventional sprays have limited value when applied as flowering begins and mites are only just starting to disperse. The possibility of using mixed sprays of organic and sulphur materials has yet to be considered.

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