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RECENT CHANGES IN THE HEALTH STATUS OF ENGLISH HOP PLANTINGS

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Summary This paper considers the contrasting effects of recent changes in cropping practices on the incidence of three viruses of hop. The increased losses now caused by hop mosaic have been more than offset by the enhanced yields due to striking decreases in the incidence of prunus necrotic ringspot and arabis mosaic viruses. These have been achieved by releasing virus-tested stocks which have been used for a high proportion of the many recent plantings.

Résumé Ce papier concerne les effets contrastants des changements récents en cultures, exercés sur l'incidence de trois viroses d'houblon. Les pertes additionnelles causées maintenant par la mosaïque d'houblon ont été plus que compensées par les rendements à la suite des diminutions remarquables dans l'incidence des viruses mosaïque de l'arabette et taches annulaires nécrotiques chez prunus. Ceux-ci on été accomplis par le développement des souches ayant un meilleur état sanitaire, lesquelles ont été utilisées pour une portion importante des nombreuses plantations récemment entreprises.

INTRODUCTION

In the 19th Century the hop (Humulus lupulus) was grown in almost all English counties and in parts of Scotland and Wales. Plantings reached a maximum of 29,064 ha in 1878 and then declined. This decline has continued and there are now only 5,695 ha on 436 farms, mainly in Kent, Sussex, Herefordshire and Worcestershire. Nevertheless, the U.K. crop is currently worth £15 million per year, providing an indispensible ingredient for the brewing industry which has an annual turn-over exceeding £3,000 million.

There have recently been major changes in the demand for hops and in the varieties grown. This paper considers the impact of these changes on the prevalence of viruses and their effects on productivity.

RECENT CHANGES IN HOP-GROWING

The hop is a perennial propagated vegetatively from stem cuttings. For many years the main varieties grown in England were Fuggle and the various Goldings. These old varieties still predominated in 1969, although there were also many plantings of WGV and varieties originating from the early stages of the Wye College breeding programme (Table 1).

Brewers' requirements for Golding 'aroma' hops have decreased recently, whereas there has been increasing demand for hops with a high content of the alpha-acid bittering fraction. In the U.K. extensive areas of Fuggle and Goldings have been replaced by new 'high-alpha' varieties from Wye. This trend has been reinforced by the need to introduce varieties resistant to the progressive forms of verticillium wilt that have become prevalent in many parts of Kent and Sussex.

Table 1

The main hop varieties grown in England in 1969 and 1979

Variety	Originated	Total area (ha) 1969	Total area (ha) 1979
Goldings†	1790	1,159	489
Fuggle	1861	2,807	574
WGV*	1911	866	335
Bullion	1919	453	340
Keyworth's Mid-season*	1924	112	148
Bramling Cross*	1934	817	409
Northern Brewer	1934	294	296
Progress*	1951	118	157
Wye Northdown	1961	2	936
Wye Challenger	1963	0	763
Wye Target*	1965	0	1,016
Wye Saxon*	1968	0	164
Wye Viking	1968	0	23
Others		141	45
Total area		6,769	5,695

† mosaic-sensitive * wilt-resistant

The changeover in varieties has been exceptionally rapid for a perennial crop and almost 13% of existing plantings were replaced in 1973-1974 alone. The impetus has been provided by foreign competition and by the need to improve productivity as growing costs increase.

HOP MOSAIC VIRUS

English hop varieties segregate into two distinct groups according to their reaction to infection with hop mosaic virus (HMV). True Goldings develop conspicuous symptoms and soon die or grow so badly that they are replaced. All other varieties behave as symptomless carriers of infection and their growth and yield seem unaffected.

HMV is aphid-borne and likely to spread into Goldings and cause serious losses whenever tolerant varieties are planted nearby (Keyworth, 1947). This explains why many Goldings were being grown in 1969 at isolated sites in Berkshire, Hampshire, East Kent and North Kent. These were outside the main hop-producing areas and on many farms Goldings predominated or were grown exclusively (Table 2). Consequently mosaic was not encountered or losses were acceptable and there were few serious outbreaks.

