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CULTURAL FACTORS AFFECTING PEST INCIDENCE IN GLASSHOUSE TOMATO CROPS

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Summary The incidence of glasshouse whitefly (Trialeurodes vaporariorum), red spider mite (Tetranychus urticae) and tomato moth (Lacanobia oleracea) was surveyed in 1977-8 in tomato crops in the Clyde Valley, Scotland. A greater proportion of growers reported attack by these pests in unsterilized than in sterilized glasshouses. Limited data suggested that steam sterilization was more effective than methyl isothiocyanate in eliminating tomato moth, but that the opposite was the case for glasshouse whitefly.

Résumé L'incidence de l'aleurode (Trialeurodes vaporariorum) et de la tétranyque (Tetranychus urticae) des serres et d'une noctuelle (Lacanobia oleracea) a été examinée en 1977-8 pour les récoltes de tomates dans la vallée de la Clyde en Ecosse. Un plus grand nombre de cultivateurs a signalé des attaques de ces ravageurs dans des serres non-stérilisées plutôt que dans des serres stérilisées. Des données limitées suggèrent que la stérilisation à la vapeur est plus efficace pour l'élimination de la noctuelle que le méthyle isothiocyanate et le contraire s'applique à l'élimination de l'aleurode.

INTRODUCTION

The technology of edible crop production under glass has undergone major changes in recent years, some of which have had an obvious and direct bearing on the control of pests and diseases. Other innovations - soilless cultivation, peat culture, the replacement of glass by plastic film, thermal screening, carbon dioxide enrichment, new plant training methods, widespan aluminium structures - have had less demonstrable effects, many of which have been deduced rather than observed. Certain soil-living pests - potato cyst eelworms (Globodera spp.), rootknot eelworms (Meloidogyne spp.) and glasshouse symphylid (Scutigerella immaculata) - cease to be important when the grower changes from border soil cultivation to peat culture, despite the fact that the soil is no longer sterilized. Analysis of survey data indicates, however, that some important foliar pests increase in incidence as a result of this change.

METHOD

The incidence of the three main foliar pests of tomato - glasshouse whitefly (Trialeurodes vaporariorum), red spider mite (Tetranychus urticae) and tomato moth (Lacanobia oleracea) - was surveyed in the Clyde Valley, Scotland from 1974 to 1977 by means of a simple questionnaire (Foster and

Kelly, 1978) directed to all growers. This survey was continued in 1978, and was extended to include questions on the method (if any) of soil sterilization and the method of culture.

RESULTS

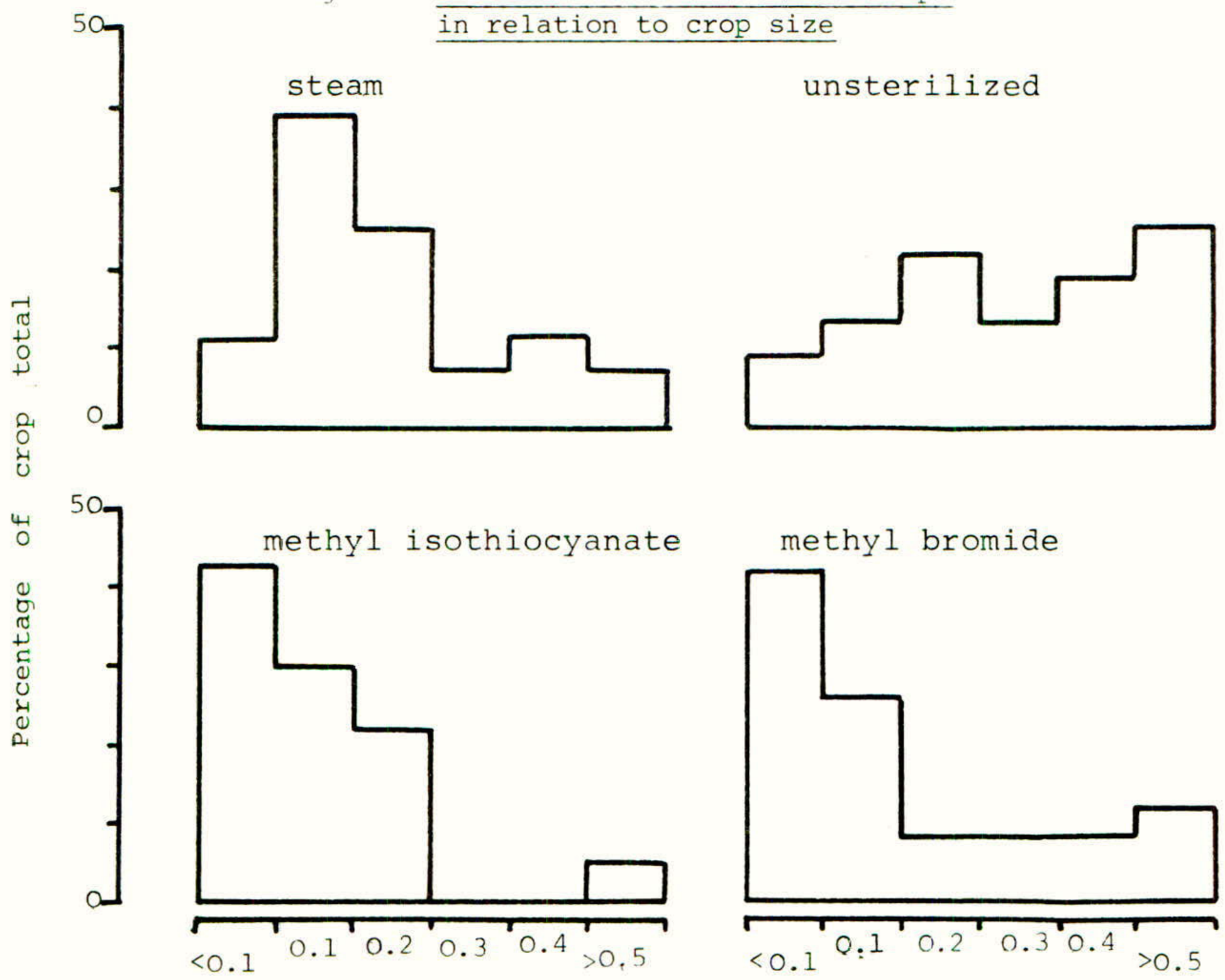
A total of 99 growers with 26 ha of tomato crop was surveyed in 1977, and 87 growers with 24 ha in 1978. A breakdown of soil preparation/media usage (Table 1) showed that 44% of the 1978 crop was grown in peat bags or troughs. Chemical sterilants were used on 48% of the cropped border soil area.

Table 1

Soil treatments for tomato crops in the Clyde Valley in 1978 (ha)

Sterilized	12.8	Unsterilized	10.7
Steam	6.7	Peat	10.4
Methyl isothiocyanate	4.1	Nutrient film	0.2
Methyl bromide	2.0	Grafted rootstocks	0.1

Fig. 1 - soil treatment for tomato crops in relation to crop size



Area of crop divided into size categories (ha)

18 growers had small areas of nutrient film channel on unsterilized soil and only one grower used grafted resistant rootstocks in unsterilized soil.

The distribution of soil treatments was analysed with respect to area of crop (Figure 1). The chemical sterilants were clearly favoured for use in areas less than 0.2 ha, steam sterilization was most popular in the middle range (0.1 - 0.3 ha) and peat was used extensively for the largest crops.

As a first step in analysis, the percentages of growers reporting the three pests were compared for sterilized and unsterilized soil (Table 2). Incidence of all three pests was highest in crops grown on unsterilized soil, being most marked in the case of glasshouse whitefly. Differences in pest incidence related to holding size as noted by Foster and Kelly (1978) could not be dissociated from this major difference related to sterilization practice.