Table 2

The number of farms growing Goldings in each main hop-growing region*

Region	1969		1979	
West Midlands	66/211	(1)	43/176	(2)
E. & N. Kent	48/59	(27)	31/40	(2)
Farnham	15/21	(7)	1/14	(0)
Weald	45/285	(1)	18/205	(1)
Total	174/576	(36)	93/435	(5)

* Farms with Goldings as a fraction of the total number in each region. Figures in parentheses are for Golding farms with no other varieties.

The situation deteriorated with the decreased demand for Goldings and increased plantings of other varieties. These are now being grown for the first time on many Golding farms and there are only five still without tolerant varieties (Table 2). The ratio of tolerants to sensitives on farms with Goldings changed from 1359 : 1159 in 1969, to 1074 : 489 ha in 1979. This increased the 'infection pressure' on the relatively small remaining area of Goldings. Spread has also been facilitated by the decreased separation between plantings of sensitives and tolerants. Losses have increased and at some sites have become so great that whole rows or even entire plantings have been removed. Elsewhere, scattered infection occurs causing gaps where it is difficult to establish replants.

Little further can be done to decrease present losses as repeated drenches or sprays are being used already against aphids. Moreover, the choice of sites for additional plantings is restricted by the need to establish tolerant varieties on existing areas rather than incur the great expense of erecting new supporting posts and wire-work elsewhere. Growers are therefore likely to encounter continuing difficulties, inconvenience and expense due to mosaic. However, recent observations indicate that infection is seldom prevalent in Goldings unless tolerants are planted immediately alongside, without headland or other separation. Much can be achieved by at least some degree of isolation and plantings should be in compact blocks with the least possible interface between tolerants and sensitives. It may also be advantageous to use mosaic-free clones derived from meristems for any new plantings of tolerant varieties. Such clones are now available and can be grown satisfactorily alongside Goldings, provided there are no other local sources of infection. Otherwise, the meristem plants soon become re-infected and menace any Goldings nearby.

Difficulties have been experienced in evaluating the effects of mosaic on tolerant varieties because of rapid reinfection in small-plot trials. However, preliminary indications are that eliminating mosaic from tolerants does not enhance growth or yield and there is at present no justification for encouraging growers to replace existing plantings with mosaic-free material other than to decrease the risk to Goldings.

PRUNUS NECROTIC RINGSPOT VIRUS IN HOP

Prunus necrotic ringspot virus (NRSV) causes important diseases of apple, cherry, plum, peach and apricot and also affects various woody ornamentals. The occurrence of the virus in hop was first suspected in the United States (Fridlund, 1959), but not confirmed until later (Bock, 1966, 1967). Surveys then revealed NRSV to be throughout all available clones of the main English hop varieties and the only uninfected plants were in seedling progenies or in exotic varieties at Wye (Thresh & Ormerod, unpublished). Consequently it was impossible to assess rates of virus spread or effects on growth and yield in commercial plantings.

The situation changed with the production of NRSV-free clones by culturing meristem-tips from heat-treated plants of old varieties (Vine & Jones, 1969; Adams, 1975) and by selecting uninfected plants from the earliest trial plantings of varieties being developed at Wye College. Trials at Wye soon established that NRSV-free plants outyield infected ones, mainly by an increased cone content of alpha-acid (Neve, unpublished). This enhances crop value without increasing production costs. Accordingly, NRSV-free clones have been released to growers and propagators and a major effort made to ensure that these clones are utilised (Adams, et al., 1977).

The NRSV-free selections of Wye Northdown and later varieties have already had a major impact as they have been used for a high proportion of all recent plantings (Table 3). There has been some spread of NRSV into such material, especially when grown in small plots close to infected plants. However, 1977-1978 surveys in Kent and the West Midlands revealed a generally low incidence of NRSV, even in some of the earliest plantings of Wye Northdown and Wye Challenger made 1969-1970. Consequently, there has

Table 3

Total areas of U.K. hop varieties 1969-1979 and the areas estimated to be largely free of NRSV

Year	Total areas (ha)		
	All vars	Latest Wye vars	NRSV-free
1969	6,767	2	2
1970	6,972	4	4
1971	7,034	21	20
1972	6,822	123	116
1973	6,770	475	420
1974	6,568	1,234	1,027
1975	6,410	2,047	1,791
1976	5,925	2,502	2,255
1977	5,877	2,782	2,517
1978	5,846	2,907	2,637
1979	5,695	2,904	2,641

been a striking decrease in the losses due to NRSV and the many growers adopting the new more productive varieties have had the additional benefits arising from the improved health status of the best stocks now available. In 1976 the new varieties produced crops worth an estimated £1 million more than if NRSV had been present. Current benefits are even greater due to recent price increases and because additional plantings have come into full production. Further progress in decreasing the incidence of NRSV is likely to be slow because of the limited plantings now being made. However, there is still a need for an additional wilt-resistant variety to decrease dependence on Wye Target and supersede WGV and other old NRSV-infected varieties. Once a suitable variety emerges there are likely to be substantial plantings and an additional improvement in productivity.

ARABIS MOSAIC VIRUS IN HOP

Arabis mosaic virus (AMV) is transmitted by the free-living nematode *Xiphinema diversicaudatum* and causes diseases of raspberry, strawberry and many other crops. Infection in hop was unsuspected until an unusual strain of AMV was shown to be solely or partially responsible for nettlehead, bare bine and severe split leaf blotch diseases (Bock, 1966; Thresh, *et al.*, 1972). These have long been prevalent in hop and were reported by many growers questioned during 1969 and 1970 (Thresh & Ormerod, 1971).

A major factor contributing to such a high incidence of infection was the limited use at that time of Ministry-certified AMV-free planting material. About two-thirds of the plants used in all areas had been propagated locally from uncertified stocks. Many were of dubious health status and some were seriously affected by AMV. This was being introduced to new areas where hops had not previously been grown and to hop sites where populations of the nematode vector were absent or not infective (Thresh, 1978). The spread of AMV and its recurrence at affected sites were also facilitated by the common practice of replanting immediately or soon after removing the previous crop (Thresh & Ormerod, 1974).

Growers were urged to be more discriminating in choosing stocks and sites for new plantings. The response has been good and the decreased demand for hops has enabled growers to abandon some of the worst-affected sites. Others have been replanted only after fumigation or fallowing procedures to eliminate nematodes or render them non-infective (McNamara, et al., 1973). There have also been benefits from the extensive replacement of Fuggle and other old varieties by recent ones from Wye College. Many of the numerous stocks required for replanting were derived directly or indirectly from the virus-tested material supplied to Ministry-certified propagators. The major problems arising from indiscriminate propagation have been recognised and largely overcome. This has achieved a great improvement in the overall situation and there are now few reports of nettlehead or other diseases due to AMV.

DISCUSSION

The Hops Marketing Board collects detailed statistics on changes in the varieties grown and on the yields and prices obtained. Information on the losses caused by pests and diseases is far less precise, due to the lack of fully comprehensive surveys of their occurrence in commercial plantings. Thus there is only limited quantitative evidence for some of the trends here described. However, they have become apparent from close contact with hop-growers over the last decade and are supported by the largely unpublished findings of questionnaires and pilot surveys done with the staff of Agricultural Development and Advisory Service and the Department of Hop Research, Wye College.

The results obtained provide clear evidence of the extent to which the prevalence of viruses and the losses they cause have been influenced by recent changes in cropping practices. Alterations in the composition, size and disposition of new plantings have had particularly important consequences, with contrasting effects on the three viruses considered. Hop mosaic has become increasingly prevalent but remains a nuisance to growers rather than a serious threat to production. Moreover, the increased losses due to mosaic have been more than offset by the decreased importance of prunus necrotic ringspot and arabis mosaic viruses. Their decline has been due largely to improvements in the health of the planting material released to growers. The use of such material for many of the recent plantings has brought enormous benefits far exceeding the research and development costs involved. This has greatly strengthened the economic position of U.K. growers at a critical period of increasing production costs and severe competition from imports.