Table 2

Percentage of growers reporting pest in 1978

Pest	Wholly sterilized soil	Partly or wholly unsterilized soil
Whitefly	34	64
Spider mite	53	76
Tomato moth	45	55

A more searching analysis was undertaken of the chances of a grower having an infestation in 1978 dependent on the presence or absence of the pest in 1977 (Table 3). The chance of reinfestation was higher than that of a new infestation developing for all three pests in both sterilized and unsterilized units, the difference being greatest in the case of tomato moth, and least for glasshouse whitefly on unsterilized holdings. The liklihood of eliminating a pest by means

Table 3

Incidence* of infestation as related to the absence or presence of the pest in 1977

	Whitefly		Spider mite		Tomato moth	
	absent	present	absent	present	absent	present
Sterilized	22	59	29	80	30	65
Unsterilized	53	75	40	91	13	94

* $\frac{100 \times \text{(No. of growers with pest in 1978)}}{\text{(No. of growers either with or without pest in 1977)}}$

of sterilization was low for spider mite and high for tomato moth. The liklihood of preventing a new pest outbreak by sterilization was high for glasshouse whitefly.

Following growers' comments on outbreaks of caterpillars in crops grown on chemically sterilized soil, a further breakdown of data was attempted. Data were too limited for analysis in the case of methyl bromide but comparison of steam with chemicals generating methyl isothiocyanate (MITC) was possible (Table 4); many units had to be excluded because both forms of sterilization were practiced in adjacent areas. The analysis indicates that MITC is less effective than steam in eliminating tomato moth whereas the opposite is the case for whitefly.

Table 4

Incidence* of infestation as related to the absence or presence of the pest in 1977

	Whitefly		Spider mite		Tomato moth	
	absent	present	absent	present	absent	present
Steam	18	78	20	80	30	40
Methyl isothiocyanate	25	20	47	100	50	78

* see Table 3

DISCUSSION

The survey results indicate that growers who abandon soil sterilization in favour of peat culture or soilless cultivation are more likely to suffer outbreaks of foliar pests. A direct relationship is not proved by the data; the increase in pest incidence in relation to the use of peat (Table 2) is confounded with increase in holding size which Foster and Kelly (1978) showed to be an important factor increasing susceptibility to pest attack.

Although each grower was asked to classify pest outbreaks as to their severity, these data were not analysed for differences in intensity of attack between sterilized and unsterilized soils because the efficacy of direct measures could not be taken into account. However, it can be deduced that the increased chances of pest survival between crops in the absence of sterilization must lead to more severe attacks.

Data can be related to the pest's method of overwintering. Whiteflies survive in all stages on crops or weeds in protected situations. Any method of foliar destruction at the end of the season (e.g. lack of watering, formaldehyde fumigation) must increase the chances of eliminating a whitefly infestation whereas the steaming of soil, which may be done piecemeal over several weeks, will have little effect. The 8-10 week cropping interval associated with the use of methyl isothiocyanate probably accounts for the success of this method (Table 4) in reducing whitefly incidence.

Red spider mites overwinter as diapausing adult females in the glasshouse structure and in the soil. The incidence of spider mite attack was least affected by sterilization (or lack of it) and the survey merely demonstrated that spider mite infestations are extremely difficult to eliminate.

Tomato moths overwinter as pupae in the soil. Survey data indicate the effectiveness of steam sterilization as a method of control; they also indicate that MITC is ineffective. Some growers using both chemical and steam sterilization reported that caterpillar outbreaks began in the chemically sterilized units. Growers using methyl bromide reported a high incidence of tomato moth. The increasing incidence of tomato moth in the Clyde Valley (from 22% of holdings in 1974 to 48% in 1978) is clearly related to a reduction in the use of steam sterilization. Both dazomet (Hams and Collyer, 1963) and peat troughs were introduced in Britain in the early 1960's but neither technique extensively replaced steam sterilization of border soil in Scotland until the cost of fuel rose sharply in 1973.

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CONTROL OF *BOTRYTIS CINEREA* ON GREENHOUSE TOMATOES BY REPEATED SPRAYING WITH VINCLOZOLIN, IPRODIONE AND IMAZALIL, AND ITS INFLUENCE ON RESIDUE LEVELS

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Summary Greenhouse grown tomatoes were sprayed with fungicides four times at fortnight interval to control grey mould (*Botrytis cinerea*). Two specific *Botrytis* fungicides, vinclozolin (50 and 100 mg a.i./m^2) and iprodione (187.5 and 375 mg a.i./m^2) were used, together with the non-specific imazalil (12.5 and 25 mg a.i./m^2). The concentrations used were those recommended by the manufacturers.