Acknowledgements

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CONTROL OF STRAWBERRY FRUIT ROTS CAUSED BY BOTRYTIS CINEREA AND PHYTOPHTHORA CACTORUM

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Summary The dicarboximide fungicide vinclozolin, procymidone and iprodione gave the best control of *Botrytis* fruit rot, whether the causal pathogen was sensitive or insensitive to carbendazim, but all failed to control the disease when the causal pathogen was iprodione-insensitive. Using these fungicides also significantly increased leathery rot caused by *Phytophthora cactorum*. The commonly used fungicide dichlofluanid gave good control of fruit rots irrespective of the sensitivity of the pathogen isolates present.

Résumé Des fongicides à base de dicarboximide - la vinclozoline, la procymidone et l'iprodione - ont été les plus efficaces contre la pourriture des fruits provoquée par *Botrytis*, que l'agent pathogène fût sensible ou insensible au carbendazime, mais ont été tous inefficaces quand l'organisme causal était insensible à l'iprodione. L'utilisation de ces fongicides a mené aussi à une augmentation significative de la pourriture coriace causée par *Phytophthora cactorum*. Le fongicide courant dichlofluanide a montré une bonne efficacité contre les pourritures des fruits indépendamment de la sensibilité des isolats des agents pathogènes présents.

INTRODUCTION

Many strawberries are lost through grey mould *(Botrytis cinerea)*, losses occur through flower abortion or fruit rot before or after picking. The disease is spread by airborne spores from dead and decaying parts of many plants, so making eradication extremely difficult. As infection may occur early it is necessary to use protective fungicidal sprays from before flowering onwards.

For ten years, the protectant fungicides thiram, captan, dichlofluanid and dicloran have commonly been used to control the disease on soft fruit; and all are still in use (Beever 1973; Borecka *et al.* 1973; Jordan & Richmond 1975; Jordan & Pappas 1977). The carbendazim-generating systemic fungicides benomyl, carbendazim, thiabendazole and thiophanate-methyl at first resulted in improved control of grey mould and were active against many other pathogens (Freeman & Pepin 1967; Tapley *et al.* 1969; Cole & Cox 1973; Jordan 1973). However biotypes of *Botrytis* insensitive to these fungicides are now common on strawberries as on many other plants, following the first report on cyclamen (Bollen & Scholten 1971). The incidence on strawberry and raspberry of *Botrytis* isolates insensitive to carbendazim-generating fungicides has been reported (Jarvis & Hargreaves 1973). Jordan and Richmond (1975) showed that both sensitive and insensitive isolates were able to survive successfully on strawberry debris. These changes made control of strawberry grey mould much more difficult, whereas when first introduced the carbendazim-based fungicides gave the best control. The dicarboximide fungicides iprodione, procymidone and vinclozolin offered a possible alternative and their efficacy in controlling

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Botrytis on strawberry has been reported (Hess and Locher 1975; Jordan and Pappas 1977). However, Leroux *et al.* (1977), by selection from the *Botrytis* population, produced isolates *in vitro* which were insensitive to dicarboximide fungicides.

In 1978, the first record in the United Kingdom of *B. cinerea* insensitive to iprodione, procymidone and vinclozolin (as well as to benomyl) was obtained from field plots of strawberry plants sprayed with iprodione, and initially inoculated with a benomyl-insensitive isolate of the fungus (Pappas *et al.* 1979). It was therefore necessary to investigate the ability of such isolates to survive in the natural population and to evaluate disease control by the dicarboximide fungicides where the dicarboximide-insensitive isolate was prevalent.

Jordan and Pappas (1977) also showed that fruit rot caused by *Phytophthora cactorum* increased significantly on plants sprayed with iprodione or vinclozolin. The economic importance of the fruit rot caused by *P. cactorum* is uncertain but it could be increased by using these fungicides.

METHODS AND MATERIALS

We wished to test whether dicarboximide-insensitive *Botrytis* can overwinter on strawberry plant debris to provide inoculum for flower infection in the following year. Therefore, in March 1979 senescent strawberry leaves were removed from plots in which the insensitive *Botrytis* had been detected the previous year, and incubated in moist chambers in the laboratory for 4 days. Distinct sporing *Botrytis* lesions, arising from senescent debris, were checked for insensitivity by point inoculation on 3% malt agar containing either carbendazim or iprodione (100 µg a.i./ml).

The ability of *Botrytis* isolates insensitive to carbendazim, insensitive to iprodione, or sensitive to both fungicides to cause infection was examined in the glasshouse, by inoculating flowers of pot-grown strawberry plants cv. Cambridge Vigour with spore suspensions (50,000/ml) of each isolate. The competitive infection ability of these isolates was examined when flowers were inoculated with mixtures (1 : 1) of the various isolates.

Either 1-year-old or 2-year-old strawberry plants, cv. Cambridge Vigour, planted as runners 30 cm apart in randomised blocks of guarded plots were used for field trials. In each trial the fungicide treatments were applied to 4 plant plots by hand-operated knapsack sprayer at 1,120 l/ha. Ripe fruit was picked twice weekly and the numbers and weight of healthy and *Botrytis*-infected berries from each plant were recorded. The pathogens causing rots on other fruit were identified following isolation and culture on artificial media.

The fungicides evaluated were: benomyl - 0.05% a.i. (50% W.P.); dichlofluanid - 0.1% a.i. (50% W.P.); iprodione - 0.05% a.i. (50% W.P.); metiram - 0.1% a.i. (80% W.P.); prochloraz - 0.05% a.i. (25% e.c.); procymidone - 0.05% a.i. (50% W.P.); vinclozolin - 0.05% a.i. (50% W.P.).

TRIAL I

In 1978, the effectiveness of the fungicides dichlofluanid, iprodione, prochloraz, procymidone, vinclozolin individually and a combined spray programme of vinclozolin/metiram was compared for control of *Botrytis/Phytophthora* fruit rots on 2-year-old strawberry plants. The soil around each plant had been inoculated with oospores of *Phytophthora cactorum* on 7 March 1978 by incorporating macerated apple tissue, artificially inoculated with the fungus, into the soil between the plant rows. The number of oospores incorporated into soil (4×10^7 oospores/m^2) was estimated by counting 3 random samples (0.2 g) of the apple slurry.

On three occasions during flowering (13 April, 23 April and 3 May) all plants were atomised with a suspension of conidia of a benomyl-insensitive *Botrytis* isolate. With the exception of the vinclozolin/metiram programme, where metiram was applied at the green bud stage (5 April) followed by two flower applications of vinclozolin on 15 April and 25 April, the fungicides were applied on three occasions at 10-day intervals from 'first-open' flower (15 April).

TRIAL II

In 1979, the same fungicide programmes were compared; applications were made at green bud with metiram (17 April), followed by vinclozolin (27 April and 8 May) and the flower protection programme applied at first open flower (27 April) which were then followed by two applications (8 May and 18 May). In this trial, attempts were made to reduce the incidence of *Botrytis* by removing all senescent strawberry leaf debris in February: the flowers were also left uninoculated.

TRIAL III

In 1979, the fungicides benomyl, dichlofluanid, iprodione, prochloraz, procymidone and vinclozolin were tested against a dicarboximide-insensitive *Botrytis* (Pappas *et al.* 1979) on 1-year-old strawberry plants. Each fungicide was applied on three occasions, 17 April, 27 April and 8 May; strawberry flowers were inoculated, by atomising with a conidial suspension (50,000/ml) of iprodione-insensitive *Botrytis*, 6 h after each fungicide spray.

RESULTS

Botrytis lesions were present in March 1979 on all samples of incubated strawberry leaf debris; 23 per cent of isolates from these lesions were insensitive to iprodione and procymidone, and 68 per cent were carbendazim-insensitive.