Best grey mould control and highest tomato production was obtained with vinclozolin; a slightly lower disease control and lower yiels was given by iprodione. Imazalil was not effective in grey mould control.

Residue analyses showed that in no case was the proposed or fixed tolerance (2 ppm in Germany, The Netherlands, France, Belgium) for vinclozolin and iprodione surpassed.

Résumé Des tomates en serre ont été pulvérises quatre fois avec des fongicides avec un intervalle de deux semaines pour lutter contre la pourriture grise (*Botrytis cinerea*). Deux fongicides à action spécifique contre *Botrytis*, donc le vinclozolin (50 et 100 mg m.a./m^2) et l'iprodione (187.5 et 375 mg m.a./m^2) ont été repris dans les expériences, autant que le fongicide non-specifique, l'imazalil (12.5 et 25 mg m.a./m^2). Les doses sont calculées selon les recommendations des fabricants.

Les résultats les meilleurs, dans le cas de la maladie et de la production, sont obtenu avec le vinclozolin; l'iprodione a donné des résultats dans la proximité du vinclozolin. L'imazalil n'était pas éffective pour lutter contre la pourriture grise.

L'analyse des résidus a prouvé qu'il n'y a dans aucun cas un dépassage des tolérances proposées ou fixées (2 ppm en Allemagne, Pays-Bas, France, Belgique) pour vinclozolin et iprodione.

INTRODUCTION

Botrytis cinerea is a polyphagous fungus which can attack a wide range of important crops. Apart from the so called "pourriture noble" on grapes, which is necessary for the quality of some specific wines, infection by grey mould (*B. cinerea*) can cause severe losses in yield and quality of several crops such as vine, lettuce, onion, tomato and strawberry. In all cases, disease development is positively influenced by cold moist weather and low light intensity. In protected cultivation these conditions can occur frequently, but as well as monitoring the greenhouse environment, chemical protection is also necessary.

A special problem in maintaining a strict spraying schedule is presented by the harvesting period of tomato. Fruits are harvested twice or three times a week. Therefore, only fungicides which are very effective in low concentrations can be used

and since a harvest interval of more than three days is not realistic, the residue level must be lower than the acceptable tolerance within this short period.

Recently a few new fungicides with specific action against B. cinerea and related fungi (e.g. Sclerotinia, Sclerotium, Monilia) have been put on the market. Schiller (1977) obtained good results with iprodione treatments for B. cinerea control on grapes in Germany. Faure et al. (1976) reported efficient control with the same compound and a residue level below the locally accepted tolerance for the grape as well as for the wine. Similar results are published by Eichhorn and Lorenz (1977) for iprodione, as well as for vinclozolin. Mappes (1977) reported positive results from experiments with vinclozolin in different crops, including lettuce, endive, onion, french bean, gherkin, tomato and aubergine. Sarojak et al. (1978) obtained good results in B. cinerea control in strawberries with vinclozolin. Fischer (1978) compared the effectiveness of vinclozolin and iprodione in lettuce growing and found equal grey mould control with both chemicals. The effect against Rhizoctonia solani however was better with iprodione than it was with vinclozolin.

From this it seems that iprodione and vinclozolin are powerful fungicides in B. cinerea control and our experiments on tomato confirm this but it is essential to have a safe residue level after repeated applications and our experiments were designed to study this.

In the same experiments imazalil was also examined. Good "in vitro" activity against B. cinerea was found for this compound by Leroux et al. (1976). In "in vivo" experiments on powdery mildew control in cucumbers, melons and gherkins, imazalil also gave good control of B. cinerea (Dalebout, 1978). In Holland the harvest interval after treatment with imazalil is three days.

MATERIALS AND METHODS

Cropping data Tomatoes, cv. 'King C_3F', were grown in greenhouse conditions, and cropped for six trusses. Normal cultural practices and pest control procedures were adopted but fungicidal treatments were those required for the experiments and growing conditions were altered so as to favour B. cinerea infection. The experiments were done during the summer of 1978 and so as to maintain high air humidity, no heat was applied and windows were left open at night.