In glasshouse tests no difference was found between the carbendazim-insensitive isolate, iprodione-insensitive isolate and the sensitive isolate in their ability to induce infection of strawberry flowers, nor was there a difference when mixtures of isolates were used (Table 1).

Table 1

Infection ability of *Botrytis* isolates

Isolate used for inoculation	Infection (%)	Strain reisolated A	B	C
A. Sensitive	58.0	+		
B. Carbendazim-insensitive	64.9		+	
C. Iprodione and carbendazim-insensitive	66.7		+	+
D. A + C	60.5	+	+	+
E. B + C	61.7	+	+	+

TRIAL I

Vinclozolin, procymidone, iprodione and the combined vinclozolin/metiram spray programme gave very good *Botrytis* control when applied 48 h after each flower inoculation, whereas prochloraz and dichlofluanid were less effective (Table 2). Although significantly more *Phytophthora* fruit rot occurred on plots treated with vinclozolin, procymidone and iprodione, the total rotted fruit, irrespective of the causal pathogen, was less than that from plots treated with dichlofluanid. The combined spray of vinclozolin/metiram did not improve the control of *Phytophthora*. Less than one per cent of the total rots were caused by *Pythium ultimum* on plots that received applications of vinclozolin, procymidone or iprodione. On unsprayed plots and on those treated with dichlofluanid or prochloraz the incidence of *Phytophthora* rots was much less.

Table 2

Evaluation of fungicides for control of *Botrytis* and *Phytophthora* fruit rots in strawberry (cv. C. Vigour) 1978

Treatment	Conc. (% a.i.)	Yield/ plot (g)	*Fruit infection*			
			Botrytis cinerea		*Phytophthora cactorum*	
			$\sin^{-1}\sqrt{p}^{o}$	%	$\sin^{-1}\sqrt{p}^{o}$	%
Vinclozolin	0.05	2,006 ab	9.83	2.9 a	24.22	16.8 bc
Procymidone	0.05	2,380 a	10.23	3.2 a	25.01	17.9 bc
Iprodione	0.05	2,201 ab	14.56	6.3 a	30.33	25.5 c
Prochloraz	0.05	2,257 a	22.42	14.5 b	18.85	10.4 ab
Metiram + Vinclozolin	0.10 0.05	1,896 ab	14.23	6.0 a	24.27	16.9 bc
Dichlofluanid	0.1	1,656 ab	33.70	30.8 c	15.25	6.9 a
Untreated	-	1,105 b	58.22	72.3 d	11.50	4.0 a
S.E.		306.56	2.035		2.190	

Data followed by the same letter do not differ significantly at P = 0.05

TRIAL II

In the 1979 trial, vinclozolin, procymidone and the combined vinclozolin/metiram programme again gave the best control of *Botrytis* fruit rot: dichlofluanid, iprodione and prochloraz reduced the disease significantly (P = 0.05) but were less effective than the first three (Table 3). All the fungicides, except dichlofluanid, significantly increased (P = 0.05) the amount of fruit infected by *P. cactorum* compared to unsprayed plots. The incidence of soft rots caused by *Rhizopus* spp. or *Mucor* spp. was small with no observed differences between treatments.

Total fruit spoilage, irrespective of the causal pathogen, was significantly reduced by all fungicide treatments (P = 0.05): procymidone, vinclozolin/metiram, vinclozolin and dichlofluanid gave better overall disease control (P = 0.05) than the other compounds tested.

TRIAL III

On plots which had been left unsprayed after inoculation with the iprodione-insensitive *Botrytis* isolate during flowering, 28 per cent of the berries were rotted (Table 4). Dichlofluanid or prochloraz significantly (P = 0.01) reduced this infection and were significantly (P = 0.05) better than the other fungicide treatments. Although iprodione reduced fruit rot compared with unsprayed, the difference was not significant at P = 0.01.