Fungicides and concentrations Two concentrations of each fungicide were selected from the range recommended by the manufacturers :

Vinclozolin (Ronilan 50 % w.p.) - Mappes et al. (1977).
proposed for tomato : 0.3 - 1 kg a.i./ha
concentrations used : 50 mg (n) and 100 mg (2n) a.i./m^2

Iprodione (Rovral 50 % w.p.) - Anonymous. Rovral fungicide, Rhône-Poulenc Phytosanitaire, Juillet 1977.
proposed for tomato : 50 - 75 g a.i./hl
concentrations used : 37.5 and 75 g a.i./hl
187.5 mg (n) and 375 mg (2n) a.i./m^2

Imazalil (Fungaflor - Imazalil base 20 % e.c.) - Dalebout (1978).
proposed for cucumber : 0.025 % of formulation
concentrations used : 25 mg and 50 mg a.i./l.

Application was in water at 0.5 l/m^2.

Spraying treatments Four times with a two week interval; first time 17 days before harvest. Groups of six plants were separated with a plastic sheet during the whole cropping period to avoid contamination with unwanted chemicals. Each treatment was replicated twice.

Harvest and storage Ripe fruits were harvested twice per week, thus 3, 6, 10 and 13 days after spray applications and weighed to give individual and total weights per replication and per treatment respectively. From each harvesting date and spray application mixed samples were homogenised in a waring blendor and stored in a refrigerator at -20 °C for residue analysis later.

Residue analysis Vinclozolin and iprodione residues were estimated by gas-liquid chromatography following the procedure described for lettuce by Dejonckheere et al.

(1978) with an additional column chromatographic clean-up of the approximately 3 ml evaporated final extract. This volume was put on a glass chromatographic column (200 mm length x 13 mm inner diameter) with a solvent reservoir (200 mm length x 37 mm inner diameter) filled with a wad of glass wool and 10 grams of Florisil (inactivated with 2 % water vol./wt after heating for 90 min at 650 °C followed by 8 h at 200 °C and cooling in a desiccator). The column was eluted with a mixture of 90 ml petroleum ether (b.p.r. 40 - 60 °C) and 30 ml ethyl acetate. The final solution was evaporated to dryness at 40 °C and the last traces of solvent were removed by a nitrogen stream. The dry residue was redisolved in 5 ml petroleum ether. Recoveries were 80 and 69 % for vinclozolin and iprodione respectively.

The procedure for imazalil residue analysis in tomato was not available to us.

RESULTS

The effect of the fungicides on grey mould control at the end of the experiment is given in Table 1. The figures in column A are for stem lesions arising from infection passing from leaf lesions via the petiole; in column B only localised lesions on individual leaves are given.

Yield data in Table 2 are expressed as cumulative weights of the six trusses from the 12 plants per treatment. Relative weights with regard to check are given, as well as a mean value per fungicide.

Residue values for the different harvesting dates are shown in Table 3. Only results for vinclozolin and iprodione results are given here, because imazalil analysis from tomato extracts was not satisfactory. There are no data resulting from only one spraying; the first analysis was done on samples sprayed 17 and 3 days before the first sampling date. Samples were also taken and analysed on days 17, 20, 24 and 27 after the last spraying.

Table 1

Grey mould infection of tomato plants. Number of leaf and stem infections (A) and of other leaf infections (B) at the end of the season after treatment with fungicides. Sum of six plants per replicate

Treatment		Replication 1		Replication 2		Sum	
		A	B	A	B	A	B
Vinclozolin	n	1	4	2	7	3	11
Vinclozolin	2n	1	8	2	8	3	16
Iprodione	n	5	15	4	16	9	31
Iprodione	2n	2	12	10	16	12	28
Imazalil	n	13	31	8	18	21	49
Imazalil	2n	13	24	30	39	43	63
Check		12	24	21	43	33	67

Table 2

Cumulative weight (kg) of tomato fruits (total of 12 plants per treatment) after different fungicide treatments and with constant infection pressure of Botrytis cinerea

Treatment	Truss 1	Truss 2	Truss 3	Truss 4	Truss 5	Truss 6	%	mean
Vinclozolin n	8.214	14.969	22.511	28.789	34.039	36.829	111.2	108.8
Vinclozolin 2n	7.089	13.960	21.410	26.022	30.185	35.196	106.3	
Iprodione n	7.689	13.907	19.786	25.673	30.571	34.160	103.2	105.4
Iprodione 2n	6.881	12.679	20.305	26.819	32.260	35.590	107.5	
Imazalil n	8.387	14.365	20.761	27.416	32.234	36.020	108.8	102.4
Imazalil 2n	6.131	12.274	19.287	24.659	28.939	31.747	95.9	
Check	7.308	14.596	19.610	25.885	30.052	33.108	100.0	100.0

Table 3

Residues (ppm) of vinclozolin and iprodione on tomato fruits, at 3, 6, 10 and 13 days after spray application

Treatment Date	Harvest	ppm Vinclozolin n	ppm Vinclozolin 2n	ppm Iprodione n	ppm Iprodione 2n
16/6	19/6	0.14	0.15	1.13	1.12
	22/6	0.14	0.21	0.56	0.39
	26/6	0.07	0.07	0.44	0.80
	29/6	0.06	0.05	0.44	0.81
30/6	3/7	0.17	0.27	1.01	1.91
	6/7	0.15	0.21	0.91	0.55
	10/7	0.16	x	-	-
	13/7	0.20	0.20	0.77	1.11
14/7	17/7	0.20	0.27	0.85	0.86
	20/7	0.12	0.19	0.85	1.22
	24/7	0.16	-	0.60	0.73
	27/7	0.13	0.12	-	-
	31/7	0.09	0.15	0.59	0.83
	3/8	0.10	0.11	-	-
	7/8	0.02	0.03	-	-
	10/8	0.01	0.03	0.08	0.13

x Not detected.

DISCUSSION

Grey mould infection data (Table 1) show a great difference between the treatments. These results were obtained one month after the last fungicide application and thus they do not give an entire view. On the other hand they are very interesting in showing the persistence of the fungicides. Observations during the experiment showed that vinclozolin and iprodione were about equally effective but the differences shown in Table 1 indicate a longer activity for vinclozolin. This is supported by the residue data for vinclozolin (Table 3) which show that only the third week after spraying have the residues values diminished to negligible.

The differences in applied dose seems not to be important with vinclozolin since activity is equal for both concentrations and the lower dose gave a higher production. Similarly for the iprodione treatments there is no clear difference in disease control and only a slight increase in production with the higher dose. From these data it seems that both products can give a good grey mould control and, especially in circumstances of high disease pressure, as it was in our conditions, a clear increase of production is to be expected.

Although imazalil was not effective in grey mould control (Table 1), the lower dose showed a remarkable "side effect", on yield (Table 2). The higher concentration seems to have had a phytotoxic effect, though at no time could we observe specific symptoms; nevertheless the decreased production could not be the result only of high grey mould infection. The high amount of spray solution (0.5 l./m^2 or 5000 l./ha), and the way of calculating the dose for imazalil (starting from a given concentration in a solution) indicates that the plants received 2 to 3 times the concentration recommended for cucumber, and this could explain the yield reduction.

The residue values (Table 3) show that in no case were the proposed or fixed to-

lerances for vinclozolin and iprodione (2 ppm in Germany, The Netherlands, France, Belgium) exceeded. There are large difference in the values obtained for the two products which can be accounted for by the difference in spray concentrations employed. The residue level of the 2n dose is higher than with the n dose, but not by a factor two. The residue level of iprodione decreased faster than that of vinclozolin. Although the amount of vinclozolin detected was found to be 10 times lower than the acceptable tolerance level, there was no marked decrease during the two week interval between the sprayings and only after the third week did the residue level decrease rapidly.

From these results it is clear that vinclozolin and iprodione can be used successfully for grey mould control in tomatoes and a spraying interval of 2 weeks ensures both good activity and a safe residue level. Vinclozolin would perform satisfactority at the lower concentration used here and would be satisfactory at the higher concentration applied at 3 week intervals. For iprodione it would be more satisfactory to use the higher dose or one intermediate between that and the lower dose.

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