Table 3

Evaluation of fungicides for control of *Botrytis* and *Phytophthora* fruit rots in strawberry (cv. C. Vigour) 1979

Treatment	Conc. (% a.i.)	Yield/ plot (g)	Fruit infection				Total infection	
			Botrytis cinerea		*Phytophthora cactorum*			
			$\sin^{-1}\sqrt{p}^{o}$	%	$\sin^{-1}\sqrt{p}^{o}$	%	$\sin^{-1}\sqrt{p}^{o}$	%
Vinclozolin	0.05	3,158 a	12.12	4.4 a	31.21	26.9 c	35.03	33.0 ab
Procymidone	0.05	2,772 ab	14.44	6.2 a	23.69	16.1 bc	30.04	25.1 a
Metiram + Vinclozolin	0.1 0.05	2,581 ab	16.09	7.7 a	27.49	21.3 c	34.87	32.7 ab
Dichlofluanid	0.1	2,472 b	36.93	36.1 b	7.37	1.6 a	38.38	38.6 ab
Prochloraz	0.05	2,218 b	40.63	42.4 b	18.09	9.6 b	46.61	52.8 b
Iprodione	0.05	1,563 c	40.79	42.7 b	17.42	9.0 b	46.23	52.1 b
Untreated		918 d	63.60	80.2 c	5.93	1.1 a	64.43	81.4 c
S.E.D.		257	5.475		3.244		6.053	

Data followed by the same letters do not differ significantly at P = 0.05

Table 4

Evaluation of fungicides for control of iprodione-insensitive *Botrytis cinerea* on strawberry (cv. C. Vigour)

Treatment	Conc. (% a.i.)	Yield/ plot (g)	*Botrytis* infection	
			$\sin^{-1}\sqrt{p}^{o}$	%
Dichlofluanid	0.1	1,329 a	14.61	6.4 a
Prochloraz	0.05	1,184 a	18.40	10.0 a
Iprodione	0.05	1,558 a	25.67	18.8 b
Procymidone	0.05	1,136 a	26.17	19.5 bc
Vinclozolin	0.05	1,420 a	26.40	19.8 bc
Benomyl	0.05	1,269 a	27.32	21.1 bc
Unsprayed		1,436 a	31.61	27.5 c
S.E.D.		191.21	2.248	

DISCUSSION

Jordan and Pappas (1977) showed that the dicarboximide fungicides, applied during flowering, controlled infection by *Botrytis* isolates both sensitive and insensitive to benomyl and were more effective than dichlofluanid. These trials show that vinclozolin and procymidone controlled *Botrytis* fruit rot better than prochloraz or dichlofluanid. However, there was significantly more rot caused by *P. cactorum* on plots treated with vinclozolin, procymidone or iprodione. There is no evidence that the dicarboximide fungicides stimulated *P. cactorum* to increase leathery rot, but this fungus may have prospered through the lack of competition at sites for fruit infection due to selective suppression by fungicides active only against *B. cinerea*.

Fungi are more likely to become insensitive to fungicides with a specific-site mode of action than to those exhibiting multi-site inhibition. Often fungicide insensitive pathogens decrease in populations after discontinuation of that fungicide, but where the insensitive form is as pathogenic as wild types it may successfully compete with the sensitive form (Dekker 1977). Georgopoulos (1977) stated that a benomyl-insensitive population of *Cercospora beticola* on sugar beet did not decline in three years after application of benzimidazole fungicides. The occurrence of an isolate of *B. cinerea* exhibiting insensitivity to the dicarboximide fungicides and cross-insensitivity to benomyl in field trials has already been demonstrated (Pappas *et al.* 1979). These results show not only that this isolate can survive on strawberry debris to provide inoculum for flower infection, but also that it can compete equally with fungicide-sensitive isolates and with those isolates insensitive to carbendazim.

Although the occurrence and distribution of this dicarboximide-insensitive isolate in strawberry fields throughout the U.K. is not known, these results show that where it was introduced (artificially inoculated) the fungicides vinclozolin, procymidone and iprodione failed to control the disease. There is clearly a danger that dicarboximide fungicides may cease to be effective in controlling grey mould where insensitive isolates develop, as occurred with the carbendazim producing fungicides. However, no such problem has yet been found with the established fungicide dichlofluanid.

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